Appendix 2.A
Covered Species Accounts

Appendix 2A

Covered Species Accounts

Contents

Appendix 2A Covered Species Accounts ... 2A-1
2A.0 Introduction ... 2A-1
2A.0.1 Species Account Organization ... 2A-2
2A.0.2 References ... 2A-5
2A.1 Delta Smelt (*Hypomesus transpacificus*) ... 2A.1-1
2A.1.1 General ... 2A.1-1
2A.1.2 Legal Status ... 2A.1-1
2A.1.3 Distribution and Abundance ... 2A.1-2
2A.1.4 Life Stages ... 2A.1-6
2A.1.5 Life History ... 2A.1-8
2A.1.6 Threats and Stressors ... 2A.1-9
2A.1.7 Relevant Conservation Efforts ... 2A.1-16
2A.1.8 References Cited ... 2A.1-17
2A.2 Longfin Smelt (*Spirinchus thaleichthys*) ... 2A.2-1
2A.2.1 General ... 2A.2-1
2A.2.2 Legal Status ... 2A.2-1
2A.2.3 Distribution and Abundance ... 2A.2-2
2A.2.4 Life Stages ... 2A.2-3
2A.2.5 Life History ... 2A.2-4
2A.2.6 Threats and Stressors ... 2A.2-6
2A.2.7 Relevant Conservation Efforts ... 2A.2-10
2A.2.8 References Cited ... 2A.2-11
2A.3 Sacramento River Winter-Run Chinook Salmon (*Oncorhynchus tshawytscha*) ... 2A.3-1
2A.3.1 Legal Status ... 2A.3-1
2A.3.2 Species Distribution and Status ... 2A.3-1
2A.3.3 Habitat Requirements and Special Considerations ... 2A.3-4
2A.3.4 Life History ... 2A.3-7
2A.3.5 Threats and Stressors ... 2A.3-9
2A.3.6 Relevant Conservation Efforts ... 2A.3-18
2A.3.7 Recovery Goals ... 2A.3-21
2A.3.8 References Cited ... 2A.3-22
2A.4 Central Valley Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) ... 2A.4-1
2A.4.1 Legal Status ... 2A.4-1
2A.4.2 Species Distribution and Status ... 2A.4-2
2A.4.3 Habitat Requirements and Special Considerations ... 2A.4-4
2A.4.4 Life History ... 2A.4-7
2A.4.5 Threats and Stressors ... 2A.4-10
2A.4.6 Relevant Conservation Efforts ... 2A.4-18

2A.4.7 Recovery Goals ... 2A.4-21
2A.4.8 References Cited ... 2A.4-21

2A.5 Central Valley Fall- and Late Fall–Run Chinook Salmon (*Oncorhynchus tshawytscha*) ... 2A.5-1
2A.5.1 Legal Status ... 2A.5-1
2A.5.2 Species Distribution and Status ... 2A.5-1
2A.5.3 Habitat Requirements and Special Considerations ... 2A.5-3
2A.5.4 Life History ... 2A.5-6
2A.5.5 Threats and Stressors ... 2A.5-10
2A.5.6 Relevant Conservation Efforts ... 2A.5-18
2A.5.7 Recovery Goals ... 2A.5-20
2A.5.8 References Cited ... 2A.5-20

2A.6 Central Valley Steelhead (*Oncorhynchus mykiss*) ... 2A.6-1
2A.6.1 Legal Status ... 2A.6-1
2A.6.2 Species Distribution and Status ... 2A.6-1
2A.6.3 Habitat Requirements and Special Considerations ... 2A.6-3
2A.6.4 Life History ... 2A.6-5
2A.6.5 Threats and Stressors ... 2A.6-9
2A.6.6 Relevant Conservation Efforts ... 2A.6-14
2A.6.7 Recovery Goals ... 2A.6-15
2A.6.8 References Cited ... 2A.6-16

2A.7 Sacramento Splittail (*Pogonichthys macrolepidotus*) ... 2A.7-1
2A.7.1 General ... 2A.7-1
2A.7.2 Legal Status ... 2A.7-1
2A.7.3 Distribution and Abundance ... 2A.7-1
2A.7.4 Life Stages ... 2A.7-2
2A.7.5 Life History ... 2A.7-3
2A.7.6 Life Cycle ... 2A.7-5
2A.7.7 Threats and Stressors ... 2A.7-6
2A.7.8 Relevant Conservation Efforts ... 2A.7-10
2A.7.9 Recovery Goals ... 2A.7-11
2A.7.10 References Cited ... 2A.7-11

2A.8 Green Sturgeon (*Acipenser medirostris*) ... 2A.8-1
2A.8.1 Legal Status ... 2A.8-1
2A.8.2 Species Distribution and Abundance ... 2A.8-2
2A.8.3 Habitat Requirements and Special Considerations ... 2A.8-3
2A.8.4 Life History ... 2A.8-4
2A.8.5 Threats and Stressors ... 2A.8-6
2A.8.6 Relevant Conservation Efforts ... 2A.8-12
2A.8.7 Recovery Goals ... 2A.8-13
2A.8.8 References Cited ... 2A.8-13

2A.9 White Sturgeon (*Acipenser transmontanus*) ... 2A.9-1
2A.9.1 Legal Status ... 2A.9-1
2A.9.2 Species Distribution and Abundance ... 2A.9-1
2A.9.3 Life Stages ... 2A.9-2
2A.9.4 Life History ... 2A.9-2
2A.9.5 Threats and Stressors ... 2A.9-3
2A.9.6 Relevant Conservation Efforts ... 2A.9-9

2A.9.7 Recovery Goals 2A.9-9
2A.9.8 References Cited 2A.9-10

2A.10 Pacific Lamprey (*Entosphenus tridentatus*) 2A.10-1
2A.10.1 General 2A.10-1
2A.10.2 Legal Status 2A.10-1
2A.10.3 Distribution and Abundance 2A.10-1
2A.10.4 Life Stages 2A.10-2
2A.10.5 Life History 2A.10-2
2A.10.6 Threats and Stressors 2A.10-3
2A.10.7 Relevant Conservation Efforts 2A.10-5
2A.10.8 Recovery Goals 2A.10-5
2A.10.9 References Cited 2A.10-5

2A.11 River Lamprey (*Lampetra ayresii*) 2A.11-1
2A.11.1 General 2A.11-1
2A.11.2 Legal Status 2A.11-1
2A.11.3 Distribution and Abundance 2A.11-1
2A.11.4 Life Stages 2A.11-2
2A.11.5 Life History 2A.11-2
2A.11.6 Threats and Stressors 2A.11-3
2A.11.7 Relevant Conservation Efforts 2A.11-3
2A.11.8 Recovery Goals 2A.11-4
2A.11.9 References Cited 2A.11-4

2A.12 Riparian Brush Rabbit (*Sylvilagus bachmani riparius*) 2A.12-1
2A.12.1 Legal Status 2A.12-1
2A.12.2 Species Distribution and Status 2A.12-1
2A.12.3 Habitat Requirements and Special Considerations 2A.12-3
2A.12.4 Life History 2A.12-3
2A.12.5 Threats and Stressors 2A.12-5
2A.12.6 Relevant Conservation Efforts 2A.12-6
2A.12.7 Species Habitat Suitability Model 2A.12-8
2A.12.8 Recovery Goals 2A.12-10
2A.12.9 References Cited 2A.12-12

2A.13 Riparian Woodrat (*Neotoma fuscipes riparia*) 2A.13-1
2A.13.1 Legal Status 2A.13-1
2A.13.2 Species Distribution and Status 2A.13-1
2A.13.3 Habitat Requirements and Special Considerations 2A.13-2
2A.13.4 Life History 2A.13-3
2A.13.5 Threats and Stressors 2A.13-4
2A.13.6 Relevant Conservation Efforts 2A.13-5
2A.13.7 Species Habitat Suitability Model 2A.13-6
2A.13.8 Recovery Goals 2A.13-7
2A.13.9 References Cited 2A.13-8

2A.14 Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*) 2A.14-1
2A.14.1 Legal Status 2A.14-1
2A.14.2 Species Distribution and Status 2A.14-1
2A.14.3 Habitat Requirements and Special Considerations 2A.14-2
2A.14.4 Life History 2A.14-2

2A.14.5 Threats and Stressors 2A.14-3
2A.14.6 Relevant Conservation Efforts 2A.14-4
2A.14.7 Species Habitat Suitability Model 2A.14-8
2A.14.8 Recovery Goals 2A.14-15
2A.14.9 References Cited 2A.14-15

2A.15 San Joaquin Kit Fox (*Vulpes macrotis mutica*) 2A.15-1
2A.15.1 Legal Status 2A.15-1
2A.15.2 Species Distribution and Status 2A.15-1
2A.15.3 Habitat Requirements and Special Considerations 2A.15-3
2A.15.4 Life History 2A.15-3
2A.15.5 Threats and Stressors 2A.15-5
2A.15.6 Relevant Conservation Efforts 2A.15-6
2A.15.7 Species Habitat Suitability Model 2A.15-6
2A.15.8 Recovery Goals 2A.15-8
2A.15.9 References Cited 2A.15-8

2A.16 Suisun Shrew (*Sorex ornatus sinuosus*) 2A.16-1
2A.16.1 Legal Status 2A.16-1
2A.16.2 Species Distribution and Status 2A.16-1
2A.16.3 Habitat Requirements and Special Considerations 2A.16-2
2A.16.4 Life History 2A.16-2
2A.16.5 Threats and Stressors 2A.16-3
2A.16.6 Relevant Conservation Efforts 2A.16-4
2A.16.7 Species Habitat Suitability Model 2A.16-7
2A.16.8 Recovery Goals 2A.16-10
2A.16.9 References Cited 2A.16-10

2A.17 California Black Rail (*Laterallus jamaicensis coturniculus*) 2A.17-1
2A.17.1 Legal Status 2A.17-1
2A.17.2 Species Distribution and Status 2A.17-1
2A.17.3 Habitat Requirements and Special Considerations 2A.17-3
2A.17.4 Life History 2A.17-4
2A.17.5 Threats and Stressors 2A.17-5
2A.17.6 Relevant Conservation Efforts 2A.17-6
2A.17.7 Species Habitat Suitability Model 2A.17-6
2A.17.8 Recovery Goals 2A.17-13
2A.17.9 References Cited 2A.17-14

2A.18 California Clapper Rail (*Rallus longirostris obsoletus*) 2A.18-1
2A.18.1 Legal Status 2A.18-1
2A.18.2 Species Distribution and Status 2A.18-1
2A.18.3 Habitat Requirements and Special Considerations 2A.18-2
2A.18.4 Life History 2A.18-3
2A.18.5 Threats and Stressors 2A.18-4
2A.18.6 Relevant Conservation Efforts 2A.18-5
2A.18.7 Species Habitat Suitability Model 2A.18-9
2A.18.8 Recovery Goals 2A.18-12
2A.18.9 References Cited 2A.18-13

2A.19 Greater Sandhill Crane (*Grus canadensis tabida*) 2A.19-1
2A.19.1 Legal Status 2A.19-1

2A.19.2 Species Distribution and Status 2A.19-1
2A.19.3 Habitat Requirements and Special Considerations 2A.19-3
2A.19.4 Life History 2A.19-4
2A.19.5 Threats and Stressors 2A.19-5
2A.19.6 Relevant Conservation Efforts 2A.19-6
2A.19.7 Species Habitat Suitability Model 2A.19-7
2A.19.8 Recovery Goals 2A.19-12
2A.19.9 References Cited 2A.19-13

2A.20 Least Bell's Vireo (*Vireo bellii pusillus*) 2A.20-1
2A.20.1 Legal Status 2A.20-1
2A.20.2 Species Distribution and Status 2A.20-1
2A.20.3 Habitat Requirements and Special Considerations 2A.20-2
2A.20.4 Life History 2A.20-3
2A.20.5 Threats and Stressors 2A.20-5
2A.20.6 Relevant Conservation Efforts 2A.20-6
2A.20.7 Species Habitat Suitability Model 2A.20-7
2A.20.8 Recovery Goals 2A.20-9
2A.20.9 References Cited 2A.20-10

2A.21 Suisun Song Sparrow (*Melospiza melodia maxillaris*) 2A.21-1
2A.21.1 Legal Status 2A.21-1
2A.21.2 Species Distribution and Status 2A.21-1
2A.21.3 Habitat Requirements and Special Considerations 2A.21-2
2A.21.4 Life History 2A.21-3
2A.21.5 Threats and Stressors 2A.21-4
2A.21.6 Relevant Conservation Efforts 2A.21-5
2A.21.7 Species Habitat Suitability Model 2A.21-8
2A.21.8 Recovery Goals 2A.21-11
2A.21.9 References Cited 2A.21-12

2A.22 Swainson's Hawk (*Buteo swainsoni*) 2A.22-1
2A.22.1 Legal Status 2A.22-1
2A.22.2 Species Distribution and Status 2A.22-1
2A.22.3 Habitat Requirements and Special Considerations 2A.22-3
2A.22.4 Life History 2A.22-5
2A.22.5 Threats and Stressors 2A.22-7
2A.22.6 Relevant Conservation Efforts 2A.22-8
2A.22.7 Species Habitat Suitability Model 2A.22-9
2A.22.8 Recovery Goals 2A.22-17
2A.22.9 References Cited 2A.22-17

2A.23 Tricolored Blackbird (*Agelaius tricolor*) 2A.23-1
2A.23.1 Legal Status 2A.23-1
2A.23.2 Species Distribution and Status 2A.23-1
2A.23.3 Habitat Requirements and Special Considerations 2A.23-3
2A.23.4 Life History 2A.23-5
2A.23.5 Threats and Stressors 2A.23-7
2A.23.6 Relevant Conservation Efforts 2A.23-8
2A.23.7 Species Habitat Suitability Model 2A.23-9
2A.23.8 Recovery Goals 2A.23-20

2A.23.9 References Cited ... 2A.23-21

2A.24 Western Burrowing Owl (*Athene cunicularia hypugaea*) ... 2A.24-1

2A.24.1 Legal Status ... 2A.24-1
2A.24.2 Species Distribution and Status ... 2A.24-1
2A.24.3 Habitat Requirements and Special Considerations ... 2A.24-4
2A.24.4 Life History ... 2A.24-5
2A.24.5 Threats and Stressors ... 2A.24-8
2A.24.6 Relevant Conservation Efforts ... 2A.24-9
2A.24.7 Species Habitat Suitability Model ... 2A.24-10
2A.24.8 Recovery Goals ... 2A.24-16
2A.24.9 References Cited ... 2A.24-17

2A.25 Western Yellow-Billed Cuckoo (*Coccyzus americanus occidentalis*) ... 2A.25-1

2A.25.1 Legal Status ... 2A.25-1
2A.25.2 Species Distribution and Status ... 2A.25-1
2A.25.3 Habitat Requirements and Special Considerations ... 2A.25-3
2A.25.4 Life History ... 2A.25-4
2A.25.5 Threats and Stressors ... 2A.25-6
2A.25.6 Relevant Conservation Efforts ... 2A.25-6
2A.25.7 Species Habitat Suitability Model ... 2A.25-7
2A.25.8 Recovery Goals ... 2A.25-9
2A.25.9 References Cited ... 2A.25-9

2A.26 White-Tailed Kite (*Elanus leucurus*) ... 2A.26-1

2A.26.1 Legal Status ... 2A.26-1
2A.26.2 Species Distribution and Status ... 2A.26-1
2A.26.3 Habitat Requirements and Special Considerations ... 2A.26-2
2A.26.4 Life History ... 2A.26-3
2A.26.5 Threats and Stressors ... 2A.26-5
2A.26.6 Relevant Conservation Efforts ... 2A.26-5
2A.26.7 Species Habitat Suitability Model ... 2A.26-6
2A.26.8 Recovery Goals ... 2A.26-16
2A.26.9 References Cited ... 2A.26-16

2A.27 Yellow-Breasted Chat (*Icteria virens*) ... 2A.27-1

2A.27.1 Legal Status ... 2A.27-1
2A.27.2 Species Distribution and Status ... 2A.27-1
2A.27.3 Habitat Requirements and Special Considerations ... 2A.27-2
2A.27.4 Life History ... 2A.27-3
2A.27.5 Threats and Stressors ... 2A.27-4
2A.27.6 Relevant Conservation Efforts ... 2A.27-5
2A.27.7 Species Habitat Suitability Model ... 2A.27-5
2A.27.8 Recovery Goals ... 2A.27-8
2A.27.9 References Cited ... 2A.27-9

2A.28 Giant Garter Snake (*Thamnophis gigas*) ... 2A.28-1

2A.28.1 Legal Status ... 2A.28-1
2A.28.2 Species Distribution and Status ... 2A.28-1
2A.28.3 Habitat Requirements and Special Considerations ... 2A.28-6
2A.28.4 Life History ... 2A.28-7
2A.28.5 Threats and Stressors ... 2A.28-9

2A.28.6 Relevant Conservation Efforts 2A.28-10
2A.28.7 Species Habitat Suitability Model 2A.28-11
2A.28.8 Recovery Goals 2A.28-21
2A.28.9 References Cited 2A.28-22
2A.29 Western Pond Turtle (*Actinemys marmorata*) 2A.29-1
2A.29.1 Legal Status 2A.29-1
2A.29.2 Species Distribution and Status 2A.29-1
2A.29.3 Habitat Requirements and Special Considerations 2A.29-2
A.29.4 Life History 2A.29-3
2A.29.5 Threats and Stressors 2A.29-5
2A.29.6 Relevant Conservation Efforts 2A.29-6
2A.29.7 Species Habitat Suitability Model 2A.29-7
2A.29.8 Recovery Goals 2A.29-13
2A.29.9 References Cited 2A.29-13
2A.30 California Red-Legged Frog (*Rana draytonii*) 2A.30-1
2A.30.1 Legal Status 2A.30-1
2A.30.2 Species Distribution and Status 2A.30-1
2A.30.3 Habitat Requirements and Special Considerations 2A.30-2
2A.30.4 Life History 2A.30-3
2A.30.5 Threats and Stressors 2A.30-4
2A.30.6 Relevant Conservation Efforts 2A.30-6
2A.30.7 Species Habitat Suitability Model 2A.30-6
2A.30.8 Recovery Goals 2A.30-10
2A.30.9 References 2A.30-10
2A.31 California Tiger Salamander (*Ambystoma californiense*) 2A.31-1
2A.31.1 Legal Status 2A.31-1
2A.31.2 Species Distribution and Status 2A.31-1
2A.31.3 Habitat Requirements and Special Considerations 2A.31-2
2A.31.4 Life History 2A.31-3
2A.31.5 Threats and Stressors 2A.31-5
2A.31.6 Relevant Conservation Efforts 2A.31-7
2A.31.7 Species Habitat Suitability Model 2A.31-8
2A.31.8 Recovery Goals 2A.31-11
2A.31.9 References Cited 2A.31-12
2A.32 Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*) 2A.32-1
2A.32.1 Legal Status 2A.32-1
2A.32.2 Species Distribution and Status 2A.32-1
2A.32.3 Habitat Requirements and Special Considerations 2A.32-2
2A.32.4 Life History 2A.32-3
2A.32.5 Threats and Stressors 2A.32-4
2A.32.6 Relevant Conservation Efforts 2A.32-5
2A.32.7 Species Habitat Suitability Model 2A.32-6
2A.32.8 Recovery Goals 2A.32-8
2A.32.9 References Cited 2A.32-8
2A.33 California Linderiella (*Linderiella occidentalis*) 2A.33-1
2A.33.1 Legal Status 2A.33-1
2A.33.2 Species Distribution and Status 2A.33-1

2A.33.3 Habitat Requirements and Special Considerations 2A.33-2
2A.33.4 Life History 2A.33-2
2A.33.5 Threats and Stressors........ 2A.33-3
2A.33.6 Relevant Conservation Efforts 2A.33-5
2A.33.7 Species Habitat Suitability Model 2A.33-6
2A.33.8 Recovery Goals........ 2A.33-8
2A.33.9 References Cited 2A.33-8

2A.34 Conservancy Fairy Shrimp (*Branchinecta conservatio*) 2A.34-1
2A.34.1 Legal Status 2A.34-1
2A.34.2 Species Distribution and Status 2A.34-1
2A.34.3 Habitat Requirements and Special Considerations 2A.34-2
2A.34.4 Life History 2A.34-2
2A.34.5 Threats and Stressors........ 2A.34-3
2A.34.6 Relevant Conservation Efforts 2A.34-5
2A.34.7 Species Habitat Suitability Model 2A.34-6
2A.34.8 Recovery Goals........ 2A.34-8
2A.34.9 References Cited 2A.34-8

2A.35 Longhorn Fairy Shrimp (*Branchinecta longiantenna*) 2A.35-1
2A.35.1 Legal Status 2A.35-1
2A.35.2 Species Distribution and Status 2A.35-1
2A.35.3 Habitat Requirements and Special Considerations 2A.35-2
2A.35.4 Life History 2A.35-2
2A.35.5 Threats and Stressors........ 2A.35-3
2A.35.6 Relevant Conservation Efforts 2A.35-5
2A.35.7 Species Habitat Suitability Model 2A.35-5
2A.35.8 Recovery Goals........ 2A.35-7
2A.35.9 References Cited 2A.35-8

2A.36 Midvalley Fairy Shrimp (*Branchinecta mesovallensis*) 2A.36-1
2A.36.1 Legal Status 2A.36-1
2A.36.2 Species Distribution and Status 2A.36-1
2A.36.3 Habitat Requirements and Special Considerations 2A.36-2
2A.36.4 Life History 2A.36-3
2A.36.5 Threats and Stressors........ 2A.36-4
2A.36.6 Relevant Conservation Efforts 2A.36-5
2A.36.7 Species Habitat Suitability Model 2A.36-6
2A.36.8 Recovery Goals........ 2A.36-8
2A.36.9 References Cited 2A.36-8

2A.37 Vernal Pool Fairy Shrimp (*Branchinecta lynchi*)........ 2A.37-1
2A.37.1 Legal Status 2A.37-1
2A.37.2 Species Distribution and Status 2A.37-1
2A.37.3 Habitat Requirements and Special Considerations 2A.37-2
2A.37.4 Life History 2A.37-2
2A.37.5 Threats and Stressors........ 2A.37-3
2A.37.6 Relevant Conservation Efforts 2A.37-6
2A.37.7 Species Habitat Suitability Model 2A.37-7
2A.37.8 Recovery Goals........ 2A.37-9
2A.37.9 References Cited 2A.37-9

2A.38 Vernal Pool Tadpole Shrimp (*Lepidurus packardi*) 2A.38-1
2A.38.1 Legal Status 2A.38-1
2A.38.2 Species Distribution and Status 2A.38-1
2A.38.3 Habitat Requirements and Special Considerations 2A.38-2
2A.38.4 Life History 2A.38-2
2A.38.5 Threats and Stressors 2A.38-4
2A.38.6 Relevant Conservation Efforts 2A.38-6
2A.38.7 Species Habitat Suitability Model 2A.38-6
2A.38.8 Recovery Goals 2A.38-8
2A.38.9 References Cited 2A.38-9
2A.39 Carquinez Goldenbush (*Isocoma arguta*) 2A.39-1
2A.39.1 Legal Status 2A.39-1
2A.39.2 Species Distribution and Status 2A.39-1
2A.39.3 Habitat Requirements and Special Considerations 2A.39-2
2A.39.4 Life History 2A.39-2
2A.39.5 Threats and Stressors 2A.39-2
2A.39.6 Relevant Conservation Efforts 2A.39-2
2A.39.7 Species Habitat Suitability Model 2A.39-2
2A.39.8 Recovery Goals 2A.39-4
2A.39.9 References Cited 2A.39-4
2A.40 Delta Button Celery (*Eryngium racemosum*) 2A.40-1
2A.40.1 Legal Status 2A.40-1
2A.40.2 Species Distribution and Status 2A.40-1
2A.40.3 Habitat Requirements and Special Considerations 2A.40-2
2A.40.4 Life History 2A.40-2
2A.40.5 Threats and Stressors 2A.40-3
2A.40.6 Relevant Conservation Efforts 2A.40-3
2A.40.7 Species Habitat Suitability Model 2A.40-3
2A.40.8 Recovery Goals 2A.40-4
2A.40.9 References Cited 2A.40-4
2A.41 Mason's Lilaeopsis (*Lilaeopsis masonii*) 2A.41-1
2A.41.1 Legal Status 2A.41-1
2A.41.2 Species Distribution and Status 2A.41-1
2A.41.3 Habitat Requirements and Special Considerations 2A.41-2
2A.41.4 Life History 2A.41-3
2A.41.5 Threats and Stressors 2A.41-3
2A.41.6 Relevant Conservation Efforts 2A.41-4
2A.41.7 Species Habitat Suitability Model 2A.41-4
2A.41.8 Recovery Goals 2A.41-5
2A.41.9 References Cited 2A.41-5
2A.42 Delta Mudwort (*Limosella subulata*) 2A.42-1
2A.42.1 Legal Status 2A.42-1
2A.42.2 Species Distribution and Status 2A.42-1
2A.42.3 Habitat Requirements and Special Considerations 2A.42-2
2A.42.4 Life History 2A.42-2
2A.42.5 Threats and Stressors 2A.42-3
2A.42.6 Relevant Conservation Efforts 2A.42-3

2A.42.7 Species Habitat Suitability Model 2A.42-3
2A.42.8 Recovery Goals 2A.42-4
2A.42.9 References Cited 2A.42-4

2A.43 Delta Tule Pea (*Lathyrus jepsonii* var. *jepsonii*) 2A.43-1
2A.43.1 Legal Status 2A.43-1
2A.43.2 Species Distribution and Status 2A.43-1
2A.43.3 Habitat Requirements and Special Considerations 2A.43-2
2A.43.4 Life History 2A.43-2
2A.43.5 Threats and Stressors 2A.43-3
2A.43.6 Relevant Conservation Efforts 2A.43-3
2A.43.7 Species Habitat Suitability Model 2A.43-3
2A.43.8 Recovery Goals 2A.43-5
2A.43.9 References Cited 2A.43-5

2A.44 Suisun Marsh Aster (*Symphyotrichum lentum*, Formerly *Aster lentus*) 2A.44-1
2A.44.1 Legal Status 2A.44-1
2A.44.2 Species Distribution and Status 2A.44-1
2A.44.3 Habitat Requirements and Special Considerations 2A.44-2
2A.44.4 Life History 2A.44-2
2A.44.5 Threats and Stressors 2A.44-3
2A.44.6 Relevant Conservation Efforts 2A.44-3
2A.44.7 Species Habitat Suitability Model 2A.44-3
2A.44.8 Recovery Goals 2A.44-4
2A.44.9 References Cited 2A.44-5

2A.45 Brittlescale (*Atriplex depressa*) 2A.45-1
2A.45.1 Legal Status 2A.45-1
2A.45.2 Species Distribution and Status 2A.45-1
2A.45.3 Habitat Requirements and Special Considerations 2A.45-2
2A.45.4 Life History 2A.45-2
2A.45.5 Threats and Stressors 2A.45-3
2A.45.6 Relevant Conservation Efforts 2A.45-3
2A.45.7 Species Habitat Suitability Model 2A.45-3
2A.45.8 Recovery Goals 2A.45-4
2A.45.9 References Cited 2A.45-4

2A.46 Heartscale (*Atriplex cordulata* var. *cordulata*) 2A.46-1
2A.46.1 Legal Status 2A.46-1
2A.46.2 Species Distribution and Status 2A.46-1
2A.46.3 Habitat Requirements and Special Considerations 2A.46-2
2A.46.4 Life History 2A.46-2
2A.46.5 Threats and Stressors 2A.46-3
2A.46.6 Relevant Conservation Efforts 2A.46-3
2A.46.7 Species Habitat Suitability Model 2A.46-3
2A.46.8 Recovery Goals 2A.46-4
2A.46.9 References Cited 2A.46-4

2A.47 Side-Flowering Skullcap (*Scutellaria lateriflora*) 2A.47-1
2A.47.1 Legal Status 2A.47-1
2A.47.2 Species Distribution and Status 2A.47-1
2A.47.3 Habitat Requirements and Special Considerations 2A.47-2

2A.47.4 Life History ... 2A.47-2
2A.47.5 Threats and Stressors ... 2A.47-2
2A.47.6 Relevant Conservation Efforts ... 2A.47-3
2A.47.7 Species Habitat Suitability Model ... 2A.47-3
2A.47.8 Recovery Goals ... 2A.47-4
2A.47.9 References Cited ... 2A.47-4
2A.48 Slough Thistle (*Cirsium crassicaule*) ... 2A.48-1
2A.48.1 Legal Status ... 2A.48-1
2A.48.2 Species Distribution and Status ... 2A.48-1
2A.48.3 Habitat Requirements and Special Considerations ... 2A.48-2
2A.48.4 Life History ... 2A.48-2
2A.48.5 Threats and Stressors ... 2A.48-2
2A.48.6 Relevant Conservation Efforts ... 2A.48-3
2A.48.7 Species Habitat Suitability Model ... 2A.48-3
2A.48.8 Recovery Goals ... 2A.48-3
2A.48.9 References Cited ... 2A.48-3
2A.49 Soft Bird's-Beak (*Chloropyron molle* ssp. *molle*) ... 2A.49-1
2A.49.1 Legal Status ... 2A.49-1
2A.49.2 Species Distribution and Status ... 2A.49-1
2A.49.3 Habitat Requirements and Special Considerations ... 2A.49-2
2A.49.4 Life History ... 2A.49-3
2A.49.5 Threats and Stressors ... 2A.49-3
2A.49.6 Relevant Conservation Efforts ... 2A.49-4
2A.49.7 Species Habitat Suitability Model ... 2A.49-5
2A.49.8 Recovery Goals ... 2A.49-7
2A.49.9 References Cited ... 2A.49-8
2A.50 Suisun Thistle (*Cirsium hydrophilum* var. *hydrophilum*) ... 2A.50-1
2A.50.1 Legal Status ... 2A.50-1
2A.50.2 Species Distribution and Status ... 2A.50-1
2A.50.3 Habitat Requirements and Special Considerations ... 2A.50-2
2A.50.4 Life History ... 2A.50-2
2A.50.5 Threats and Stressors ... 2A.50-3
2A.50.6 Relevant Conservation Efforts ... 2A.50-3
2A.50.7 Species Habitat Suitability Model ... 2A.50-4
2A.50.8 Recovery Goals ... 2A.50-5
2A.50.9 References Cited ... 2A.50-6
2A.51 Alkali Milk-Vetch (*Astragalus tener* var. *tener*) ... 2A.51-1
2A.51.1 Legal Status ... 2A.51-1
2A.51.2 Species Distribution and Status ... 2A.51-1
2A.51.3 Habitat Requirements and Special Considerations ... 2A.51-2
2A.51.4 Life History ... 2A.51-3
2A.51.5 Threats and Stressors ... 2A.51-3
2A.51.6 Relevant Conservation Efforts ... 2A.51-4
2A.51.7 Species Habitat Suitability Model ... 2A.51-4
2A.51.8 Recovery Goals ... 2A.51-6
2A.51.9 References Cited ... 2A.51-6

2A.52 Boggs Lake Hedge-Hyssop (*Gratiola heterosepala*) 2A.52-1
2A.52.1 Legal Status 2A.52-1
2A.52.2 Species Distribution and Status 2A.52-1
2A.52.3 Habitat Requirements and Special Considerations 2A.52-2
2A.52.4 Life History 2A.52-2
2A.52.5 Threats and Stressors 2A.52-2
2A.52.6 Relevant Conservation Efforts 2A.52-2
2A.52.7 Species Habitat Suitability Model 2A.52-3
2A.52.8 Recovery Goals 2A.52-4
2A.52.9 References Cited 2A.52-5
2A.53 Dwarf Downingia (*Downingia pusilla*) 2A.53-1
2A.53.1 Legal Status 2A.53-1
2A.53.2 Species Distribution and Status 2A.53-1
2A.53.3 Habitat Requirements and Special Considerations 2A.53-2
2A.53.4 Life History 2A.53-2
2A.53.5 Threats and Stressors 2A.53-2
2A.53.6 Relevant Conservation Efforts 2A.53-2
2A.53.7 Species Habitat Suitability Model 2A.53-3
2A.53.8 Recovery Goals 2A.53-4
2A.53.9 References Cited 2A.53-4
2A.54 Heckard's Peppergrass (*Lepidium latipes* var. *heckardii*) 2A.54-1
2A.54.1 Legal Status 2A.54-1
2A.54.2 Species Distribution and Status 2A.54-1
2A.54.3 Habitat Requirements and Special Considerations 2A.54-2
2A.54.4 Life History 2A.54-3
2A.54.5 Threats and Stressors 2A.54-3
2A.54.6 Relevant Conservation Efforts 2A.54-3
2A.54.7 Species Habitat Suitability Model 2A.54-3
2A.54.8 Recovery Goals 2A.54-5
2A.54.9 References Cited 2A.54-5
2A.55 Legenere (*Legenere limosa*) 2A.55-1
2A.55.1 Legal Status 2A.55-1
2A.55.2 Species Distribution and Status 2A.55-1
2A.55.3 Habitat Requirements and Special Considerations 2A.55-2
2A.55.4 Life History 2A.55-2
2A.55.5 Threats and Stressors 2A.55-3
2A.55.6 Relevant Conservation Efforts 2A.55-3
2A.55.7 Species Habitat Suitability Model 2A.55-3
2A.55.8 Recovery Goals 2A.55-5
2A.55.9 References Cited 2A.55-6
2A.56 San Joaquin Spearscale (*Atriplex joaquinana*) 2A.56-1
2A.56.1 Legal Status 2A.56-1
2A.56.2 Species Distribution and Status 2A.56-1
2A.56.3 Habitat Requirements and Special Considerations 2A.56-2
2A.56.4 Life History 2A.56-2
2A.56.5 Threats and Stressors 2A.56-3
2A.56.6 Relevant Conservation Efforts 2A.56-3

2A.56.7 Species Habitat Suitability Model 2A.56-3
2A.56.8 Recovery Goals 2A.56-5
2A.56.9 References Cited 2A.56-5

Figures

[At end of each species account]

2A.1-1 Delta Smelt Inland Range
2A.1-2 Annual Abundance Indices of Delta Smelt from 1959 to 2009
2A.1-3 Historical Sampling Locations Where Delta Smelt Have Been Captured Since 1976
2A.1-4 Delta Smelt Designated Critical Habitat
2A.1-5 Example of Distribution of Adult Delta Smelt in Spring-Summer of a Representative Above-Normal Water Year
2A.1-6 Example of Distribution of Post-Larval/Juvenile Delta Smelt in Spring-Summer of a Representative Above-Normal Water Year
2A.2-1 Longfin Smelt Range
2A.2-2 Historical Sampling Locations Where Longfin Smelt Have Been Captured Since 1976
2A.2-3 Annual Abundance Indices of Longfin Smelt from 1967 to 2009
2A.2-4 Longfin Smelt Abundance (log_{10}) from Fall Midwater Trawl Survey as a Function of Mean Delta Outflow from December through May (log_{10})
2A.2-5 Example of Distribution of Post-Larval and Juvenile Longfin Smelt in Spring-Summer of a Representative Above-Normal Water Year
2A.3-1 Sacramento River Winter-Run Chinook Salmon Inland Range
2A.3-2 Estimated Historical Spawner Escapement of Sacramento River Winter-Run Chinook Salmon (1970–2009)
2A.3-3 Sacramento River Winter-Run Chinook Salmon Inland Designated Critical Habitat
2A.3-4 Sacramento River Winter-Run Chinook Salmon Inland Essential Fish Habitat
2A.4-1 Central Valley Spring-Run Chinook Salmon Inland Range
2A.4-2 Estimate Historical Spawner Escapement of Spring-Run Chinook Salmon throughout the Central Valley (1960–2009)
2A.4-3 Estimated Historical Spawner Escapement of Spring-Run Chinook Salmon in Mill, Deer, and Butte Creeks (1960–2009)
2A.4-4 Central Valley Spring-Run Chinook Salmon Inland Designated Critical Habitat
2A.4-5 Central Valley Spring-Run Chinook Salmon Inland Essential Fish Habitat
2A.5-1 Central Valley Fall-Run Chinook Salmon Inland Range
2A.5-2 Central Valley Late Fall-Run Chinook Salmon Inland Range
2A.5-3 Estimated Historical Spawner Escapement of Central Valley Fall-Run Chinook Salmon (1952–2009)
2A.5-4 Estimated Historical Spawner Escapement of Central Valley Late Fall-Run Chinook Salmon (1971–2009) in the Sacramento River
2A.5-5 Central Valley Fall-Run Chinook Salmon Inland Essential Fish Habitat
2A.5-6 Central Valley Late Fall-Run Chinook Salmon Inland Essential Fish Habitat
2A.6-1 Central Valley Steelhead Inland Range

2A.6-2 Estimated Historical Spawner Escapement of Wild Central Valley Steelhead in the Upper Sacramento River Upstream of the Red Bluff Diversion Dam (1967–2008)
2A.6-3 Central Valley Steelhead Critical Inland Habitat
2A.7-1 Sacramento Splittail Inland Range
2A.7-2 Annual Abundance Indices of Splittail from 1967 to 2009
2A.7-3 Historical Sampling Locations Where Splittail Have Been Captured Since 1976
2A.7-4 Example of Distribution of Post-Larval and Juvenile Longfin Smelt in Spring-Summer of a Representative Above-Normal Water Year
2A.8-1 Green Sturgeon Inland Range
2A.8-2 Green Sturgeon Inland Critical Habitat
2A.9-1 White Sturgeon Inland Range
2A.10-1 Pacific Lamprey Inland Range
2A.11-1 River Lamprey Inland Range
2A.12-1 Riparian Brush Rabbit Statewide Range and Recorded Occurrences
2A.12-2 Riparian Brush Rabbit Habitat Model and Recorded Occurrences
2A.13-1 Riparian Woodrat Statewide Range and Recorded Occurrences
2A.13-2 Riparian Woodrat Habitat Model and Recorded Occurrences
2A.14-1 Salt Marsh Harvest Mouse Statewide Range and Recorded Occurrences
2A.14-2 Salt Marsh Harvest Mouse Habitat Model and Recorded Occurrences
2A.15-1 San Joaquin Kit Fox Statewide Range and Recorded Occurrences
2A.15-2 San Joaquin Kit Fox Habitat Model and Recorded Occurrences
2A.16-1 Suisun Shrew Statewide Range and Recorded Occurrences
2A.16-2 Suisun Shrew Habitat Model and Recorded Occurrences
2A.17-1 California Black Rail Statewide Range and Recorded Occurrences
2A.17-2 California Black Rail Habitat Model and Recorded Occurrences
2A.18-1 California Clapper Rail Statewide Range and Recorded Occurrences
2A.18-2 California Clapper Rail Habitat Model and Recorded Occurrences
2A.19-1 Greater Sandhill Crane Statewide Range and Recorded Occurrences
2A.19-2 Greater Sandhill Crane Habitat Model and Recorded Occurrences
2A.19-3 Greater Sandhill Crane Foraging Habitat and Associated Value Rankings
2A.20-1 Least Bell’s Vireo Statewide Range and Recorded Occurrences
2A.20-2 Least Bell’s Vireo Habitat Model
2A.21-1 Suisun Song Sparrow Statewide Range and Recorded Occurrences
2A.21-2 Suisun Song Sparrow Habitat Model and Recorded Occurrences
2A.22-1 Swainson’s Hawk Statewide Range and Recorded Occurrences
2A.22-2 Swainson’s Hawk Habitat Model and Recorded Occurrences
2A.22-3 Swainson’s Hawk Foraging Habitat and Associated Value Rankings
2A.23-1 Tricolored Blackbird Statewide Range and Recorded Occurrences
2A.23-2 Tricolored Blackbird Habitat Model and Recorded Occurrences
2A.23-3 Tricolored Blackbird Foraging Habitat Model and Associated Value Rankings

2A.24-1 Western Burrowing Owl Statewide Range and Recorded Occurrences
2A.24-2 Western Burrowing Owl Habitat Model and Recorded Occurrences
2A.25-1 Western Yellow-Billed Cuckoo Statewide Range and Recorded Occurrences
2A.25-2 Western Yellow-Billed Cuckoo Habitat Model and Recorded Occurrences
2A.26-1 White-Tailed Kite Statewide Range and Recorded Occurrences
2A.26-2 White-Tailed Kite Habitat Model and Recorded Occurrences
2A.27-1 Yellow-Breasted Chat Statewide Range and Recorded Occurrences
2A.27-2 Yellow-Breasted Chat Habitat Model and Recorded Occurrences
2A.28-1 Giant Garter Snake Statewide Range and Recorded Occurrences
2A.28-2 Giant Garter Snake Habitat Model and Recorded Occurrences
2A.29-1 Western Pond Turtle Statewide Range and Recorded Occurrences
2A.29-2 Western Pond Turtle Habitat Model and Recorded Occurrences
2A.30-1 California Red-Legged Frog Statewide Range and Recorded Occurrences
2A.30-2 California Red-Legged Frog Habitat Model and Recorded Occurrences
2A.31-1 California Tiger Salamander Statewide Range and Recorded Occurrences
2A.31-2 California Tiger Salamander Habitat Model and Recorded Occurrences
2A.32-1 Valley Elderberry Longhorn Beetle Statewide Range and Recorded Occurrences
2A.32-2 Valley Elderberry Longhorn Beetle Habitat Model and Recorded Occurrences
2A.33-1 California Linderiella Statewide Range and Recorded Occurrences
2A.33-2 California Linderiella Habitat Model and Recorded Occurrences
2A.34-1 Conservancy Fairy Shrimp Statewide Range and Recorded Occurrences
2A.34-2 Conservancy Fairy Shrimp Habitat Model and Recorded Occurrences
2A.35-1 Longhorn Fairy Shrimp Statewide Range and Recorded Occurrences
2A.35-2 Longhorn Fairy Shrimp Habitat Model and Recorded Occurrences
2A.36-1 Midvalley Fairy Shrimp Statewide Range and Recorded Occurrences
2A.36-2 Midvalley Fairy Shrimp Habitat Model and Recorded Occurrences
2A.37-1 Vernal Pool Fairy Shrimp Statewide Range and Recorded Occurrences
2A.37-2 Vernal Pool Fairy Shrimp Habitat Model and Recorded Occurrences
2A.38-1 Vernal Pool Tadpole Shrimp Statewide Range and Recorded Occurrences
2A.38-2 Vernal Pool Tadpole Shrimp Habitat Model and Recorded Occurrences
2A.39-1 Carquinez Goldenbush Statewide Range and Recorded Occurrences
2A.39-2 Carquinez Goldenbush Habitat Model and Recorded Occurrences
2A.40-1 Delta Button Celery Statewide Range and Recorded Occurrences
2A.40-2 Delta Button Celery Habitat Model and Recorded Occurrences
2A.41-1 Mason’s Lilaeopsis Statewide Range and Recorded Occurrences
2A.41-2 Mason’s Lilaeopsis Habitat Model and Recorded Occurrences
2A.42-1 Delta Mudwort Statewide Range and Recorded Occurrences
2A.42-2 Delta Mudwort Habitat Model and Recorded Occurrences
2A.43-1 Delta Tule Pea Statewide Range and Recorded Occurrences
2A.43-2 Delta Tule Pea Habitat Model and Recorded Occurrences

2A.44-1 Suisun Marsh Aster Statewide Range and Recorded Occurrences
2A.44-2 Suisun Marsh Aster Habitat Model and Recorded Occurrences
2A.45-1 Brittlescale Statewide Range and Recorded Occurrences
2A.45-2 Brittlescale Habitat Model and Recorded Occurrences
2A.46-1 Heartscale Statewide Range and Recorded Occurrences
2A.46-2 Heartscale Habitat Model and Recorded Occurrences
2A.47-1 Side-Flowering Skullcap Statewide Range and Recorded Occurrences
2A.47-2 Side-Flowering Skullcap Habitat Model and Recorded Occurrences
2A.48-1 Slough Thistle Statewide Range and Recorded Occurrences
2A.48-2 Slough Thistle Habitat Model and Recorded Occurrences
2A.49-1 Soft Bird's-Beak Statewide Range and Recorded Occurrences
2A.49-2 Soft Bird's-Beak Habitat Model and Recorded Occurrences
2A.50-1 Suisun Thistle Statewide Range and Recorded Occurrences
2A.50-2 Suisun Thistle Habitat Model and Recorded Occurrences
2A.51-1 Alkali Milk-Vetch Statewide Range and Recorded Occurrences
2A.51-2 Alkali Milk-Vetch Habitat Model and Recorded Occurrences
2A.52-1 Boggs Lake Hedge-Hyssop Statewide Range and Recorded Occurrences
2A.52-2 Boggs Lake Hedge-Hyssop Habitat Model and Recorded Occurrences
2A.53-1 Dwarf Downingia Statewide Range and Recorded Occurrences
2A.53-2 Dwarf Downingia Habitat Model and Recorded Occurrences
2A.54-1 Heckard's Peppergrass Statewide Range and Recorded Occurrences
2A.54-2 Heckard's Peppergrass Habitat Model and Recorded Occurrences
2A.55-1 Legenere Statewide Range and Recorded Occurrences
2A.55-2 Legenere Habitat Model and Recorded Occurrences
2A.56-1 San Joaquin Spearscale Statewide Range and Recorded Occurrences
2A.56-2 San Joaquin Spearscale Habitat Model and Recorded Occurrences

Acronyms and Abbreviations

AB	Assembly Bill
Bay-Delta	San Francisco Bay/Sacramento–San Joaquin River Delta
BiOp	biological opinion
BLM	Bureau of Land Management
CALFED	California Bay Delta Authority
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
Delta	Sacramento–San Joaquin River Delta
DO	dissolved oxygen
DPR	California Department of Parks and Recreation
DPS	distinct population segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
EFH	essential fish habitat
EPA	U.S. Environmental Protection Agency
ESA	federal Endangered Species Act
ESRP	Endangered Species Recovery Program
ESU	evolutionarily significant unit
FR	*Federal Register*
G	globally
GIS	geographic information systems
HCP	habitat conservation plans
HSU	habitat suitability unit
I-205	Interstate 205
I-5	Interstate 5
I-580	Interstate 580
I-680	Interstate 680
I-80	Interstate 80
LSZ	low-salinity zone

mg/L	milligrams per liter
NAVD88	North American Vertical Datum 1988
NFD	not formally defined
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NWR	National Wildlife Refuge
PCBs	polychlorinated biphenyls
PCE	primary constituent elements
POD	pelagic organism decline
ppb	parts per billion
ppt	parts per thousand
psu	practical salinity units
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROA	Restoration Opportunity Area
S	state
SAV	submerged aquatic vegetation
SR	State Route
SSURGO	Soil Survey Geographic Database
State Water Baord	State Water Resources Control Board
SWP	State Water Project
T	variety
TMDL	total maximum daily load
Upland Recovery Plan	*Recovery Plan for the Upland Species of the San Joaquin Valley, California*
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Program
Vernal Pool Recovery Plan	*Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*
X2	2 ppt isohaline

Appendix 2A
Covered Species Accounts

2A.0 Introduction

This Bay Delta Conservation Plan (BDCP) appendix includes species accounts for covered wildlife and plant species that occur in the Plan Area. Fish species included in this appendix are the delta smelt (*Hypomesus transpacificus*); longfin smelt (*Spirinchus thaleichthys*); Chinook salmon (*Oncorhynchus tshawytscha*)—Sacramento River winter-run evolutionarily significant unit (ESU), Central Valley spring-run ESU, and Central Valley fall- and late fall–run ESUs; steelhead (*Oncorhynchus mykiss*)—Central Valley distinct population segment (DPS); Sacramento splittail (*Pogonichthys macrolepidotus*); green sturgeon (*Acipenser medirostris*)—southern DPS; white sturgeon (*Acipenser transmontanus*); Pacific lamprey (*Entosphenus tridentatus*); and river lamprey (*Lampetra ayresii*).

Mammal species included in this appendix are the riparian brush rabbit (*Sylvilagus bachmani riparius*), riparian woodrat (*Neotoma fuscipes riparia*), salt marsh harvest mouse (*Reithrodontomys raviventris*), San Joaquin kit fox (*Vulpes macrotis mutica*), and Suisun shrew (*Sorex ornatus sinuosus*).

Bird species included in this appendix are the California black rail (*Laterallus jamaicensis coturniculus*), California clapper rail (*Rallus longirostris obsoletus*), greater sandhill crane (*Grus canadensis tabida*), least Bell's vireo (*Vireo bellii pusillus*), Suisun song sparrow (*Melospiza melodia maxillaris*), Swainson's hawk (*Buteo swainsoni*), tricolored blackbird, western burrowing owl (*Athene cunicularia hypugaea*), western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), white-tailed kite (*Elanus leucurus*), and yellow-breasted chat (*Icteria virens*).

Reptile species included in this appendix are the giant garter snake (*Thamnophis gigas*) and the western pond turtle (*Actinemys marmorata*).

Amphibians included in this appendix are the California red-legged frog (*Rana draytonii*) and the California tiger salamander (*Ambystoma californiense*).

Invertebrate species included in this appendix are the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), California linderiella (*Linderiella occidentalis*), conservancy fairy shrimp (*Branchinecta conservatio*), longhorn fairy shrimp (*Branchinecta longiantenna*), midvalley fairy shrimp (*Branchinecta mesovallensis*), vernal pool fairy shrimp (*Branchinecta lynchi*), and vernal pool tadpole shrimp (*Lepidurus packardi*).

Plant species included in this appendix are the alkali milk-vetch (*Astragalus tener* var. *tener*), Boggs Lake hedge-hyssop (*Gratiola heterosepala*), brittlescale (*Atriplex depressa*), Carquinez goldenbush (*Isocoma arguta*), delta button celery (*Eryngium racemosum*), delta mudwort (*Limosella subulata*), Delta tule pea[1] (*Lathyrus jepsonii* var. *jepsonii*), dwarf downingia (*Downingia pusilla*), heartscale (*Atriplex cordulata* var. *cordulata*), Heckard's peppergrass (*Lepidium latipes* var. *heckardii*), legenere

[1] CalFlora and the U.S. Department of Agricultural plant lists capitalize *delta* for Delta tule pea only. The *delta* is not capitalized in the other delta species (delta mudwort, delta button celery).

(*Legenere limosa*), Mason's lilaeopsis (*Lilaeopsis masonii*), San Joaquin spearscale (*Atriplex joaquinana*), side-flowering skullcap (*Scutellaria lateriflora*), slough thistle (*Cirsium crassicaule*), soft bird's-beak (*Chloropyron molle* subsp. *molle*), Suisun Marsh aster (*Symphyotrichum lentum*), and Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*).

2A.0.1 Species Account Organization

2A.0.1.1 Legal Status

State and federal sources were reviewed to determine legal status designations for covered wildlife and plant species found in the Plan Area. For wildlife and plants, listing status under the Federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA) was determined. For wildlife, the California Department of Fish and Wildlife (CDFW) lists of California Species of Special Concern and California Fully Protected Animals were consulted to determine state designations. The *Birds of Conservation Concern 2008* (U.S. Fish and Wildlife Service 2008) was also consulted to determine federal designation for birds. For plants, the California Rare Plant Rank and Heritage Ranking for each species were obtained from the current *Special Vascular Plants, Bryophytes, and Lichens List* (California Department of Fish and Game 2012a). The designation of critical habitat was determined for each wildlife or plant species as well as status of recovery plans using the U.S. Fish and Wildlife Service (USFWS) databases.

2A.0.1.2 Species Distribution and Status

The overall range and status for the species is described, as well as its distribution and status in the Plan Area. This information reflects the body of available literature through June 2012. For plants, California Natural Diversity Database (CNDDB) occurrence data were used to establish the current number of statewide occurrences as well as number of occurrences in the Plan Area (California Department of Fish and Game 2012b). To describe statewide distribution, only CNDDB *extant* occurrences are included in the discussion. However, when relevant to the conservation strategy, *possibly extirpated* and *extirpated* CNDDB occurrences in the Plan Area are discussed. Additional occurrence data collected under the auspices of the Delta Habitat Conservation and Conveyance Program (2011) is also considered and displayed on the figures.

For plants, data not yet incorporated into the CNDDB were assigned to occurrences consistent with the CNDDB definition of occurrences: "an occurrence for a plant is defined as any population or group of nearby populations located more than 0.24 mile from any other population" (California Department of Fish and Game 2012a). These new data were composed of survey data from the Delta Habitat Conservation and Conveyance Program (2010 and 2011) and a set of data on alkali milk-vetch (Witham 2003).

For new point and line data, each point was buffered by 100 feet to generate a polygon. Distance was then measured between the new polygons and CNDDB occurrences, using only extant CNDDB occurrences with specific area polygons or at least 80-meter accuracy. The new data were designated as new occurrences as follows:

- New data points that overlapped or were within 0.24 mile of an existing CNDDB occurrence were assigned to the existing CNDDB occurrence.

- New data that were over 0.24 mile from an existing CNDDB occurrence were designated new occurrences (if multiple new data features were within 0.24 mile of each other, they were combined into the new occurrence).
- In the rare case that new data were within 0.24 mile of *two* existing CNDDB occurrences, the CNDDB occurrences plus the new data were combined into a single occurrence.

2A.0.1.3 Habitat Requirements and Special Considerations

The habitat types that the species is associated with throughout its range and also specifically within the Plan Area are summarized. This includes associated vegetation types for many of the species. For birds, this section may include a description of nest structure and nesting materials. For fish, this section includes information regarding spawning habitat and timing as well as habitat associations by life stages. For plants, this section may also include blooming periods and associated plant species.

2A.0.1.4 Life History

This section varies depending on species but in general it provides a physical description of the species, daily and seasonal activity, reproduction timing and behavior, home range and territory size, foraging behavior and diet, and predator descriptions. Blooming periods are also included for plants.

2A.0.1.5 Threats and Stressors

The most common threats to each species within its range are identified. These threats may include habitat loss and fragmentation, agricultural crop conversion, grazing, water diversions and impoundments, rodent control, predation, invasive species, and mercury contamination. For fish, these threats may include reduced food availability, reduced rearing habitat, elevated water temperatures, reduced turbidity, reduced spawning habitat, entrainment, and exposure to toxins.

2A.0.1.6 Relevant Conservation Efforts

Conservation efforts by various federal, state, local, and private organizations to minimize impacts to the species are summarized. Information regarding preserves that have been established to protect the species and protective policies pertaining to the species is included. Any relevant habitat conservation plans (HCPs), recovery plans, or other documents pertaining to the species' conservation are also summarized.

2A.0.1.7 Species Habitat Suitability Model Methods

Species habitat suitability models for plant and wildlife species are formulated primarily using vegetation data from existing geographic information systems (GIS) data sources (described below). Habitat suitability for each species is determined on the basis of whether or not a vegetation type or association is likely to be occupied based on the species' habitat requirements, as described in the species account. The models are not formulated on the basis of species occurrence data, which is incomplete for most covered species in the Plan Area. Instead, species occurrence data are used to verify the habitat models and as necessary revise the vegetation input data.

By its nature, this type of model tends to overestimate suitable habitat by being as inclusive as possible in the absence of site-specific data on vegetation structure, species composition, hydrology, occurrence of or proximity to other habitat elements, and other variables that would provide more certainty with respect to habitat quality and the potential for occurrence.

However, because of minimum mapping unit limitations, it is possible to underestimate as well as overestimate the extent of suitable habitat. For example, suitable habitat areas below the minimum mapping unit size (1 acre) may not be identified. This may be important for species that can use small, isolated habitat features, such as individual trees or small groups of trees. Still, the more likely scenario is that an overestimate occurs as small acreages of unsuitable habitat are absorbed into larger suitable habitat polygons. Nonetheless, it is also important to note that while the models portray a reasonable distribution of habitat suitability for each covered species, they do not necessarily indicate with certainty that covered species would not occur in all areas not identified as habitat; but instead indicate that these areas have a much lower probability of species occurrence compared with areas identified as suitable habitat. Habitat suitability models are a tool used to estimate impacts to obtain a maximum allowable habitat loss. On-the-ground surveys, performed by professional biologists, will determine impacts during implementation.

Where applicable, habitat suitability is also identified according to the life requisite of the species, such as breeding, foraging, or movement/dispersal habitat, and in some cases according to minimum habitat area requirements using home range or territory size data. Where appropriate, habitat suitability is also defined qualitatively (e.g., high, medium, and low value) based on broad suitability categories (e.g., grassland, pastureland, cultivated land) or through a general examination of species associations within vegetation types (e.g., species and range of percent cover of understory shrub layer) such as that provided by Hickson and Keeler-Wolf (2007). When habitat suitability categories are used, a complete description of the rationale and assumptions for those categories are included in the species account model description. Finally, other input variables are used to address specific conditions that are not accounted for in the vegetation databases but that can be generated through GIS analysis. These include soils and elevation data, buffers, connectivity between habitat types, and specific land use types such as levee slopes.

For each model, the mapping data sets are identified and each vegetation type or association is identified along with its life requisite association. Finally, the assumptions used in the formulation of the model are described, as well as the potential for the model to over- or under-estimate the extent of habitat in the Plan Area.

Supplemental Mapping Areas

In 2011 and 2012, the Plan Area was expanded in four locations to include covered activity footprints and areas of additional conservation opportunity: the area just north of Conservation Zone 11, west of Rio Vista, and to the west and east of Yolo Bypass. Species models in these areas were mapped using a GIS method different than that used to map areas within the original Plan Area. In addition, several areas inside the Plan Area that had been previously unmapped, along the northeast and eastern border of Suisun Marsh, were mapped using data sources and GIS methods that differ from the original species models.

The species models for the areas of additional mapping were created using natural community and vegetation alliance data as well as other types such as soils and elevation data. In some areas, vegetation was only mapped to the natural community level because more detailed alliance data was not available: generally these are areas that would not be affected by covered activities. The methods used to create the natural community models are described in Chapter 2, *Existing Ecological Conditions*, Section 2.3.1 *Data Sources and Natural Community Classification*. Natural community, vegetation, or other data specifically used to then create each species model is detailed in each species account.

2A.0.1.8 Recovery Goals

Any recovery plans for the species as well as other relevant recovery documents are identified.

2A.0.2 References

California Department of Fish and Game 2012a. California Natural Diversity Database (CNDDB). *Special Vascular Plants, Bryophytes, and Lichens List.* May. Sacramento, CA. Available: <http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPPlants.pdf>.

California Department of Fish and Game. 2012b. California Natural Diversity Database (CNDDB). Element Occurrence Query. RareFind, Version 4.0 (Commercial Subscription). Sacramento, California: CDFG, Biogeographic Data Branch. Available: <http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp>.

Delta Habitat Conservation and Conveyance Program. 2011. *2009 to 2011 Bay Delta Conservation Plan EIR/EIS Environmental Data Report*. Review Draft 1. December. Prepared for consideration by the lead agencies. Published by California Department of Water Resources, Bureau of Reclamation, National Marine Fisheries Service, and U.S. Fish and Wildlife Service.

Delta Habitat Conservation and Conveyance Program. 2011. *2009 to 2011 Bay Delta Conservation Plan EIR/EIS Environmental Data Report*. Review Draft 1. December. Prepared for consideration by the lead agencies. Published by California Department of Water Resources, Bureau of Reclamation, National Marine Fisheries Service, and U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2008. *Birds of Conservation Concern.* 2008. Arlingtn, VA: Division of Migratory Bird Management. Available: <http://www.fws.gov/migratorybirds/>.

Witham, C. W. 2003. *Tule Ranch Vernal Pools Botanical Resources Survey Report*. Davis, CA: Yolo Basin Foundation.

Appendix 2A.1

Delta Smelt (*Hypomesus transpacificus*)

2A.1.1 General

Delta smelt are a small, translucent fish endemic to the Sacramento–San Joaquin River Delta (Delta) (Moyle 2002). They inhabit open surface waters of the Plan Area, where they form loose aggregations. Their life history has been described as semi anadromous by Bennett (2005), reflecting a cycle of spawning in freshwater areas generally followed by juvenile migration to shallow, open-water areas of the West Delta and Suisun Bay subregions to feed and mature. More recent analyses suggest that year-round populations of delta smelt may exist in central locations (Lower Sacramento River to Suisun Marsh and in the Cache Slough and Deep Water Ship Channel regions) suggesting that they are not 100% obligatorily semi-anadromous or migratory, but may show several life history strategies (Merz et al. 2011; Baxter et al. 2010; Murphy et al. in press). Delta smelt populations have shown a long-term decline in the upper estuary (the Delta and Suisun Bay), although the Fall Mid-Water Trawl index has fluctuated greatly from year to year, with change points detected in 1975–76, 1980–81 and 1998–99 by Manly and Chotkowski (2006). Using a different analytical method, a trend change was identified in 2000–2002, and a step decline in 2004 (Thomson et al. 2010).There has been extremely low abundance in recent years as part of the pelagic organism decline (POD) (Sommer et al. 2007; Baxter et al. 2010).

The low abundance of delta smelt since the early 1980s is hypothesized to relate to a number of interacting factors. These factors include larval advection during high flows in the winter and spring of 1982 and 1983 (Kimmerer 2002a); the prolonged drought from 1987 to 1992 (Baxter et al. 2010); entrainment in water diversions (although a small effect at population level) (Kimmerer 2008); increases in salinity, water clarity, and temperature constricting habitat for juveniles (Nobriga et al. 2008) and maturing individuals (Feyrer et al. 2007;Thomson et al. 2010); predation and competition from introduced species (Bennett 2005); a decline in food resources (Maunder and Deriso 2011, Miller et al. 2012); and changes in the foodweb due to changes in nutrients (Glibert et al. 2011; Dugdale et al. 2012; Parker et al. 2012a; Parker et al. 2012b). In its most recent review of the factors potentially threatening the delta smelt, the U.S. Fish and Wildlife Service (USFWS) determined that operation of upstream reservoirs, increased water exports, and upstream water diversions has altered the location and extent of the low-salinity zone. Upstream reservoirs and the increased presence of *Egeria densa* have reduced turbidity levels in rearing habitat, which may reduce foraging efficiency. Predation, deficiency of current regulatory processes, entrainment into water diversions, the presence of nonnative plant and animal species, contaminants, and the potential for effects related to small population size all are likely having an effect on the abundance of the delta smelt. The delta smelt is also highly vulnerable to climate change (Brown et al. 2013).

2A.1.2 Legal Status

The U.S. Fish and Wildlife Service (USFWS) determined that delta smelt warranted listing as a threatened species under the federal Endangered Species Act (ESA) effective April 5, 1993. The listing decision was based on a substantial reduction in delta smelt abundance within the Bay-Delta estuary in a variety of fishery sampling programs, threats to its habitat, and the inadequacy of regulatory mechanisms to protect delta smelt (58 *Federal Register* [FR] 12863). The delta smelt was listed as a threatened species under the California Endangered Species Act (CESA) on December 9, 1993. The *Sacramento-San Joaquin Delta Native Fishes Recovery Plan*, which includes delta smelt, was completed in 1996 (U.S. Fish and Wildlife Service 1996).

In response to several law suits, USFWS conducted a 5-year status review for delta smelt and, on March 31, 2004, concluded that delta smelt abundance remained relatively low compared to historical levels and that many of the threats to the species identified at the time of listing were still in existence, precluding delisting of the species (U.S. Fish and Wildlife Service 2004). Subsequent indices of delta smelt abundance based on results of California Department of Fish and Wildlife (CDFW) fishery sampling have shown that the abundance of delta smelt and other POD species has declined substantially in recent years, reaching record low levels of abundance.

In March 2006, the Center for Biological Diversity, the Bay Institute, and the Natural Resources Defense Council filed an emergency petition with USFWS requesting delta smelt be reclassified from threatened to endangered under the ESA (Center for Biological Diversity et al. 2006). Emergency status was not accorded the petition by USFWS. However, on July 10, 2008, USFWS announced in a 90-day finding that consideration for reclassification of delta smelt was warranted and, after an information collection stage, a status review would be initiated (73 FR 39639). On April 7, 2010, USFWS ruled that the change in status from threatened to endangered was warranted, but precluded by other higher priority listing actions (75 FR 17667).

An emergency petition was filed in February 2007 to the California Fish and Game Commission to elevate the status of delta smelt from threatened to endangered under CESA (The Bay Institute et al. 2007). On March 4, 2009, the California Fish and Game Commission elevated the status of delta smelt to endangered under CESA.

Critical habitat was designated by USFWS for the delta smelt under the ESA effective January 18, 1995 (59 FR 65256). The designated critical habitat extends throughout Suisun Bay (including Grizzly and Honker Bays), the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch) and Montezuma Sloughs, and the contiguous waters of the legal Delta (59 FR 65256). Designation of critical habitat for delta smelt was intended to provide additional protection under Section 7 of the ESA with regard to activities that require federal agency action.

2A.1.3 Distribution and Abundance

The geographic distribution of delta smelt occurs primarily downstream of Isleton on the Sacramento River, in the Cache Slough subregion (Cache Slough-Liberty Island and the Deep Water Ship Channel), downstream of Mossdale on the San Joaquin River, and Suisun Bay and Suisun Marsh (Moyle 2002; Kimmerer 2004) (Figure 2A.1-1). Delta smelt also have been collected in the Petaluma and Napa Rivers (Bennett 2005). A delta smelt was caught just below Knights Landing on the Sacramento River, representing the highest known point of the distribution (Vincik and Julienne 2012). Over the last two decades, the center of the adult delta smelt abundance in the fall (September through December) has been the West Delta and Suisun Bay subregions (Sommer et al. 2011). There is evidence that delta smelt may remain in the Cache Slough subregion throughout their lives (Nobriga et al. 2008; Sommer et al. 2011; Lehman et al., possibly because turbidity and prey abundance are sufficient to support them (Sommer et al. 2004; Lehman et al. 2010). Merz et al.

(2011) examined the recent (1995 to 2009) frequency of occurrence of delta smelt in various surveys in the species' range, including the Plan Area. They found that larval delta smelt (less than 15 millimeters) were most frequently found in the West Delta subregion (confluence of the Sacramento/San Joaquin Rivers and the lower San Joaquin River) and the Suisun Marsh subregion. Subjuveniles (15 to 30 millimeters) were most commonly found in the Cache Slough subregion, West Delta subregion (confluence and lower Sacramento River), and Suisun Marsh and Suisun Bay subregions. Juveniles (30 to 55 millimeters) were most frequently found in the Suisun Bay, Cache Slough, and West Delta subregions. Subadults (larger than 55 millimeters) were most commonly found in the West Delta and Suisun Bay subregions. Mature adults had their highest frequency of occurrence in the Suisun Bay subregion, whereas prespawning adults were most frequently collected in the Suisun Marsh, West Delta, and Suisun Bay subregions. Adults in spawning condition were most frequently sampled in the Suisun Marsh and Cache Slough subregions.

Although an unbiased estimate of the abundance of delta smelt is not presently available, indices of relative abundance have been developed using catch data from surveys conducted by the Interagency Ecological Program. Several of the program's surveys provide annual delta smelt abundance information, including the Spring Kodiak Trawl, the larva survey, the 20-millimeter survey, the Summer Townet Survey, and the Fall Midwater Trawl. Relative abundance information can also be obtained from count data on delta smelt entrained into the federal and state water export facilities. The Fall Midwater Trawl provides the best available long-term index of the relative abundance of delta smelt (Moyle et al. 1992; Sweetnam 1999). The indices derived from the Fall Midwater Trawl closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2005), but do not, at present, support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). Fall Midwater Trawl -derived data are generally accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance. The Fall Midwater Trawl -derived indices have ranged from a low of 17 in 2009 to 1,673 in 1970. For comparison, Summer Townet Survey -derived indices have ranged from a low of 0.3 in 2005 and 2009 to a high of 62.5 in 1978. Although the peak high and low values have occurred in different years, the Fall Midwater Trawl and Summer Townet Survey indices show a similar pattern of delta smelt relative abundance that is higher prior to the mid-1980s and very low in the past decade. Smelt abundance is indexed from surveys at different locations and times that sample various life-history stages of delta smelt (Table 2A.1-1). Multiple permanent sites sampled by CDFW and USFWS using many different collection methods intended to sample various life history stages of delta smelt provide a basis for examining trends in abundance of delta smelt under different hydrologic conditions, as well as the temporal and geographic distribution of the species within and among years (Table 2A.1-2, Figure 2A.1-2, Figure 2A.1-3).

Table 2A.1-1. Average Annual Frequency of Delta Smelt Occurrence by Life Stage, Interagency Ecological Program Monitoring Program, and Region, with BDCP Subregion in Brackets

Region [BDCP Subregion]	Average Annual Frequency (%)										
Life Stage:	Larvae (<15 mm)	Sub-Juvenile (≥15, <30 mm)		Juvenile (30–55 mm)			Sub-Adult (>55 mm)	Mature Adults (>55 mm)		Pre-Spawning[a]	Spawning[a]
Monitoring Program:	20-mm	20m-mm	STN	20m-mm	STN	FMWT	FMWT	BS	BMWT	KT	KT
Years of Data Used:	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2006	2002–2009	2002–2009
Time Period:	Apr–Jun	Apr–Jul	Jun–Aug	May–Jul	Jun–Aug	Sep–Dec	Sep–Dec	Dec–May	Jan–May	Jan–Apr	Jan–May
San Francisco Bay	NS	NS	NS	NS	NS	NS	NS	0.0	0.0	NS	NS
West San Pablo Bay	NS	NS	NS	NS	NS	0.2	0.0	0.0	1.2	NS	NS
East San Pablo Bay	0.0	1.0	0.0	2.8	3.6	0.7	0.6	NS	2.7	NS	NS
Lower Napa River	7.3	7.7	3.3	13.3	14.0	1.7	0.8	NS	NS	14.3	11.8
Upper Napa River	11.6	21.2	NS	12.0	NS	NS	NS	NS	NS	NS	NS
Carquinez Strait	5.7	9.3	1.1	24.4	33.7	1.9	3.3	NS	5.4	16.7	0.0
Suisun Bay (SW) [Suisun Bay]	17.8	18.3	1.3	17.5	26.9	4.3	4.3	NS	4.3	23.3	5.6
Suisun Bay (NW) [Suisun Bay]	2.2	8.9	1.1	21.7	34.8	7.3	10.0	NS	8.7	23.3	5.6
Suisun Bay (SE) [Suisun Bay]	19.5	24.9	11.0	20.9	45.7	11.0	12.1	NS	6.5	28.3	6.9
Suisun Bay (NE) [Suisun Bay]	17.8	19.2	33.6	29.7	66.7	20.3	29.3	NS	28.3	48.3	13.9
Grizzly Bay [Suisun Bay]	16.3	27.6	17.9	42.9	72.8	15.0	19.6	NS	30.4	30.0	5.6
Suisun Marsh [Suisun Marsh]	21.4	33.6	14.2	18.5	19.2	22.8	27.2	NS	NS	62.0	23.1
Confluence [West Delta]	35.7	41.6	25.7	29.2	36.1	20.2	24.5	1.8	17.4	30.0	10.4
Lower Sacramento River [West Delta]	16.5	37.0	43.3	26.2	55.5	22.9	37.1	NS	18.8	54.4	17.8
Upper Sacramento River [North Delta]	10.8	8.2	1.3	0.0	0.0	2.7	8.0	5.8	16.7	21.7	15.3
Cache Slough and Ship Channel [Cache Slough]	17.2	47.3	NS	54.3	NS	9.8	26.7	NS	NS	33.9	21.1

Region [BDCP Subregion]	**Average Annual Frequency (%)**										
Life Stage:	**Larvae (<15 mm)**	**Sub-Juvenile (≥15, <30 mm)**		**Juvenile (30–55 mm)**			**Sub-Adult (>55 mm)**	**Mature Adults (>55 mm)**		**Pre-Spawning[a]**	**Spawning[a]**
Monitoring Program:	20-mm	20m-mm	STN	20m-mm	STN	FMWT	FMWT	BS	BMWT	KT	KT
Years of Data Used:	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2009	1995–2006	2002–2009	2002–2009
Time Period:	Apr–Jun	Apr–Jul	Jun–Aug	May–Jul	Jun–Aug	Sep–Dec	Sep–Dec	Dec–May	Jan–May	Jan–Apr	Jan–May
Lower San Joaquin River [West Delta]	28.0	24.5	4.1	5.1	5.6	2.6	3.5	0.9	12.6	30.6	9.7
East Delta [East Delta]	14.6	8.8	0.0	1.2	0.0	0.0	0.0	1.6	NS	5.7	2.3
South Delta [South Delta]	18.4	10.8	0.0	1.4	0.3	0.0	0.0	0.3	NS	7.1	1.1
Upper San Joaquin River [South Delta]	NS	NS	NS	NS	NS	NS	NS	0.2	NS	NS	NS
Sacramento Valley [Sacramento River: North Delta to RM 143]	NS	NS	NS	NS	NS	NS	NS	0.2	NS	NS	NS

Source: Merz et al. 2011

[a] Gonadal stages of male and female delta smelt found in Spring Kodiak Trawl database were classified by California Department of Fish and Wildlife following Mager (1996). Descriptions of these reproduction stages are available at: <http://www.dfg.ca.gov/delta/data/skt/eggstages.asp>.

Mature adults, pre-spawning: Reproductive stages[a]: females 1–3; males 1–4.

Mature adults: spawning: Reproductive stages[a]: females 4; males 5.

20-mm = 20-millimeter Townet
BMWT = Bay Midwater Trawl.
BS = Beach Seine.
FMWT = Fall Midwater Trawl.
KT = Kodiak Trawl.
NS = indicates no survey conducted in the given life stage and region.
SKT = Spring Kodiak Trawl.
STM = Summer Tow-Net.

Table 2A.1-2. Sampling Methods Used to Index the Abundance of Delta Smelt

Sampling Program	Sampling Period	Life-Stage Focus	Target Species
Summer Townet Survey	July–August	Juveniles	Striped bass juveniles
Fall Midwater Trawl	September–December	Preadults	Striped bass juveniles
20 millimeter Townet	March–June	Larvae–juveniles	Delta smelt larvae
Kodiak Trawl	January–May	Juvenile–adult	Delta smelt pre-spawning adults

The surveys vary considerably in sampling methodology, life stage collected, spatiotemporal coverage, and methods used to expand sample data (Bennett 2005). Regardless, all sampling methods consistently have shown that the abundance of delta smelt inhabiting the Bay-Delta system has declined since the 1980s (Figure 2A.1-2). The observed decline in delta smelt abundance is consistent with declines of other pelagic species in the Delta (Sommer et al. 2007; Baxter et al. 2010). Indices of delta smelt abundance in the fall, as reflected in CDFW fall midwater trawl surveys, were the lowest on record in 2006 (Figure 2A.1-2). It should be noted that the CDFW Fall Midwater Trawl survey seems to catch fewer smelt than other methods like the Spring Kodiak Trawl. Significantly more delta smelt have been recorded in a sampling area on the flood tide as opposed to the ebb tide (Feyrer pers. comm.). Because the Fall Midwater Trawl does not take into account the tidal exchange when sampling, it may be under-reporting actual catch due to delta smelt movement out of channel sampling sites during the ebb tide.

Designated critical habitat is displayed in Figure 2A.1-4.

2A.1.4 Life Stages

The life cycle of delta smelt has been reviewed by Moyle et al. (1992), Moyle (2002), and Bennett (2005) and summarized by Nobriga and Herbold (2009). The life cycle generally spans a single year that ends with spawning in the early spring, although a small proportion of the population survives to spawn a second time.

Bennett (2005) describes seven life stages of delta smelt. These seven life stages were reduced to four in Nobriga and Herbold (2009). For purposes of the BDCP analysis, a fifth life stage, spawners, has been added to those of the Nobriga and Herbold (2009) scheme. *Spawners* was added to recognize that adults include adult delta smelt in nearshore spawning areas (spawners) as well as adults in open water (feeding adults, which may be staging prior to spawning). Table 2A.1-3 compares the delta smelt life stages of Bennett (2005) and Nobriga and Herbold (2009).

Table 2A.1-3. Delta Smelt Life Stages

Bennett 2005	Nobriga and Herbold 2009	BDCP
Eggs	Eggs	Eggs
Yolk-sac larvae	Eggs	Eggs
Feeding larvae	Larvae	Larvae
Post larvae	Larvae	Larvae
Juveniles	Juveniles	Juveniles
Adults	Adults	Feeding adults
Maturity	Adults	Spawners

Distribution of delta smelt life stages appears to be based largely on salinity and temperature (Bennett 2005). Larvae, in particular, distribute themselves in relation to the two-parts-per-thousand (2ppt) salinity isohaline, usually about 10 km upstream of it (Dege and Brown 2004). The Summer Tow-Net Survey and the Fall Midwater Trawl survey indicate that over 70% of juveniles and 60% of preadults are collected at salinities less than 2 practical salinity units (psu), with over 90% occurring at salinities less than 7 psu (Bennett 2005). Abundance is centered near or slightly upstream of 2 psu in the entrapment or low-salinity zone (LSZ) (Dege and Brown 2004). Water temperatures above 25°C are above delta smelt tolerance and can constrain available habitat especially in late summer and fall (Swanson et al. 2000). The LSZ, or the entrapment zone, is an area just seaward of the extent of salinity intrusion and is an area of high retention of fishes and zooplankton. It is determined by the interaction of Delta outflow and tidal inflow of marine water from San Francisco and San Pablo Bays. The downstream location of the LSZ typically is in Suisun Bay, extending farther to the west in response to higher Delta outflows and farther to the east in response to lower Delta outflows. Delta smelt have been collected in Carquinez Strait, the Napa River, and even as far downstream as the East Bay Shoreline in wet years (Bennett 2005; Merz et al. 2011). Smaller larvae and spawning activity are distributed away from the LSZ, while prespawning adults and juveniles are distributed along the edge of the LSZ, as indicated by the position of X2 (i.e., the location of the 2-psu bottom salinity isohaline; Jassby et al. 1995). Juvenile delta smelt are most abundant at the upstream edge of the LSZ where salinity is less than 3 psu, water transparency is low (Secchi disk depth less than 0.5 meter), and water temperatures are cool (less than 24°C) (Feyrer et al. 2007; Nobriga et al. 2008). The association with the LSZ may be related to distribution of food as well as abiotic factors such as salinity.

Migrating, staging, and spawning delta smelt reportedly require low-salinity and freshwater habitats, turbidity, and water temperatures less than 20°C (68°F) (Sommer et al. 2011; Grimaldo et al. 2009). Subadult and adult delta smelt densities are positively correlated with turbidity (Feyrer et al. 2007; Nobriga et al. 2008). Several hypotheses have been suggested for the observed positive correlation with turbidity.

- Greater feeding ability because of the contrast of prey against a more visible background.
- A lower risk of predation.

Turbidity has declined in the Delta in the past few decades in part due to trapping of sediment in reservoirs and depletion of the erodible sediment pool from hydraulic mining in the late 1800s, and to increases of submerged aquatic vegetation that traps sediment (Wright and Shoellhamer 2004; Shoellhamer 2011; Hestir et al. 2008). Declining turbidity has been hypothesized as one factor in the long-term decline of delta smelt (Baxter et al. 2010).

2A.1.5 Life History

Sommer et al. 2011 suggest that, from December to March, mature delta smelt move upstream from brackish rearing areas in and around Suisun Bay and the confluence of the Sacramento and San Joaquin Rivers). Murphy et al. (in press) propose that the observed change in distribution is an expansion of smelt distribution using fresher waters throughout their range. The initiation of migration is associated with pulses of freshwater inflow, which are turbid, cool, and less saline (Grimaldo et al. 2009). Spawning has not been observed in the wild; timing and locations may be inferred from the collection of gravid females and larvae. Preferred substrates have been inferred from laboratory observations and other smelt species. From collection of larval smelt, it appears that delta smelt spawn from February to June at water temperatures ranging from approximately 10°C to 20°C, with most spawning in mid-April and May (California Department of Fish and Game 2007; Bennett 2005; Moyle 2002). Recent (2002 to 2009) sampling data showed that individuals in spawning condition were collected in the Suisun Marsh and Cache Slough subregions, and were also collected in upper portions of the West Delta subregion and lower portion of the North Delta subregion (Table 1 in Merz et al. 2011). Sampling of larval smelt in the Delta suggests spawning occurs in the Sacramento River; Barker, Lindsey, Cache, Georgiana, Prospect, Beaver, Hog, Miner, Steamboat and Sycamore Sloughs; in the San Joaquin River off Bradford Island, including Fisherman's Cut; False River along the shore zone between Frank's and Webb Tracts; and possibly other areas (Wang 1991). CDFW sampling has suggested that spawning is often centered in Cache Slough and the lower end of the Sacramento Deep Water Ship Channel (California Department of Fish and Game 2007). In winters with high Delta outflow, the spawning range of delta smelt extends west and includes the Napa River (Hobbs et al. 2005; 2007), as indicated an average of nearly 12% of Kodiak trawl samples containing spawning-condition delta smelt (Table 1 in Merz et al. 2011).

Mager (1996) reported a length/fecundity range spanning 1,196 eggs for a 56-millimeter female to 1,856 eggs for a 66-millimeter female. Captive-reared females may be more fecund than a wild female of the same size; however, the variability in the length-fecundity relationship also appears to be greater for captive females (Bennett 2005). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests strongly that most adults die after they spawn (Radtke 1966; Moyle 2002).

Based on laboratory observations, it is thought that the adhesive, demersal eggs of delta smelt attach by means of a chorion stalk to hard substrates like sand or gravel that are washed by gentle currents adjacent to river channels (Moyle 2002). Spawning occurs mainly at night when females broadcast their eggs while swimming against the current. Eggs incubate from 8 to 15 days, depending on water temperature (Bennett 2005). Temperatures that are optimal for survival of embryos and larvae have not yet been determined, although survival of newly spawned larvae and older delta smelt appears to peak at temperatures about 16°C (Bennett 2005). Postlarval delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay, where the waters are well-oxygenated and temperatures are relatively cool, usually lower than 20°C to 22°C (68°F to 72°F) in summer. Delta smelt tolerate a wide range of temperatures, from less than 6°C to approximately 25°C (Swanson et al. 2000). More than 90% of juvenile and preadult delta smelt caught in the CDFW Summer Townet Survey and Fall Midwater Trawl Survey were collected at water temperatures lower than 20°C (Bennett 2005).

Larvae emerge near where they are spawned, and mainly inhabit tidal fresh water at temperatures between 10°C to 20°C (Bennett 2005). The center of distribution (1995 to 2001) for delta smelt larvae less than 20 millimeters is usually 5 to 20 kilometers upstream of X2, but most larvae move closer to X2 as the spring progresses into summer (Dege and Brown 2004). Survival during the larval period is linked to the minimum density of zooplankton prey (Maunder and Deriso 2011; Miller et al. 2012). The effects of outflow are complex, affecting not only abundance, but also patterns of distribution, and possibly the timing of spawning events (Moyle 2002). The lowest numbers of smelt generally occur in years of either low or extremely high outflow, but outflow and smelt numbers show no relationship at intermediate flows where abundance is highly variable (Moyle 2002; Bennett 2005).

Feeding success is highly dependent upon prey densities (Nobriga 2002) and turbidity (Baskerville-Bridges et al. 2004; Mager et al. 2004). Juveniles grow to 40 to 50 millimeters total length by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). Delta smelt reach 55 to 70 millimeters standard length in 7 to 9 months (Moyle 2002). Growth during the next 3 months slows down considerably (only 3 to 9 millimeters total), presumably because most of the energy ingested is directed toward gonadal development (Erkkila et al. 1950; Radtke 1966).

In a near-annual fish like delta smelt, maximizing recruitment success is vital to the long-term persistence of the population. There is some evidence that density-dependent (preferred food resources) and density-independent (turbidity, salinity and temperature) factors may affect the population (Bennett 2005; Maunder and Deriso 2011; Miller et al. 2012).

Figures 2A.1-5 and 2A.1-6 show the distribution of adult and larval/juvenile delta smelt in a typical above-normal water year.

2A.1.6 Threats and Stressors

Threats can be defined as conditions or events that change an organism's probability of survival. Stressors are conditions or events that change an organism's behavior or physiology. There are multiple threats and stressors to delta smelt that appear to act in complicated and synergistic ways to influence their distribution and abundance (Moyle 2002). Delta smelt are particularly vulnerable to these threats and stressors because of their short life span, low fecundity, low current abundance, and limited geographic range. Stressor rankings and the certainty associated with these rankings are provided in Chapter 5, *Effects Analysis,* of the BDCP. The discussion below outlines some of the main threats and stressors to delta smelt.

2A.1.6.1 Water Exports

Despite the number of delta smelt that have been entrained by the State Water Project (SWP) and Central Valley Project (CVP) export facilities and over 2,200 smaller diversions in the Delta (Herren and Kawasaki 2001), the direct effects of water diversions on the overall population dynamics of delta smelt are not well understood and there is disagreement among experts about the magnitude of these effects (Bennett 2005; Kimmerer 2008; Kimmerer 2011; Miller 2011).

Entrainment risk for delta smelt has largely been based on analyses of SWP/ CVP fish salvage data and Delta hydrodynamics. At least one analysis seemed to suggest a correlation between SWP/ CVP exports and indices of delta smelt abundance, suggesting that entrainment may negatively affect delta smelt abundance (Kimmerer 2011). These relationships do not establish causality, but they are an indicator that entrainment as indexed by salvage is a contributing factor in delta smelt population dynamics. Kimmerer (2008) estimated that entrainment losses of adult delta smelt had a median value of 15% (range 1 to 50%) while seasonal losses for juvenile delta smelt had a median value of 13% (range of 0 to 25%). In response to criticism from Miller (2010), Kimmerer (2011) reexamined his analysis in 2008 and revised his adult delta smelt entrainment losses down by 24%. In his reexamination of juvenile numbers, Kimmerer concluded that Miller was mistaken about his conclusion of high bias and, if anything, his (Kimmerer 2008) estimates were probably biased low. Kimmerer (2008) concluded that the effect of these losses on population abundance of delta smelt was obscured by a 50-fold variation in the overall survival of delta smelt between summer and fall. Kimmerer (2011) also found that, even when entrainment loss appeared to be moderate, it could still be significant in terms of its effects on abundance in some years. Thomson et al. (2010) found that water clarity and the volume of winter water exports statistically significant predicators of the long-term abundance of delta smelt and other fish, but could not explain the recent record low levels of delta smelt. Mac Nally et al. (2010) found that winter and spring export volumes showed some evidence for a negative association with delta smelt abundance in the subsequent fall. Miller et al. (2012) found that combined winter/spring entrainment of adult and larval-juvenile delta smelt was included in the best-fitting equation describing survival from fall to summer, although they did not find entrainment to be one of the important predictors of survival from fall to fall.

The risk of entrainment to delta smelt varies seasonally and among years. The most important entrainment risk has been hypothesized to occur during winter, when prespawning adults migrate into the Delta in preparation for spawning (Moyle 2002; Sommer et al. 2007). Bennett (2005) has hypothesized that delta smelt that spawn earlier in the winter are more vulnerable to entrainment by the south Delta export facilities. Fish that hatch earlier can grow larger prior to spawning than fish that hatch later. Larger females may be more fecund, spawn repeatedly, and produce more offspring with higher fitness than smaller females. As a result, Bennett hypothesized that entrainment during winter months may have a disproportionately large impact on the overall population dynamics of delta smelt than entrainment during other periods of the year.

A 2007 federal court decision regarding interim operational restrictions on SWP/CVP exports (Wanger decision). The 2007 decision on the Occupational Criteria and Plan (OCAP) litigation centered on the District Court's finding that the biological opinion (BiOp) did not provide reasonable certainty that mitigation would occur, and was therefore inadequate to protect the species. The Interim Remedies and subsequent BiOp (2008) used the Old and Middle River relationship to both better assess the effects of SWP/CVP operations and to design a more effective means of addressing the impacts. (U.S. Fish and Wildlife Service 2008b.) The analyses indicated that delta smelt salvage remained relatively low when reverse flows in Old and Middle Rivers were below approximately -5,000 cubic feet per second (cfs), but salvage increased substantially as reverse flows increased above 5,000 cfs.

Several limitations of current fish salvage operations are recognized. First, the salvage facilities were designed primarily for salmonids; the overall facility efficiency of delta smelt salvage is relatively poor (Bowen et al 2004; Castillo et al 2012). Further, while it is assumed that salvage is proportional to entrainment, the relationship is likely to vary with both operations and fish densities. Another limitation of the salvage operation is due to the inherent difficulty of identifying larval fishes by species in real time, thus it only identifies and counts fish greater than 20 millimeters in length. As a result, smaller larval delta smelt are not included in fish salvage estimates. Until now, estimates of entrainment losses for larval delta smelt and estimates of population abundance have been based on extrapolations from results of the CDFW 20-millimeter delta smelt survey. However, those estimates have been criticized because some of the assumptions supporting the population and entrainment loss estimates have not been tested or validated. Recognizing that larval delta smelt are vulnerable to SWP/ CVP entrainment that may vary in magnitude and potential effect on the population among years, the federal district court ordered that a study be conducted beginning in 2008 to monitor the densities of larval delta smelt vulnerable to SWP/CVP entrainment to determine whether or not protective measures are needed for larvae.

Delta smelt are not believed to be threatened by small agriculture diversions. Nobriga and Matica (2000) and Nobriga et al. (2004) found low and inconsistent entrainment of juvenile delta smelt by small agricultural diversions near Sherman Island; the low entrainment rates were hypothesized to be the result of juvenile delta smelt occurring offshore of the intake location and in the upper portions of the water column. Cook and Buffaloe (1998) also reported that unscreened agricultural diversions entrained low numbers of delta smelt. Larvae may have higher entrainment losses than juveniles and adults because they are planktonic, with poor swimming ability.

Power plants located in the Plan Area at Pittsburg has the potential to entrain large numbers of fish, including delta smelt and other covered fish species, particularly because these species may be located near these facilities for much of the year (Matica and Sommer 2005). However, use of cooling water is currently low because of the retirement of older units. According to recent regulations, units at these two plants must be equipped with a closed cycle cooling system by 2017 that eliminates fish entrainment.

2A.1.6.2 Habitat Loss

2A.1.6.2.1 Reduced Spawning Habitat

Although delta smelt spawning has not been observed in the Bay-Delta, it is generally thought that spawning occurs in shallow, low-salinity areas with sand or gravel substrate on which to deposit adhesive egg sacs (Bennett 2005). The extent of these areas is dependent on the spatial distribution of fresh water in the estuary (Hobbs et al. 2005; 2007). Such habitat could occur in Cache Slough or in shallow shoals located in the Deep Water Ship Channel (Bennett 2007) and may be reduced because of land reclamation, channelization, and riprapping of historical intertidal and shallow subtidal wetlands. The extent to which such habitat loss may be limiting the population is unknown (Bennett 2005; Miller et al. 2012); however, spawning substrates are not thought to be a limiting factor for delta smelt

2A.1.6.2.2 Reduced Rearing Habitat

There is evidence that the availability and suitability of delta smelt rearing habitat varies with salinity and the location of the LSZ (Moyle et al. 1992; Hobbs et al.2006; Feyrer et al 2007; Kimmerer et al 2009). The Suisun Marsh salinity control gates function to decrease salinity in managed wetlands of Suisun Marsh to support crops that attract waterfowl to duck clubs located throughout the marsh. When in operation, generally from October through May, the control gates near Collinsville divert up to 2,500 cubic feet per square inch (cfs) of fresh water from upstream flows into the marsh. Because the minimum outflow standard during fall months is 5,000 cfs, a significant proportion of total Delta outflow (up to 50%) does not flow through the eastern Suisun Bay region. This diversion moves the LSZ upstream resulting in a measurable increase in salinity in eastern Suisun Bay, which may correspond to a decrease in low salinity habitat for delta smelt. The LSZ also moves in response to gross hydrology (e.g., precipitation in the watershed) and SWP/CVP diversions. Outflow objectives in the State Water Resources Control Board Decision 1641 recognize the importance of the location of the LSZ, and are intended to protect beneficial uses for fish and wildlife. Recent assessments conducted by mandate of the Delta Reform Act indicate that current Delta flow criteria may not be sufficient to protect public trust resources (State Water Resources Control Board and California Environmental Protection Agency 2010). The BDCP delta smelt conceptual model includes a submodel for fall X2, as discussed in Chapter 5, *Effects Analysis*.

2A.1.6.3 Water Temperature

Delta smelt are members of the cold water fish family (Osmeridae) and it is adapted to cold to cool water temperatures like many other California fish species (Moyle 2002). Delta smelt are sensitive to exposure to elevated water temperatures (Swanson and Cech 1995), and high temperatures are known to reduce delta smelt survival (Swanson et al. 2000) and interfere with spawning (Bennett 2005). During the late spring, summer, and early fall months water temperatures in the central and southern regions of the Delta typically exceed 25°C (77°F), which has been found to be close to the incipient lethal temperature for delta smelt. During these warmer periods, results of fishery sampling have shown that delta smelt avoid inhabiting the central and south Delta and are typically located downstream in Suisun Bay and Suisun Marsh. Although water temperatures are cooler in Suisun Bay during the summer months, water temperatures in excess of 20°C (68°F) are typical in July (Nobriga et al. 2008). Under these warm summer conditions, delta smelt rearing in Suisun Bay and Suisun Marsh would be stressed by exposure to elevated water temperatures and would experience higher metabolic demands and a greater demand for food supplies to maintain individual health and a positive growth rate. Stresses experienced by rearing delta smelt during the warmer summer months, which include the synergistic effects of salinity and seasonally elevated water temperatures, have been hypothesized to be a potentially significant factor affecting delta smelt survival, abundance, and subsequent reproductive success in the Bay-Delta estuary (Baxter et al. 2010; Mac Nally et al. 2010; Miller et al. 2012).

Recent climate change analyses have examined the potential implications of climate warming for delta smelt (Wagner et al. 2011; Brown et al. 2013). Modeling results projected increases in the number of days with lethal and stressful water temperatures (especially along the Sacramento River) and a shift in thermal conditions for spawning to earlier in the year, upstream movement of the LSZ, and decreasing habitat suitability.

2A.1.6.4 Turbidity

Turbidity is a significant predictor of delta smelt occurrence in the Delta (Feyrer et al. 2007; Resources Agency 2007; Nobriga et al. 2008; Grimaldo et al. 2009). Delta smelt require turbidity for both successful foraging (Feyrer et al. 2007; Nobriga et al. 2008) and predator escape (Feyrer et al. 2007), and turbidity is an important cue for delta smelt spawning movements (Grimaldo et al. 2009). Thompson et al. (2010) found fall water clarity to be a significant covariate associated with changes in delta smelt abundance over time.

Turbidity levels have declined in the Bay-Delta estuary since the 1970s as a result of numerous factors (Kimmerer 2004):

- Upstream sediment inputs have declined because of a range of anthropogenic actions, including river bank protection, trapping of sediments by dams and reservoirs, levee construction that has reduced floodplain inundation and channel meanders, and changes in land use (Wright and Shoellhamer 2004; Shoellhamer 2011). Wright and Shoellhamer (2004) estimated that the yield of suspended sediments from the Sacramento River declined by approximately 50% from 1957 to 2001.

- There has been a dramatic increase over the past 20 years in the distribution and abundance of nonnative aquatic plant species, particularly Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*) (Nobriga et al. 2005; Brown and Michniuk 2007). Both species can reduce turbidity by reducing local water velocities and trapping fine suspended sediments (Grimaldo and Hymanson 1999; Nestor et al. 2003; Hobbs et al. 2006).

- The high filtering efficiency of invasive clams has dramatically reduced phytoplankton and zooplankton abundance in the western Delta and Suisun Bay (Kimmerer and Orsi 1996; Jassby et al. 2002; Kimmerer 2002b, 2004). The reduction in phytoplankton in the water column may contribute to increased water clarity and reduced turbidity in the Delta.

- Hydraulic residence time in the Delta has declined because of increased channelization and the movement of water from the Sacramento River into the interior Delta channels to improve water quality and provide increased supplies to the SWP/CVP exports. Reduced hydraulic residence time reduces the ability of phytoplankton and bacteria to incorporate nutrients and carbon, ultimately reducing the abundance of these organisms in the water column, and increasing water clarity (Jassby et al. 2002; Kimmerer 2002a, 2004; Resources Agency 2007).

- The creation of large, shallow open water areas makes it likely that turbidity inside and near several of the restoration opportunity areas will increase seasonally due to wind-wave sediment resuspension. There is evidence that declining wind speeds may be a factor in declining turbidity throughout the Plan Area (Fullerton pers. comm.). A dynamic suspended sediment model of the Plan Area would be required to take into account the many interacting factors that may influence water clarity and to reduce uncertainty regarding the potential effects of the BDCP on water clarity.

2A.1.6.5 Food Resources

Reduced food availability in the Bay-Delta estuary has been identified as a major stressor on delta smelt. Recent analyses by Maunder and Deriso (2011) and Miller et al. (2012) indicated that prey density was the most important environmental factor explaining variations in delta smelt abundance from 1972 to 2006 and over the recent period of decline. Delta smelt feed primarily on calanoid copepods, cladocerans, amphipods, and, to a lesser extent, on insect larvae (Moyle et al. 1992; Lott 1998; Nobriga 2002). Larger delta smelt may also feed on the mysid shrimp, *Neomysis* (Moyle et al. 1992). Mac Nally et al. (2010) found evidence for a relationship between summer calanoid copepod biomass and changes in delta smelt abundance. The most important food organism for all sizes of delta smelt appears to be the euryhaline copepod, *Eurytemora*, although the nonnative *Pseudodiaptomus* has become a major part of the diet since its introduction in 1988 (Kimmerer and Orsi 1996; Nobriga 2002; Hobbs et al. 2006). In recent years, heavy grazing by introduced clams has depleted phytoplankton standing stock, limiting food supplies for the zooplankton prey of delta smelt and other fish species. The overbite clam, *Potamocorbula amurensis*, found in brackish areas, has had a dramatic effect on food resources in the western Delta, Suisun Bay, and Suisun Marsh (Kimmerer and Orsi 1996), while the effect of the freshwater Asian clam, *Corbicula fluminea*, are mainly limited to freshwater flooded island areas (Lucas et al. 2002; Lopez et al. 2006). By filtering large quantities of phytoplankton from the water column and increasing water clarity, the clams may also reduce delta smelt foraging efficiency.

The following factors may contribute to the observed reductions in zooplankton prey densities.

- Historically, a significant reduction in tidal and shallow-water subtidal habitat caused a reduction in emergent vegetation, nutrient cycling, and the production of phytoplankton, zooplankton, macroinvertebrates, and other aquatic organisms that provide food resources for delta smelt. These changes were in place when delta smelt abundance was much higher than it is today.
- Historical loss of seasonally inundated floodplains reduces food exports. Upstream reservoirs and levees have reduced the seasonal inundation of floodplains in the Delta (Moyle et al. 2010). Floodplains are highly productive due to their shallow, warm, and low velocity water (Sommer et al. 2001a, 2001b; Harrell and Sommer 2003) and the input of organic material and nutrients from the terrestrial community (Booth et al. 2006). Floodplains provide benefits to the larger estuary by exporting food resources to downstream systems, providing increased production for pelagic species such as delta smelt (Schemel et al. 2004; Ahearn et al. 2006; Lehman et al. 2008).
- The historical loss of complex dendritic channel morphology and water operations has reduced hydraulic residence time, which reduces phytoplankton production (Jassby et al. 2002; Kimmerer 2002a, 2004; Resources Agency 2007).
- SWP/ CVP exports and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) exports has changed system energetics of a low productivity system by removing organic material biomass including phytoplankton equivalent to 30% of the Delta's primary productivity (Jassby et al. 2002; Cloern and Jassby 2012).
- High concentrations of ammonia[1] from municipal wastewater treatment plants inhibit sdiatom production, reducing the food available for the zooplankton prey of delta smelt and other fish species (Wilkerson et al. 2006; Dugdale et al. 2007; Glibert 2010; Cloern et al. 2011; Glibert et al. 2011; Parker et al. 2012; Dugdale et al. 2012). Changes in nitrogen and phosphorus ratios and ammonia and nitrate ratios may have enhanced phytoplankton and zooplankton species that are less beneficial as food resources for delta smelt (Glibert et al. 2011). Nitrogen to phosphorus ratios may also affect several metabolic pathways in phytoplankton, including growth, cell membrane thickness, chemical makeup, toxin production, fecundity, and eventual outcome of the population (Mitra and Flynn 2005; Jeyasingh and Weider 2005, 2007). High concentrations of ammonia may also be directly toxic to organisms. Teh et al. (2011) found that total ammonium at levels commonly found in the Sacramento River significantly affects the recruitment of new adult copepods (*Pseudodiaptomus forbesis*) and the number of newborn nauplii surviving to 3 days.

2A.1.6.6 Contaminants and Exposure to Toxins

Exposure of delta smelt to toxic substances can result from point and nonpoint sources associated with agricultural, urban, and industrial land uses. Delta waters contain a wide variety and large volume of toxic substances, including agricultural pesticides, herbicides, endocrine disruptors, heavy metals, and other agricultural and urban products (Thompson et al. 2000; Brooks et al. 2012). There is some indication that the ammonia discharged from municipal wastewater treatment plants may contribute to localized toxicity in delta smelt, but results are highly variable (Werner et al.

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

2008). Toxics may affect delta smelt indirectly by reducing food resources (Luoma 2007; Werner 2007; Teh et al 2011), but the short life span (1 to 2 years) and location of their food sources in the food web (zooplankton are primary consumers) reduce the ability of toxic chemicals to bioaccumulate in the tissue of delta smelt (Moyle 2002). Exposure to environmentally relevant pyrethroid concentrations resulted in significant swimming abnormalities in delta smelt. Kuivila and Moon (2004) found that the exposure to multiple pesticides for an extended period could pose potential lethal or sublethal effects on delta smelt, particularly during the larval development stage. This scenario occurred at the confluence of the Sacramento and San Joaquin Rivers with pesticide concentrations and fish densities coinciding for several weeks.

Exposure to copper contamination also results in significant sublethal effects on Delta fish species, with implications for their vulnerability to other stressors (Hetrick et al. 1979; Sandahl et al. 2006; Little and Finger 1990; Oros and Werner 2005). Dissolved copper causes acute toxicity to the calanoid copepod, *Eurytemora affinis*, in the north and south Delta (Teh et al. 2009). Additionally, negative synergistic effects have been documented such that the presence of copper in combination with ammonia is more toxic to aquatic organisms than either toxicant individually (Herbert and Vandyke 1964). Copper concentrations 32 times higher than background have been found in the Sacramento River delta smelt (Bennett et al. 2001)

The short life span and location of their food source in the food web (zooplankton are primary consumers) reduce the ability of toxic chemicals to bioaccumulate in the tissue of delta smelt (Moyle 2002). Their location in the water column may further reduce the probability of some toxic impacts by those chemicals that are sequestered quickly by sediments (e.g., pyrethroids). However, Weston and Lydy (2010) found sufficient concentration of the pyrethroid bifenthrin to cause water column toxicity in two urban creeks, over at least a 30-kilometer reach of the American River, and at one site in the San Joaquin River. It is unknown to what extent these effects were evident when these chemical levels were diluted in the much larger Sacramento and San Joaquin River systems. Additional research is needed to investigate the potential risk of exposure to toxic chemicals at concentrations and exposure durations typical of Bay-Delta conditions on various life stages of delta smelt. Brooks et al. (2012) presented a conceptual model of potential contaminant effects on delta smelt, including elements such as acute toxicity to larvae and juveniles, direct or indirect food limitation, impaired behavior and disease susceptibility, harmful algal blooms, migratory release of toxins from fat reserves, and temperature effects on toxic thresholds.

2A.1.6.7 Predation and Competition

The importance of predation on delta smelt relative to others is uncertain. Statistical analyses have shown some evidence for links between delta smelt abundance or survival and predation (Mac Nally et al. 2010; Maunder and Deriso 2011). Silversides may consume delta smelt eggs and larvae (Bennett 2005). In a pilot study, genetic testing found that 41% of 37 silversides caught in the channel of Cache Slough contained delta smelt DNA in their guts, while none of 614 silversides from nearshore areas contained delta smelt DNA (Baerwald et al. 2012). Silversides are highly abundant throughout the delta smelt geographic range, their diet range encompasses that of delta smelt, and because they spawn repeatedly throughout late spring, summer, and fall, they have a competitive advantage over delta smelt (Bennett 1998, 2005).

In an experiment where delta smelt were released into Clifton Court Forebay, recapture rates were very low due to prescreen losses attributed to increased residence time, which increased exposure to predators and other sources of potential mortality (Castillo et al. 2012). Wakasagi can occur in the delta smelt geographic range and have similar life requirements. Wakasagi have a higher tolerance to salinity and temperature and a wider geographic range than delta smelt, suggesting that they have a competitive advantage over delta smelt. The two species are not closely related genetically and, although first generation hybrids have been collected, all of them have been sterile (Stanley et al. 1995; Trenham et al. 1998). However, if wakasagi abundance in delta smelt habitat were to increase dramatically, the risk of genetic introgression would be enhanced (Bennett 2005). The recent decline in delta smelt abundance has likely made the species vulnerable to inbreeding and genetic drift, leading to decreased genetic variation and reduced evolutionary fitness (Center for Biological Diversity et al. 2006). However, no estimates currently exist for the minimum viable population size of delta smelt, nor have studies been conducted to evaluate changes in genetic diversity.

2A.1.6.8 Invasive Aquatic Vegetation

Egeria and water hyacinth are fast-growing and abundant aquatic plants that have had detrimental effects on the Bay-Delta aquatic ecosystem, including competition with native vegetation and reducing dissolved oxygen concentrations and turbidity within their immediate vicinity (Grimaldo and Hymanson 1999; Brown and Michniuk 2007; Feyrer et al. 2007). These nonnative plant species grow in dense aggregations and can indirectly affect delta smelt by reducing dissolved oxygen levels and nearby flow rates, thus reducing suspended sediment concentrations and turbidity within the water column. Furthermore, because of the three-dimensional structure and shade they provide, these aquatic plants likely create excellent habitat for nonnative predators of delta smelt, primarily centrarchids (Nobriga et al. 2005). Mac Nally et al. (2010) found some evidence for a negative association between delta smelt abundance and the abundance of largemouth bass.

2A.1.7 Relevant Conservation Efforts

Pursuant to the CALFED objective of ecosystem restoration, the CALFED agencies developed the Ecosystem Restoration Plan and the Environmental Water Account for the purpose of restoring habitat and recovering at-risk populations like delta smelt in the Bay-Delta estuary (CALFED Bay-Delta Program 2000).

In January 2005, the Interagency Ecological Program established the POD work group to investigate the causes of the observed rapid decline in populations of pelagic organisms, including delta smelt, in the upper San Francisco Bay estuary (Armor et al 2006, Baxter et al. 2008, 2010). The Resources Agency prepared the *Pelagic Fish Action Plan* in March 2007 to address POD (Resources Agency 2007). The action plan identifies 17 actions that are being implemented or that are under active evaluation to help stabilize the Delta ecosystem and improve conditions for pelagic fish.

The USFWS recovery strategy for delta smelt is contained in the *Sacramento-San Joaquin Delta Native Fishes Recovery Plan* (U.S. Fish and Wildlife Service 1996). The basic strategy for recovery is to manage the estuary in such a way that it provides better habitat for native fish in general and delta smelt in particular. Since 1996, new significant findings regarding the status and biology of and threats to delta smelt have emerged, prompting development of an updated recovery plan.

In 2007, the Federal District Court, Eastern District of California, Fresno Division (Judge Wanger) issued a court order for interim actions to protect delta smelt pending completion of a new BiOpby USFWS on SWP/CVP operations. The court ruling remained in effect until the new BiOp was approved in December 2008. The 2008 BiOp indicated that “coordinated operations of CVP and SWP diversion facilities, as proposed, are likely to jeopardize the continued existence of delta smelt” (U.S. Fish and Wildlife Service 2008b). The new opinion detailed “reasonable and prudent” alternative actions to reduce the likelihood of jeopardy that include improvements to flow conditions, restoration of tidal marsh and associated subtidal habitat in the Delta and Suisun Marsh, and a comprehensive monitoring plan. However, specific portions of the new BiOp were found arbitrary and capricious by the Federal District Court and the BiOp has been partially remanded.

2A.1.8 References Cited

2A.1.8.1 Literature Cited

Ahearn, D. S., J. H. Viers, J. F. Mount, and R. A. Dahlgren. 2006. Priming the Productivity Pump: Flood Pulse Driven Trends in Suspended Algal Biomass Distribution Across a Restored Floodplain. *Freshwater Biology* 51:1417–1433.

Armor, C., R. Baxter, B. Bennett, R. Breuer, M. Chotkowski, P. Coulston, D. Denton, B. Herbold, W. Kimmerer, K. Larsen, M. Nobriga, K. Rose, T. Sommer, and M. Stacey. 2006. Interagency Ecological Program synthesis of 2005 work to evaluate the pelagic organism decline (POD) in the upper San Francisco estuary. Interagency Ecological Program for the San Francisco Estuary report.

Baerwald, M.R., B.M. Schreier, G. Schumer, and B. May. 2012. Detection of Threatened Delta Smelt in the Gut Contents of the Invasive Mississippi Silverside in the San Francisco Estuary Using TaqMan Assays. *Transactions of the American Fisheries Society* 141: 1600–1607.

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The Effect of Light Intensity, Alga Concentration, and Prey Density on the Feeding Behavior of Delta Smelt Larvae. In: F. Feyrer, L. Brown, R.Brown, and J. Orsi (eds.). *Early Life History of Fishes in the San Francisco Estuary and Watershed.* Bestheda, MD: American Fisheries Society. Symposium 39. Pages 219-228.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, B. Herbold, P. Hrodey, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. *Interagency Ecological Program 2008 Work Plan to Evaluate the Decline of Pelagic Species in the Upper San Francisco Estuary.* Available: <http://www.science.calwater.ca.gov/pdf/workshops/POD/2008_IEP-POD_Workplan_060208.pdf>.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solgar, T. Sommer, and K. Souza. 2010. *Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results*. Available: <www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf>.

Bennett, J., J. Hofius, C. Johnson, and T. Maurer. 2001. *Tissue Residues and Hazards of Water-Borne Pesticides for Federally Listed and Candidate Fishes of the Sacramento-San Joaquin River Delta, California: 1993–1995.* July. Sacramento, CA: U.S. Fish and Wildlife Service. Environmental Contaminants Division.

Bennett, W. A. 1998. *Silversides, Smelt, and the Slough of Dreams: Who Will Come if We Restore It?* Proceedings of San Francisco Estuary Institute workshop. Biological Invasions in Aquatic Ecosystems: Impacts on Restoration and Potential for Control. April 25.

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* 3(2):Article 1. Available: <http://escholarship.org/uc/item/0725n5vk>. Accessed: December 14, 2011.

Bennett, W. A. 2007. *Environmental Issues.* CALFED Science Workshop: Science Related to an Isolated Facility. August 22.

Bennett, W. A., W. J. Kimmerer, and J. R. Burau. 2002. Plasticity in Vertical Migration by Native and Exotic Estuarine Fishes in a Dynamic Low–Salinity Zone. *Limnology and Oceanography* 47(5): 1496–1507.

Booth, E., J. Mount, and J. Viers. 2006. Hydrologic Variability of the Cosumnes River Floodplain. *San Francisco Estuary and Watershed Science* [online serial] 4(2), Article 2.

Bowen, M. D., B. Baskerville-Bridges, K. W. Frizell, L. Hess, C. A. Karp, S. M. Siegfried, and S. L. Wynn. 2004. *Empirical and Experimental Analyses of Secondary Louver Efficiency at the Tracy Fish Collection Facility: March 1996 To November 2007.* Tracy Fish Facility Studies Vol. 11. Springfield, Va.

Brooks, M., E. Fleishman, L. Brown, P. Lehman, I. Werner, N. Scholz, C. Mitchelmore, J. Lovvorn, M. Johnson, D. Schlenk, S. van Drunick, J. Drever, D. Stoms, A. Parker, and R. Dugdale. 2012. Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary, California, USA. *Estuaries and Coasts* 35(2):603–621.

Brown, L. R., and D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30(1):186–200.

Brown, L. R., W. A. Bennett, R. W. Wagner, T. Morgan-King, N. Knowles, F. Feyrer, D. H. Schoellhamer, M. T. Stacey, M. Dettinger. 2013. Implications for Future Survival of Delta Smelt from Four Climate Change Scenarios for the Sacramento-San Joaquin Delta, California. *Estuaries and Coasts*. DOI 10.1007/s12237-013-9585-4.

CALFED Bay-Delta Program. 2000. *Programmatic Record of Decision.* August 28, 2000.

California Department of Fish and Game. 2007. *Results of Spring Kodiak Trawl Survey Sampling.* Available: <http://www.delta.dfg.ca.gov/data/skt/>.

Castillo, G., J. Morinaka, J. Lindberg, R. Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, and L. Ellison. 2012. Pre-Screen Loss and Fish Facility Efficiency for Delta Smelt at the South Delta's State Water Project, California. *San Francisco Estuary and Watershed Science* 10(4).

Center for Biological Diversity, The Bay Institute, Natural Resources Defense Council. 2006. Emergency petition to list the delta smelt (*Hypomesus transpacificus*) as an endangered species under the endangered species Act. Submitted to the U.S. Fish and Wildlife Service, Washington DC and Sacramento Field Office, CA. March 8, 2006. Available: <http://www.biologicaldiversity.org/swcbd/species/deltasmelt/DS-Endangered-Petition-3-8-06.pdf>.

Cloern, J. E. and A. D. Jassby. 2012. Drivers of Change in Estuarine-Coastal Ecosystems: Discoveries from Four Decades of Study in San Francisco Bay. *Reviews in Geophysics* 50, RG4001, DOI:10.1029/2012RG000397.

Cloern, J. E., A. D. Jassby, J. Carstensen, W. A. Bennett, W. J. Kimmerer, R. MacNally, D. H. Schoellhamer, and M. Winder. 2011. Perils of Correlating CUSUM-Transformed Variables to Infer Ecological Relationships (Breton et al. 2006; Glibert 2010). *Limnology and Oceanography* 57:665–668.

Cook, L. and L. D. Buffaloe. 1998. *Delta Agricultural Diversion Evaluation Summary Report, 1993–1995*. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report Number 61. Sacramento, CA.

Dege, M. and L. R. Brown. 2004. Effect of Outflow on Spring and Summertime Distribution and Abundance of Larval and Juvenile Fishes in the Upper San Francisco Estuary. In: F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi (eds.). Early Life History of Fishes in the San Francisco Estuary and Watershed. *American Fisheries Society Symposium* 39:49–66.

Dugdale, R. C., F. P. Wilkerson, V. E. Hogue, and A. Marchi. 2007. The Role of Ammonium and Nitrate in Spring Bloom Development in San Francisco Bay. *Estuarine Coastal and Shelf Science* 73:17–29.

Dugdale, R., F. Wilkerson, A. E. Parker, A. Marchi, and K. Taberski. 2012. River Flow and Ammonium Discharge Determine Spring Phytoplankton Blooms in an Urbanized Estuary. *Estuarine and Coastal Shelf Science*. 115:187–199.

Erkkila, L. F., J. F. Moffett, O. B. Cope, B. R. Smith, and R. S. Nelson. 1950. *Sacramento-San Joaquin Delta Fishery Resources: Effects of Tracy Pumping Plant and Delta Cross Channel.* U.S. Fish and Wildlife Service Special Report. Fisheries 56.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Science* 64:723–734.

Ganssle, D. 1966. Fishes and Decapods of San Pablo and Suisun Bays. In: D.W. Kelley (ed.). *Ecological Studies of the Sacramento-San Joaquin Estuary, Part 1.* California Department of Fish and Game, Fish Bulletin No. 133. Pages 64–94.

Glibert, P. 2010. Long-Term Changes in Nutrient Loading and Stoichiometry and Their Relationships With Changes in The Foodweb and Dominant Pelagic Fish Species in the San Francisco Estuary, California. *Reviews in Fisheries Science* 18:211–232.

Glibert, P. M., D. Fullerton, J. M. Burkholder, J. C. Cornwell, and T. M. Kana. 2011. Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems. *Reviews in Fisheries Science* 19(4):358–417.

Gould, A. L., and W.J. Kimmerer. 2010. Development, Growth, and Reproduction of the Cyclopoid Copepod *Limnoithona tetraspina* in the Upper San Francisco Estuary. *Marine Ecology Progress Series* 412:163–177.

Grimaldo, L. F., and Z. Hymanson. 1999. What is the Impact of the Introduced Brazilian Waterweed *Egeria Densa* to the Delta Ecosystem? *Interagency Ecological Program Newsletter* 12(1):43–45. Available: <http://www.iep.water.ca.gov/report/newsletter>.

Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, P. Smith and B. Herbold. 2009. Factors Affecting Fish Entrainment into Massive Water Diversion in a Tidal Freshwater Estuary: Can Fish Losses Be Managed? *North America Journal of Fisheries Management* 29:1253–1270.

Harrell, W. C., and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. In P.M. Faber (ed.). *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration.* 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, CA. Pages 88–93.

Herbert, D. W. M. and J. M. Van Dyke. 1964. The Toxicity to Fish of Mixtures of Poisons. Copper-Ammonia and Zinc-Phenol Mixtures. *Annals of Applied Biology* 53:15–421.

Herren, J. R., and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. In R.L. Brown (ed.). Contributions to the Biology of Central Valley Salmonids. Volume 2. *California Fish and Game. Fish Bulletin* 179:343–355

Hestir, E. L., S. Khanna, M. E. Andrew, M. J. Santos, J. H. Viers, J. A. Greenberg, S. S. Rajapakse, and S. L. Ustin. 2008. Identification of Invasive Vegetation Using Hyperspectral Remote Sensing in the California Delta Ecosystem. *Remote Sensing of Environment* doi:10.1016/j.rse.2008.01.022.

Hetrick, F. M., M. D, Knittel, and J. L. Fryer. 1979. Increased Susceptibility of Rainbow Trout to Infections Hematopoietic Necrosis Virus after Exposure to Copper. *Applied and Environmental Microbiology 37*(2):198–201.

Hobbs, J. A., Y. Qing-zhu, J. E. Burton, and W. R. Bennett. 2005. Retrospective Determination of Natal Habitat for an Estuarine Fish with Otolith Strontium Isotope Ration. *Marine and Freshwater Research* 56:655–660.

Hobbs, J. A., W. A. Bennett, and J. E. Burton. 2006. Assessing Nursery Habitat for Native Smelts (*Osmeridae*) in the Low-Salinity Zone of the San Francisco Estuary. *Journal of Fish Biology* 69:907–922.

Hobbs, J. A., W. A. Bennett, J. Burton, and M. Gras. 2007. Classification of Larval and Adult Delta Smelt to Nursery Areas by Use of Trace Elemental Fingerprinting. *Transactions of the American Fisheries Society* 136:518–527. As cited in: Nobriga, M. and B. Herbold. 2009. *Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, the Little Fish in California's Water Supply: A Literature Review and Life-History Conceptual Model for Delta Smelt* (Hypomesus transpacificus) *for the Delta Regional Ecosystm Restoration and Implementation Plan (DRERIP)*.

Jassby, A. D. and J. E. Cloern. 2000. Organic Matter Sources and Rehabilitation of the Sacramento-San Joaquin Delta (California, USA). *Aquatic Conservation: Marine and Freshwater Ecosystems*. 10:323–352.

Jassby, A. D., J. E. Cloern, and B. E. Cole. 2002. Annual Primary Production: Patterns and Mechanisms of Change in a Nutrient-Rich Tidal Ecosystem. *Limnology and Oceanography* 47:698–712.

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline Position as a Habitat Indicator for Estuarine Populations. *Ecological Applications* 5:272–289.

Jevasingh, P.D. and L. J. Weider. 2005. Phosphorus Availability mediates Plasticity in Life-History Traits and Predator-Prey Interactions in Daphina. *Ecology Letters* 8:1021–1028.

Jevasingh, P.D. and L. J. Weider. 2007. Fundamental Links between Genes and Elements: Evolutinary Implications of Ecological Stoichiometry. *Molecular Ecology* 16:4649–4661.

Kimmerer, W. J. 2002a. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. *Estuaries* 25(6B): 1275–1290.

Kimmerer, W. J. 2002b. Effects of Freshwater Flow on Abundance of Estuarine Organisms: Physical Effects of Trophic Linkages. *Marine Ecology Progress Series* 243:39–55.

Kimmerer, W. J. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. *San Francisco Estuary and Watershed Science* [online serial] 2(1), Article 1.

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 6(2).

Kimmerer, W. J. 2011. Modeling Delta Smelt Losses at the South Delta Export Facilities. *San Francisco Estuary and Watershed Science* 9(1). Available: <http://escholarship.org/uc/item/0rd2n5vb>

Kimmerer, W., and M. Nobriga. 2005. Development and Evaluation of Bootstrapped Confidence Intervals for the IEP Fish Abundance Indices. *Interagency Ecological Program Newsletter* 18(2): 68–75.

Kimmerer, W. J. and J. J. Orsi. 1996. Changes in the Zooplankton of the San Francisco Bay Estuary Since the Introduction of the Clam *Potamacorbula amurensis*. In: J. T. Hollibaugh (ed.). *San Francisco Bay: The Ecosystem*. San Francisco, CA: Pacific Division, American Association for the Advancement of Science. Pages 403–424.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume? *Estuaries and Coasts* 32:375–389.

Kuivila, K. M. and G.E. Moon. 2004. Potential Exposure of Larval and Juvenile Delta Smelt to Dissolved Pesticides in the Sacramento-San Joaquin Delta, California. *American Fisheries Society Symposium* 39:229–241.

Lehman, P. W., S. Mayr, L. Mecum, and C. Enright. 2010. The Freshwater Tidal Wetland Liberty Island, CA was both a Source and Sink of Inorganic and Organic Material to the San Francisco Estuary. *Aquatic Ecology* 44:359–372.

Lehman, P. W., T. Sommer, and L. Rivard. 2008. The Influence of Floodplain Habitat on the Quantity and Quality of Riverine Phytoplankton Carbon Produced during the Flood Season in San Francisco Estuary. *Aquatic Ecology* 42:363–378.

Little E. E. and S. E. Finger. 1990. Swimming Behavior as an Indicator Of Sublethal Toxicity in Fish. *Environmental Toxicology and Chemistry* 9:13–19.

Lopez, C. B., J. E. Cloern, T. S. Schraga, A. J. Little, L. V. Lucas, J. K. Thompson, and J. R. Burau. 2006. Ecological Values of Shallow-Water Habitats: Implications for the Restoration of Disturbed Ecosystems. *Ecosystems* 9:422–440.

Lott, J. 1998. Feeding Habits of Juvenile and Adult Delta Smelt from the Sacramento-San Joaquin River Estuary. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 11(1):14–19.

Lucas, L. V., J. E. Cloern, J. K. Thompson, and N. E. Monsen. 2002. Functional Variability of Habitats with the Sacramento-San Joaquin Delta: Restoration Implications. *Ecological Applications* 12(5):1528–1547.

Luoma, S. 2007. Water Quality Issues. Presentation at CALFED Science Workshop: Science Related to an Isolated Facility. August 22.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennet, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo. 2010. Analysis of Pelagic Species Decline In The Upper San Francisco Estuary Using Multivariate Autoregressive Modeling (MAR). *Ecological Applications* 20(5):1417–1430.

Mager, R. 1996. *Gametogenesis, Reproduction, and Artificial Propagation of Delta Smelt,* Hypomesus transpacificus. PhD dissertation. University of California, Davis.

Mager, R. C., S. I. Doroshov, J. P. Van Eenennaam, and R. L. Brown. 2004. Early Life Stages Of Delta Smelt. In: F. Feyrer, F., L. R. Brown, R. L. Brown, and J. J. Orsi (eds). *Early Life History of Fishes in the San Francisco Estuary and Watershed*, American Fisheries Society Symposium 39. Pages 169–180.

Manly, B. F. and M. Chotkowski. 2006. Two New Methods For Regime Change Analyses. *Archiv fur Hydrobiologie* 167:593–607.

Matica, Z., and T. Sommer. 2005. *Aquatic Impacts of the Pittsburg and Contra Costa Power Plants* Draft. Department of Water Resources, Division of Environmental Services.

Maunder, M. N., and R. B. Deriso. 2011. A State-Space Multistage Life Cycle Model to Evaluate Population Impacts in the Presence Of Density Dependence: Illustrated with Application to Delta Smelt (*Hypomesus transpacificus*). *Canadian Journal of Fisheries and Aquatic Sciences* 68:1285–1306.

Merz, J. E., S. Hamilton, P. S. Bergman, and B. Cavallo. 2011. Spatial Perspective for Delta Smelt: A Summary of Contemporary Survey Data. *California Fish and Game* 97(4):164–189.

Miller, W. J. 2011. Revisiting Assumptions that Underlie Estimates of Proportional Entrainment of Delta Smelt by State and Federal Water Diversions from the Sacramento-San Joaquin Delta. *San Francisco Estuary & Watershed Science* 9(1).

Miller, W. J., B. F. J. Manly, D. D. Murphy, D. Fullerton, and R. R. Ramey. 2012. An Investigation of Factors Affecting the Decline of Delta Smelt (*Hypomesus transpacificus*) in the Sacramento-San Joaquin Estuary. *Reviews in Fisheries Science* 20:1–19.

Mitra, A. and K. J. Flynn. 2006. Promotion of Harmful Algal Blooms by Zooplankton Predatory Activity. *Biology Letters* 2:194–197.

Moyle, P. B. 2002. *Inland Fishes of California.* Revised and Expanded. University of California Press, Berkeley, CA.

Moyle, P. B., B. Herbold, D. E. Stevens, and L. W. Miller. 1992. Life History and Status of Delta Smelt in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 821:67–77.

Moyle, P. B., W. A. Bennett, W. E. Fleenor, and J. R. Lund. 2010. Habitat Variability and Complexity in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 9(3).

Murphy, D. D. and S. A. Hamilton. 2013. *Habitat Affinity Analysis as a Tool to Guide Environmental Restoration for an Imperiled Estuarine Fish: The Case of the Delta Smelt in the Sacramento-San Joaquin Delta.* Unpublished paper.

Nestor M., L. Rodriguez-Gallego, C. Kruk, M. Meerhoff, J. Gorga, G. Lacerot, F. Quintans, M. Loureiro, D. Larrea, and F. Garcia-Rodriguez. 2003. Effects of *Egeria densa Planch* Beds on a Shallow Lake without Piscivorous Fish. *Hydrobiologia* 506-509:591–602.

Newman, K. B. 2008. Sample Design-Based Methodology for Estimating Delta Smelt Abundance. *San Francisco Estuary and Watershed Science* 6(3).

Nobriga, M. L. 2002. Larval Delta Smelt Diet Composition and Feeding Incidence: Environmental and Ontogenetic Influences. *California Fish and Game* 88:149–164.

Nobriga, M. L. and B. Herbold. 2009. *The Little Fish in California's Water Supply: a Literature Review and Life-History Conceptual Model for Delta Smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP).* Available: <https://nrm.dfg.ca.gov/documents/ContextDocs.aspx?sub=DRERIP_Documents_Models>.

Nobriga, M. L. and Z. Matica. 2000. Sherman Island Agricultural Diversion Evaluation. *Interagency Ecological Program Newsletter*. 13:11.

Nobriga, M. L., F. Feyrer, R. D. Baxter, and M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

Nobriga, M. L., T. R. Sommer, F. Feyrer, and D. Fleming. 2008. Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (*Hypomesus transpacificus*). *San Francisco Estuary and Watershed Science* 6(1):1–13.

Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes. *American Fisheries Society Symposium.* 39:281–285.

Oros, D., and R. I. Werner. 2005. *Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley.* White Paper for the Interagency Ecological Program. SFEI Contribution 415. San Francisco Estuary Institute, Oakland, CA.

Parker, A. E., R. C. Dugdale, and F. P. Wilkerson. 2012a. Elevated Ammonium Concentrations from Wastewater Discharge Depress Primary Productivity in the Sacramento River and the Northern San Francisco Estuary. *Marine Pollution Bulletin* 64(3):574–586.

Parker, A., C. Simenstad, T. L. George, N. Monsen, T. Parker, G. Ruggerone, and J. Skalski. 2012b. *Bay Delta Conservation Plan (BDCP) Effects Analysis Phase 2 Partial Review*. Review Panel Summary Report. Delta Science Program. Available: <http://deltacouncil.ca.gov/sites/default/files/documents/files/BDCP_Effects_Analysis_Review_Panel_Final_Report_061112.pdf>.

Radtke, L. D. 1966. Distribution of Smelt, Juvenile Sturgeon, and Starry Flounder in the Sacramento-San Joaquin Delta. In J. L. Turner, D. W. Kelley (eds.). *Ecological Studies of the Sacramento-San Joaquin Estuary, Part 2.* California Department of Fish and Game Fish Bulletin No. 136.2:559-82. Pages 115–119.

Resources Agency. 2007. *Pelagic Fish Action Plan*. Available: <http://www.water.ca.gov/deltainit/030507pod.pdf>.

Sandahl J. F., G. Miyasaka, N. Koide, and H. Ueda. 2006. Olfactory Inhibition and Recovery in Chum Salmon (*Oncorhynchus keta*) following Copper Exposure. *Canadian Journal of Fisheries and Aquatic Sciences* 63(8):1840–1847.

Schemel, L. E., T. R. Sommer, A. B. Müeller-Solger, and W. C. Harrell. 2004. Hydrologic Variability, Water Chemistry, and Phytoplankton Biomass in a Large Floodplain of the Sacramento River, CA. *Hydrobiologia* 513:129–139.

Shoellhamer, D. H. 2011. Sudden Clearing of Estuarine Waters upon Crossing the Threshold from Transport to Supply Regulation of Sediment Transport as an Erodible Sediment Pool is Depleted: San Francisco Bay, 1999. *Estuaries and Coasts* 34:885–899.

Sommer T., W. C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of Flow Variation on Channel and Floodplain Biota and Habitats of the Sacramento River, California, USA. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14:247–261.

Sommer T., W. C. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001b. California's Yolo Bypass: Evidence that Flood Control Can Be Compatible with Fisheries, Wetlands, Wildlife, and Agriculture. *Fisheries* 26(8):6–16.

Sommer, T., C. Armor, and R. Baxter. 2007. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary. *Fisheries* 32(6):270-277.

Sommer, T., F. Mejia, M. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary. *San Francisco Estuary and Watershed Science* 9(2):1–16.

Sommer, T., M. L. Nobriga, W. C. Harrell, W. Bathman, and W. J. Kimmerer. 2001a. Floodplain Rearing of juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58(2):325–333.

Stanley, S. E., P. B. Moyle, and H. B. Shaffer. 1995. Allozyme Analysis of Delta Smelt, *Hypomesus transpacificus* and Longfin Smelt, *Spirinchus thaleichthys* in the Sacramento-Joaquin Estuary, California. *Copeia* 1995:390–396.

State Water Resources Control Board and California Environmental Protection Agency. 2010 Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem. Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009. August 3, 2010.

Swanson, C., and J. J. Cech, Jr. 1995. *Environmental Tolerances and Requirements of the Delta Smelt,* Hypomesus transpacificus. Final Report. Davis, California.

Swanson, C., T. Reid, P.S. Young, and J. J. Cech, Jr. 2000. Comparative Environmental Tolerances of Threatened Delta Smelt (*Hypomesus transpacificus*) and Introduced Wakasagi (*H. nipponensis*) in an Altered California Estuary. *Oecologia* 123:384–390.

Sweetnam, D. A. 1999. Status of Delta Smelt in the Sacramento–San Joaquin Estuary. *California Fish and Game* 85:22–27.

Teh, S. J., S. Lesmeister, I. Flores, M. Kawaguchi, C. Teh. 2009. Final Report. *Acute Toxicity of Ammonia, Copper, and Pesticides to Key Copepods,*Pseudodiaptomus forbesi *and* Eurytemora affinis, *of the San Francisco Estuary.* Submitted to University of California, Davis Aquatic Toxicology Laboratory. September 29. Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/sac_rcsd/srcsd_exh1u.pdf>.

Teh, S., I. Flores, M. Kawaguchi, S. Lesmeister, C. Teh. 2011. *Full Life-Cycle Bioassay Approach to assess Chronic Exposure of Pseudodiaptomus forbesi to Ammonia/Ammonium.* State Water Board / UC Davis Agreement No. 06-447=300. August 31.

The Bay Institute, Natural Resources Defense Council, and Center for Biological Diversity. 2007. Petition to the State of California Fish and Game Commission and Supporting Information for Listing the Delta Smelt (*Hypomesus transpacificus*) as an Endangered Species under the California Endangered Species Act. Available: <http://www.biologicaldiversity.org/swcbd/SPECIES/deltasmelt/ds-state-endangered-petition-02-07-2007.pdf>.

Thompson, B., R. Hoenicke, J. A. Davis, and A. Gunther. 2000. An Overview of Contaminant-Related Issues Identified by Monitoring in San Francisco Bay. *Environmental Monitoring and Assessment* 64:409–419.

Thomson, J. R, W. J. Kimmerer, L. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian Change-Point Analysis of Abundance Trends for Pelagic Fishes in the Upper San Francisco Estuary. *Ecological Applications* 20:1431–1448.

Trenham, P. C., H. B. Shaffer, and P. B. Moyle. 1998. Biochemical Identification and Population Subdivision in Morphologically Similar Native and Invading Species (*Hypomesus*) in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 127:417–424.

U.S. Fish and Wildlife Service. 1996. *Sacramento-San Joaquin Delta Native Fishes Recovery Plan.* Portland, OR.

U.S. Fish and Wildlife Service. 2004. *Five Year Status Review for the Delta Smelt*. Sacramento, CA.

U.S. Fish and Wildlife Service. 2008a. *Delta Smelt OCAP Biological Opinion.* December 15. Available: <http://www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf>.

U.S. Fish and Wildlife Service. 2008b. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP).* Available: <http://www.fws.gov/sacramento/delta_update.htm>.

Vincik, R. F. and J. M. Julienne. 2012. Occurrence of Delta Smelt (*Hypomesus transpacificus*) in the Lower Sacramento River Near Knoights Landing, California. *California Fish and Game* 98(3):171–174.

Wagner, W., M. Stacey, L. Brown, and M. Dettinger. 2011. Statistical Models of Temperature in the Sacramento–San Joaquin Delta under Climate Change Scenarios and Ecological Implications. *Estuaries and Coasts* 34(3):544–556. doi:10. 1007/s12237-010-9369-z.

Wang, J. C. S. 1991. *Early Life Stages and Early Life History of the Delta Smelt,* Hypomesus transpacificus, *in the Sacramento-San Joaquin Estuary, with Comparison of Early Life Stages of the Longfin Smelt,* Spirinchus Thaleichthys*.* Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Sacramento, California. Technical Report 28.

Werner I., L. Deanovic, D. Markiewicz, M. Stillway, N. Offer, R. Connon, and S. Brander. 2008. *Final Report. Pelagic Organism Decline (POD): Acute and Chronic Invertebrate and Fish Toxicity Testing in the Sacramento-San Joaquin Delta 2006-2007.* UC Davis – Aquatic Toxicology Laboratory, Davis, CA.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern*? Seminar, University of California, Davis, November 8.

Weston, D. P. and M. J. Lydy. 2010. Urban and Agricultural Sources of Pyrethroid Insecticides to the Sacramento-San Joaquin Delta of California. *Environmental Science and Technology* 44:1833–1840.

Wilkerson, F. P., R. C. Dugdale, V. E. Hogue and A. Marchi. 2006. Phytoplankton Blooms and Nitrogen Productivity in San Francisco Estuary. *Estuaries and Coasts* 29:401–416.

Wright, S. A., and D. H. Shoellhamer. 2004. Trends in Sediment Yield of the Sacramento River, California, 1957–2001. *San Francisco Estuary and Watershed Science* [online serial] 2(2), Article 2.

2A.1.8.2 Personal Communications

Feyrer, Fred. October 1–3, 2013—Presentation at State Water Resources Control Board, Phase II Comprehensive Review of the Bay Delta Plan,Workshop 2. Discussion regarding data from the smelt camera count. General presentation available at: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/wrkshp2/dfullerton.pdf>.

Fullerton, Dave. October 1–3, 2013—Presentation at State Water Resources Control Board, Phase II Comprehensive Review of the Bay Delta Plan,Workshop 2, regarding evidence of declining turbidity in the Plan Area. Available at: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/wrkshp2/dfullerton.pdf>.

2A.1.8.3 Federal Register Notices Cited

58 FR 12863. 1993. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Delta Smelt. *Federal Register* 58:12854.

59 FR 65256. 1994. Endangered and Threatened Wildlife and Plants; Critical Habitat Determination for the Delta Smelt. *Federal Register* 59:65256.

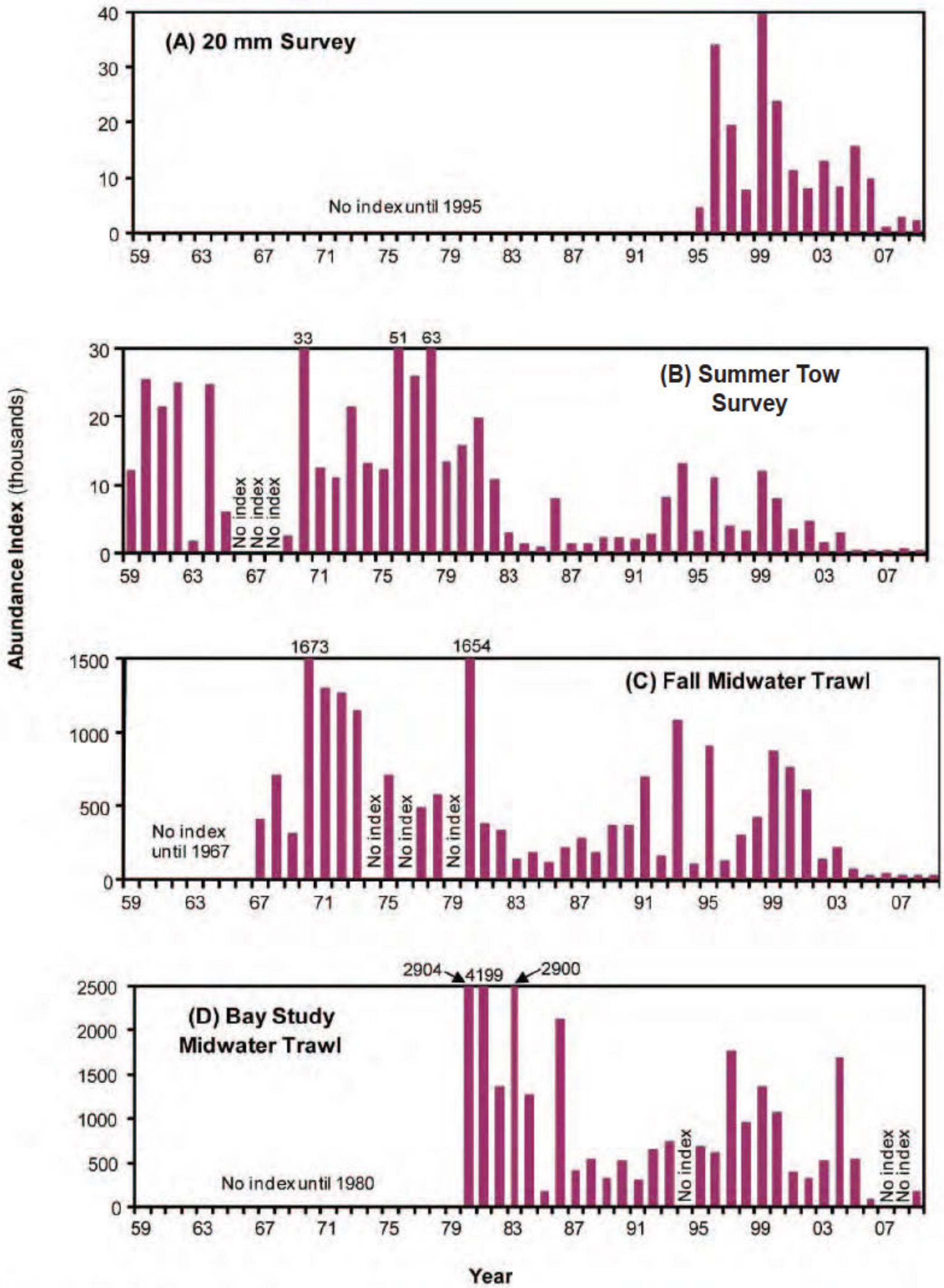
73 FR 39639. 2008. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition to Reclassify the Delta Smelt (*Hypomesus transpacificus*) from Threatened to Endangered. *Federal Register* 73:29639.

75 FR 17667. 2010. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to Reclassify the Delta Smelt From Threatened to Endangered Throughout Its Range. *Federal Register* 75:17667.

Source: Modified from Bennett 2005

BDCP-HCP 00343.12 (8-6-12) tm

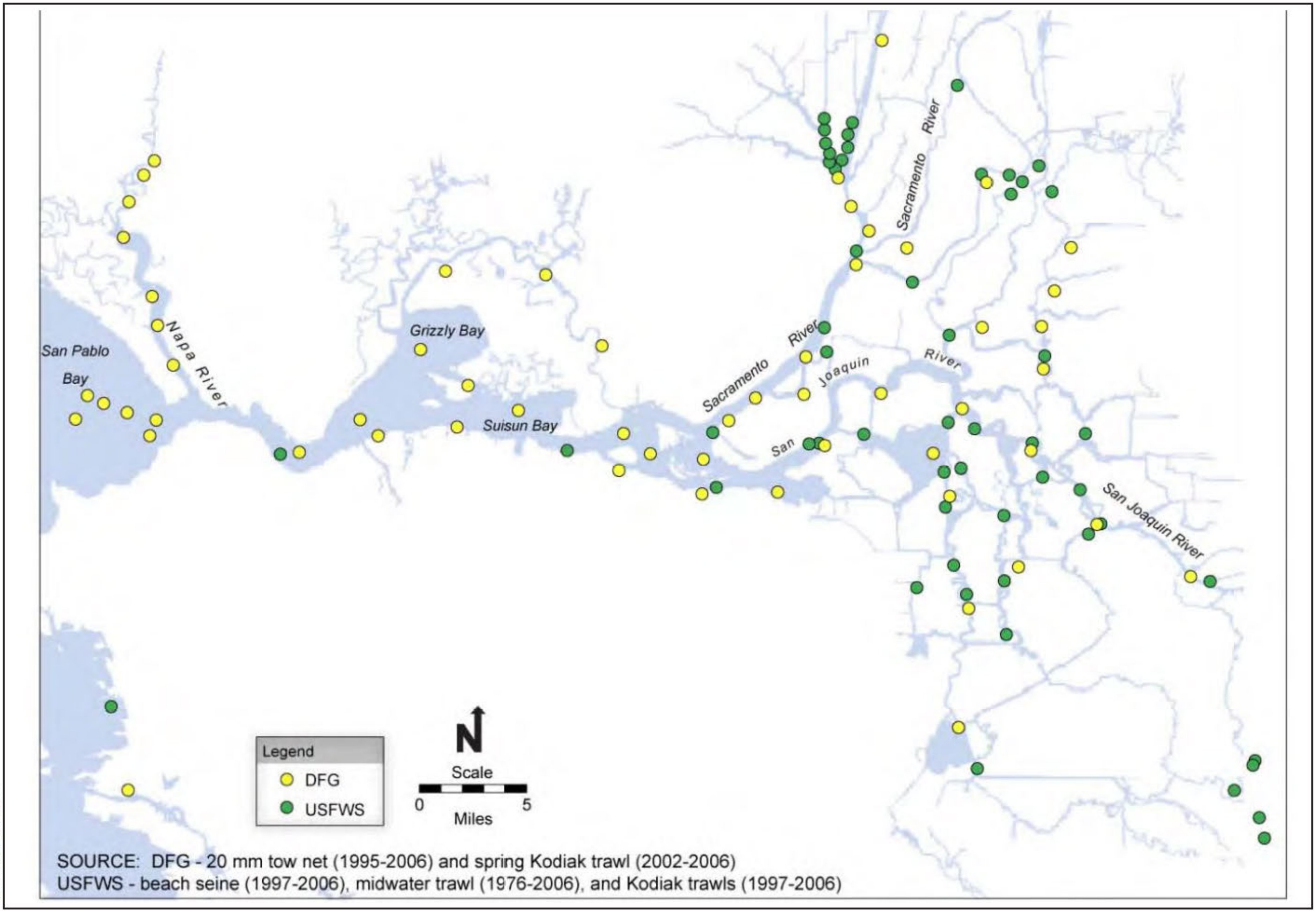
Figure 2A.1-1
Delta Smelt Inland Range



SOURCE: California Department of Fish and Game unpublished data, Interagency Ecological Program unpublished data.

BDCP-HCP 00343.12 (8-29-12) tm

Figure 2A.1-2
Annual Abundance Indices of Delta Smelt from 1959 to 2009

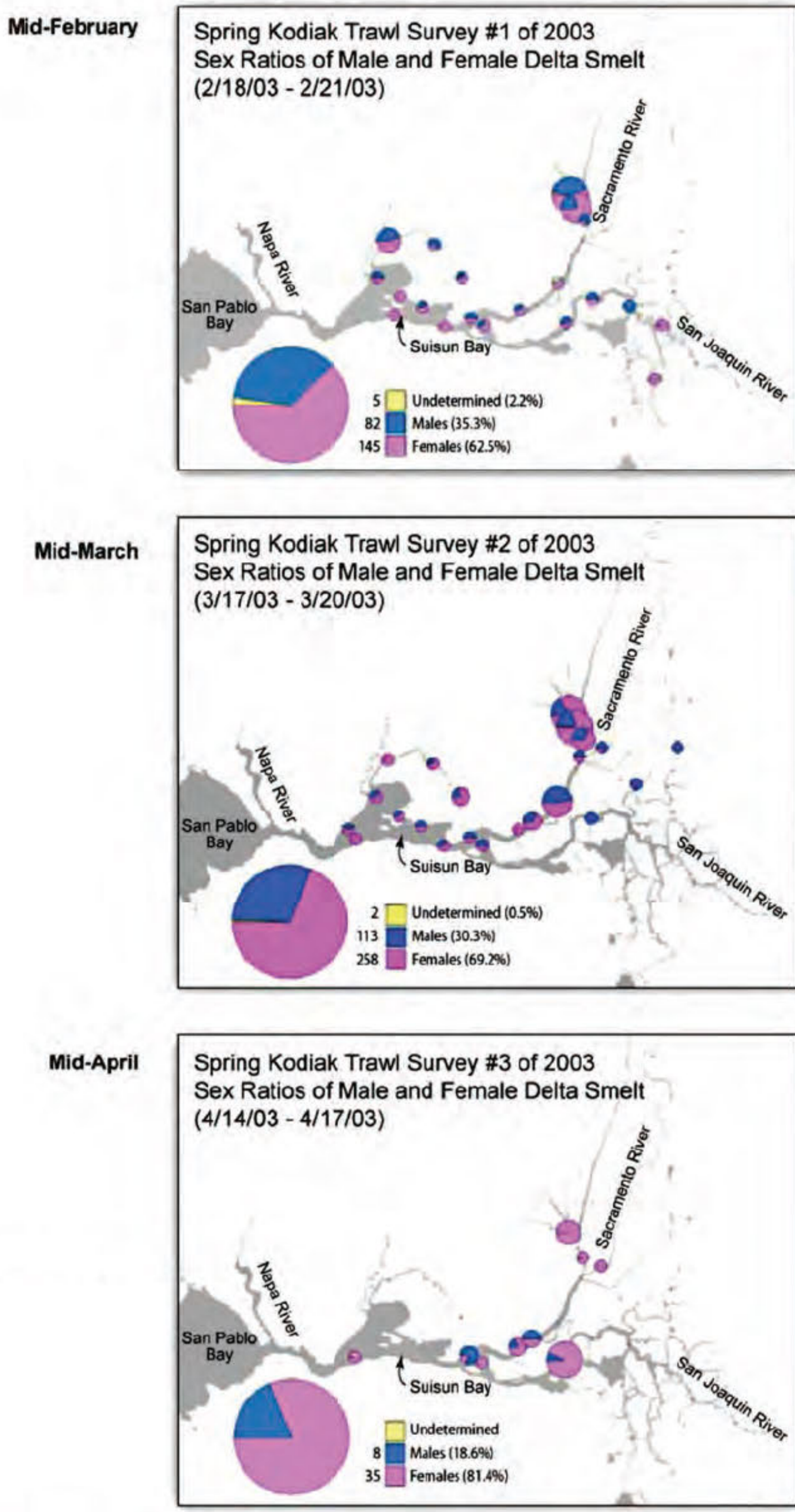


BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.1-3
Historical Sampling Locations Where Delta Smelt Have Been Captured Since 1976

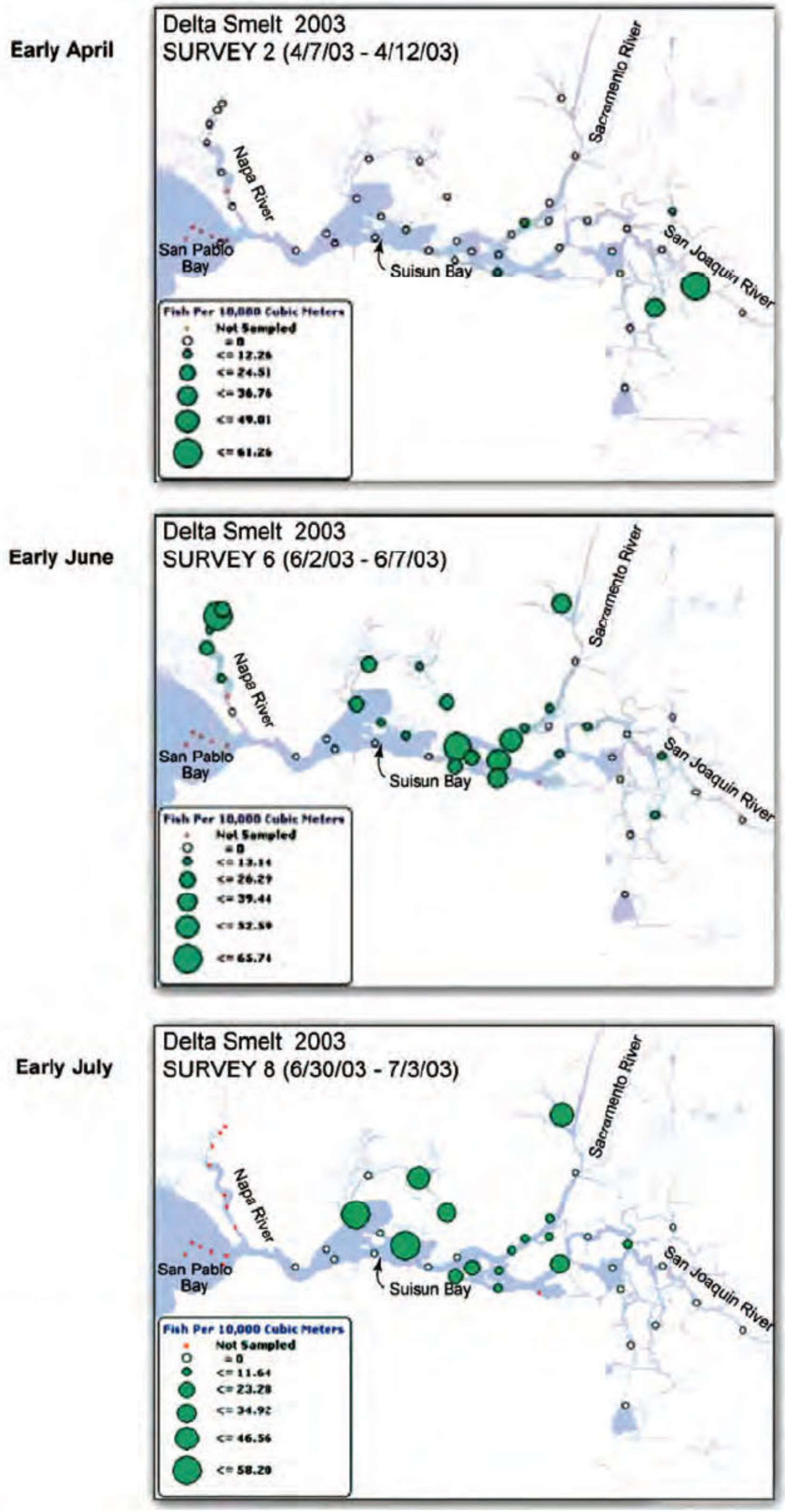
BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.1-4
Delta Smelt Designated Critical Habitat



SOURCE: California Department of Fish and Game. 2003. 20 mm Delta Smelt Survey. Available: <http://ww/delta.dfg.ca.gove/data/20mm/description.asp>.
This annual survey monitors adult delta smelt distribution and relative abundance, as well as sex ratio and gonadal stage, during spring throughout their historical range using a variable mesh Kodiak trawl fished in the top 6 feet (1.8 meters) of water column.

Figure 2A.1-5
Example of Distribution of Adult Delta Smelt in Spring-Summer of a Representative Above-Normal Water Year



SOURCE: California Department of Fish and Game. 2003. 20 mm Delta Smelt Survey. Available: <http://ww/delta.dfg.ca.gove/data/20mm/description.asp>.
This annual survey monitors post-larval and juvenile delta smelt distribution and relative abundance every two weeks during spring and early summer throughout their historical range using a 1600 μm egg and larval net.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.1-6
Example of Distribution of Post-Larval/Juvenile Delta Smelt in Spring-Summer of a Representative Above-Normal Water Year

Appendix 2A.2
Longfin Smelt (*Spirinchus thaleichthys*)

2A.2.1 General

Longfin smelt is a small, euryhaline, anadromous, and semelparous fish with a life cycle of approximately 2 years (Rosenfield 2010). Longfin smelt reach 90 to 110 millimeters standard length, with a maximum size of 120 to 150 millimeters standard length (Moyle 2002; Rosenfield and Baxter 2007). Young longfin smelt occur from the estuary's low-salinity zone, where brackish and fresh waters meet, seaward and into the coastal ocean. Longfin smelt can be distinguished from other California smelt by their long pectoral fins (which reach or nearly reach the bases of the pelvic fins), their incomplete lateral line, weak or absent striations on the opercular bones, low number of scales in the lateral series (54 to 65), and long maxillary bones (which in adults extend just short of the posterior margin of the eye) (Moyle 2002). Populations of longfin smelt occur along the Pacific Coast of North America, from Hinchinbrook Island, Prince William Sound, Alaska to the San Francisco Bay estuary (Lee et al. 1980). Although individual longfin smelt have been caught in Monterey Bay (Moyle 2002), there is no evidence of a spawning population south of the Golden Gate. Small and perhaps ephemeral longfin smelt spawning populations have been documented or suspected to exist in Humboldt Bay, the Eel River estuary, the Klamath River estuary and the Russian River (Moyle 2002; Pinnix et al. 2004). The San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) population is the southernmost and largest spawning population in California (Figure 2A.2-1). Longfin smelt have been historically sampled at numerous locations in the Sacramento–San Joaquin River Delta (Delta) (Figure 2A.2-2). The population has shown extremely low abundance in recent years, as measured by the Fall Midwater Trawl, as part of the pelagic organism decline (POD) (Sommer et al. 2007; Baxter et al. 2010).

2A.2.2 Legal Status

The Bay-Delta population of longfin smelt was petitioned for threatened status under the federal Endangered Species Act (ESA) in 1992, but the petition was denied because the population was surviving well in areas outside the Bay-Delta estuary. Subsequent research indicated that the Bay-Delta population is more geographically isolated from other west coast longfin smelt populations than previously thought (Moyle 2002). In 2007, the Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council (2007a, 2007b) petitioned to have the Bay-Delta longfin smelt population listed as a threatened species under both the California Endangered Species Act (CESA) and the ESA. On May 6, 2008, the U.S. Fish and Wildlife Service (USFWS) found that a status review for longfin smelt was warranted (73 *Federal Register* [FR] 24911). On April 9, 2009, USFWS determined that the Bay-Delta population did not meet the legal criteria for protection as a species subpopulation under the ESA (74 FR 16169). However, this determination was challenged legally and resulted in a settlement agreement to review the criteria for listing the Bay-Delta longfin smelt population as a distinct population segment (DPS) under ESA. The review resulted in a finding that listing of the Bay-Delta DPS of longfin smelt is warranted (77 FR 19755). Currently, however, listing the Bay-Delta DPS of longfin smelt is precluded by higher priority actions to amend the Lists of Endangered and Threatened Wildlife and Plants.

In December 2007, the California Department of Fish and Wildlife (CDFW) completed a preliminary review of the longfin smelt petition (California Department of Fish and Game 2007) and concluded that there was sufficient information to warrant further consideration by the California Fish and Game Commission. On February 7, 2008, the California Fish and Game Commission designated the longfin smelt as a candidate for potential listing under the CESA. On June 26, 2009, the California Fish and Game Commission ruled to list the status of longfin smelt as threatened under the CESA

2A.2.3 Distribution and Abundance

Longfin smelt occur throughout the Plan Area, but are seldom captured upstream of Rio Vista on the Sacramento River, and Jersey Point on the San Joaquin River, relative to locations in the west. Historically, longfin smelt occurred extensively year-round in the Plan Area, but more recently they are rarely collected in this area from summer through early fall (Rosenfield and Baxter 2007). In the Plan Area, longfin smelt migrate above the low-salinity zone to spawn (Rosenfield and Baxter 2007). During nonspawning periods, juvenile and prespawn adults are most often concentrated in Suisun, San Pablo, and north San Francisco Bays (Baxter 1999; Moyle 2002; Rosenfield and Baxter 2007). Large populations have also been detected in local tributaries (e.g., Napa River) (Stillwater Sciences 2005). As presented by Leidy (2007) and Rosenfield (2010), other watercourses tributary to San Pablo Bay (e.g., the Petaluma River and Sonoma Creek) and South Bay (e.g., Coyote Creek). The species is also common in nearshore coastal marine waters outside the Golden Gate Bridge in late summer and fall (Baxter 1999). Longfin smelt are periodically caught in the nearshore ocean, suggesting that some individuals migrate out into the Gulf of Farallones to feed and then back into the estuary (Rosenfield and Baxter 2007) .

Longfin smelt abundance in the Bay-Delta estuary has been highly variable and declining as reflected in the CDFW Fall Midwater Trawl surveys and Bay Study surveys (Figure 2A.2-3). The CDFW Fall Midwater Trawl samples approximately 100 locations throughout the Bay-Delta system, excepting the shallows of San Pablo Bay and Central and South San Francisco Bay, from September through December each year. However, the Fall Midwater Trawl survey does not capture the full range of the longfin smelt in the San Francisco Estuary and could be under-reporting its actual abundance. The Bay study has not shown the magnitude of decline that the Fall Midwater Trawl has, although it does show a significant decline over time, reflecting an overall decline in the species.

Additional information on trends in abundance of longfin smelt inhabiting the estuary is available from the CDFW Bay fishery surveys that have sampled monthly since 1980 at a wide range of locations using both an otter trawl and midwater trawl. Because the Fall Midwater Trawl surveys and Bay fishery surveys show similar trends in abundance of longfin smelt (Hieb et al. 2005), the following description of trends in the status of longfin smelt is based on results of the long-term CDFW Fall Midwater Trawl surveys.

Abundance indices and various environmental parameters suggest that high Delta outflow from the Delta during the longfin smelt spawning, larval, and early juvenile period (January to June) has a strong influence on longfin smelt abundance (Figure 2A.2-4) (Moyle 2002). Abundance indices were greatest in 1967 and 1969 followed by a second peak in 1980 and 1982. High abundance indices are associated with years when highDelta outflow coincides with longfin larval and juvenile occurrence, and low abundance indices are associated with low Delta outflow in the spring, such as the drought conditions that occurred in 1976 and 1977 and during the early 1990s. Mechanisms for abundance flow relationships to fish cannot be explained with correlative analysis, although these relationships are unlikely to arise from effects occurring at lower food web levels (Kimmerer 2002a). The correlation with the position of X2 is not the only strong correlational relationship. Glibert et al. (2011) found longfin smelt abundance highly correlated to ammonium concentration, Mysid shrimp abundance in Lake Washington (Chigbu and Sibley 1998), and turbidity in Napa River outflow (Fullerton pers. comm.).

Longfin abundance also showed a general decline from 1967 through 2009. In recent years, longfin smelt abundance was greatest in 1995, and then declined between 1998 and 2009. The abundance index based on the CDFW Fall Midwater Trawl survey conducted in 2007 was the lowest on record. Fall Midwater Trawl abundance indices suggest that abundance of longfin smelt within the Bay-Delta estuary has declined by over 95% since the survey began.

The Fall Midwater Trawl index showed a four-fold decline in longfin smelt abundance after the 1987 invasion of the overbite clam, *Potamocorbula amurensis*. Heavy grazing by the clam caused a dramatic drop in food resources for the Delta's fish species. However, there was no change in the slope of the relationship between freshwater outflow and longfin smelt abundance (Figure 2A.2-4) (Kimmerer 2002a; Rosenfield and Baxter 2007; Thomson et al. 2010). Furthermore, although Delta outflow conditions were relatively high in 2003, 2005, and 2006, reflecting wet and above-normal hydrologic conditions, longfin smelt abundance did not increase as much as would be expected, based on the 1987 to 2000 relationship, although there was a small increase in 2006 (Sommer et al. 2007). This finding suggests that an additional factor or factors may now be limiting the Bay-Delta population response. Recently, Kimmerer (2002b) suggested the possibility that food web changes caused by the invasive *Potamocorbula* were a contributing factor; Rosenfield and Baxter (2007) acknowledged the possibility but did not rule out other environmental factors as well. Thomson et al. (2010) hypothesized that the simultaneous, abrupt declines in the abundances of multiple species during the POD are more likely to have been caused by a common but unknown factor than by different factors for each species.

Distribution of longfin smelt may be influenced by the position of the low-salinity zone. For example, in drier years, spawning adults are further upstream and larvae are more susceptible to entrainment (reviewed by Baxter et al. 2010). Some long-term changes in distribution appear to have occurred, e.g., a shift downstream to higher salinities in summer and fall following the invasion of the clam *Potamocorbula* that resulted in lower abundance of zooplankton prey for longfin smelt (Baxter et al. 2010; Contreras et al. 2012).

2A.2.4 Life Stages

Rosenfield (2010) described five life stages of longfin smelt. Five life stages were also described by CDFW (California Department of Fish and Game 2009), although CDFW discerned between two larval stages, whereas Rosenfield (2010) discerned between two adult stages. For purposes of the BDCP analysis, five life stages recognize the unique requirements of both the larval stages and the adult stages in terms of food resources and habitat. Table 2A.2-1 compares the longfin smelt life stages of Rosenfield and CDFW.

Table 2A.2-1. Life Stages of Longfin Smelt

Rosenfield 2010	California Department of Fish and Game 2009	BDCP
Eggs	Eggs	Eggs
Larvae	Yolk-sac larvae	Larvae
Juvenile	Post-yolk-sac larvae	Juvenile
Subadult	Juvenile	Subadult
Sexually mature adult	Adult	Adult

2A.2.5 Life History

Longfin smelt generally spawn at age 2 in fresh water in the Plan Area from December to April (Moyle 2002; Rosenfield and Baxter 2007), with some individuals spawning at age 1 and some at age 3 (reviewed by California Department of Fish and Game 2009). Spawning occurs at temperatures that range from 7.0 to 14.5°C, with larvae hatching in 40 days at 7°C (Moyle 2002). Movement patterns based on catches in CDFW fishery sampling suggest that longfin smelt actively avoid water temperatures greater than 22°C (72°F) (California Department of Fish and Game 2009). Longfin smelt do not occupy areas with temperatures greater than 22°C (72°F) in combination with salinities greater than 26 parts per thousand (ppt). These conditions occur between August and September almost annually in south San Francisco Bay and periodically in shallower portions of San Pablo Bay.

Collections of larval and juvenile longfin smelt smaller than 50-millimeter fork length in the Bay-Delta showed that 90% of the individuals inhabited areas with salinities lower than 18 ppt (Baxter 1999). However, other populations of longfin smelt inhabiting west coast waters are present in coastal estuaries or may complete their entire life cycle in fresh water (Dryfoos 1965; Moulton 1974), indicating that there is no lower limit to salinity tolerance for any life stage. Healthy individuals 20-millimeter fork length and larger have been captured in salinities of 32 ppt (ocean water) and along the open coast, suggesting that high salinity may be limiting the geographic distribution for only a small portion of their lifecycle. However, larvae are not known to tolerate salinities greater than 8 ppt (77 FR 19755).

Longfin smelt have not been observed spawning in the Bay-Delta, so the exact location of spawning sites is not well understood, but location in the Plan Area can be inferred by CDFW surveys that collect adult and larval longfin smelt. Longfin smelt congregate in deep waters in the vicinity of the low-salinity zone near X2 during the spawning period, and it is thought that they make short runs upstream, possibly at night, to spawn from these locations (California Department of Fish and Game 2009; Rosenfield 2010). Based on the distribution of egg-sac larvae (Larval Smelt Survey), the spawning habitat of longfin smelt probably includes the Cache Slough subregion (Sacramento Deep Water Ship Channel, Cache-Liberty Island Complex), the West Delta subregion (lower Sacramento River), the eastern Suisun Bay subregion including upper Grizzly Bay, and Montezuma Slough in the Suisun Marsh subregion. Spawning rarely occurs in the San Joaquin River in the West Delta/South Delta subregions, but when it occurs, it is usually below Twitchell Island (Moyle 2002). CDFW data indicate that spawning longfin smelt were also once common in Suisun Marsh, but in recent years, very few adult, spawning-age longfin smelt have been collected there. As CDFW surveys do not occur north of Montezuma Slough, it is unknown how many longfin smelt may be spawning in the upper marsh. The number of longfin smelt caught is small, averaging 38 per year from 1996 through 2010 (Suisun Marsh, Marsh Database).Adult and subadult longfin smelt aggregate in deep water in channels, but it is not clear that spawning occurs there; spawning may occur on shoals adjacent to deep channels similar to delta smelt (Rosenfield and Baxter 2007). Spawning locations in the Plan Area are unknown, but spawning in the Lake Washington population occurs primarily on sand substrate in low velocity habitat of lake tributaries (California Department of Fish and Game 2009).

Larval longfin smelt have been found concentrated off the mouth of Coyote Creek, indicating that spawning can take place in tributaries of south San Francisco Bay when runoff and Delta outflow are high, such as conditions that occurred in 1982 and 1983 (Baxter 1999). Collection of small larvae in the Interagency Ecological Program 20-millimeter tow-net surveys suggests spawning regularly occurs in the Napa River.

Upon hatching from adhesive eggs (primarily January to April), buoyant longfin smelt larvae rise toward the surface and are transported downstream by surface currents resulting from both river flow and tidal mixing of fresh and marine waters. Larval longfin smelt remain in the upper part of the water column until they reach 10 to 15 millimeters, after which they move to the middle and bottom parts of the water column (Hieb and Baxter 1993; Bennett et al. 2002; Moyle 2002). The larvae are distributed broadly into all open water habitats and into marsh sloughs (Baxter 1999; Meng and Matern 2001).

The geographic distribution of larval and early juvenile life stages of longfin smelt may be influenced by freshwater inflows to the Delta during the late winter and spring, although the mechanisms are complicated and not fully understood. (Hieb and Baxter 1993; Baxter 1999; Dege and Brown 2004). Larval longfin smelt are typically collected in the region of the estuary extending from the west Delta into San Pablo Bay, but their distribution shifts downstream toward the low-salinity zone in response to Delta outflow, with local tributary flow (Napa River Flow) contributing to the downstream distribution (Baxter 1999; Dege and Brown 2004). In years when winter-spring Delta outflow is low, few larvae are detected in San Pablo Bay. In years when winter-spring Delta outflow is high, few larvae remain in the west Delta, but are abundant in San Pablo Bay and may reach northern San Francisco Bay (Baxter 1999). The center of larval distribution is closely tied to the location of the low-salinity zone, as indicated by the position of X2 (the 2 ppt isohaline) at all Delta outflows (Rosenfield and Baxter 2007; Dege and Brown 2004).

The initial distribution of young juveniles correlates positively with that of larvae, both vertically in the water column and geographically. During their first year, juveniles disperse broadly downstream, eventually inhabiting Suisun, San Pablo, Napa River, and central and south San Francisco Bays and moving into nearshore coastal marine habitats in most years (Figure 2A.2-5) (Baxter 1999; Dege and Brown 2004; Hieb and Baxter 1993; Moyle 2002). Juveniles move from offshore shoals into channels during summer and fall (Rosenfield and Baxter 2007). This movement, and the late summer emigration from south San Francisco Bay, may be a response to increasing water temperatures (greater than 20°C [68°F]) (Baxter 1999).

Longfin smelt in their second year of life (age 1) are typically distributed from the west Delta through south San Francisco Bay from January through March. Their distribution then moves toward the central San Francisco Bay, such that by August and September few, if any, are collected outside of central San Francisco Bay (Baxter 1999).

During the summer, longfin smelt occur in nearshore coastal waters. Migration out of the San Francisco Bay estuary into the marine environment is indicated by the persistent decline of longfin abundance throughout the estuary through summer and then the reappearance of part of the population during the late fall and winter (Rosenfield and Baxter 2007). There is an upstream trend in migration by subadults and adults toward Suisun Bay, Suisun Marsh and the west Delta before a protracted spawning period that can occur from late November into June (Moyle 2002). As longfin smelt begin to mature in the fall, they reinhabit the entire estuary and begin migrating toward fresh water (Baxter 1999; Rosenfield and Baxter 2007).

2A.2.6 Threats and Stressors

A number of threats (which implies a deleterious effect) and stressors (which is not necessarily deleterious as stressors could be used as cues) exist for longfin smelt. Stressor rankings and the certainty associated with these rankings for longfin smelt are provided in Chapter 5, *Effects Analysis,* of the BDCP. The discussion below outlines some of the main threats and stressors to longfin smelt.

2A.2.6.1 Water Exports and Diversions

The effect of entrainment on the population dynamics and abundance of longfin smelt has been examined less than the studies of entrainment effects on delta smelt. Because longfin smelt tend to be mostly estuarine, they likely spend most of their life (approximately 1.5 years) downstream of the influence of the State Water Project (SWP) and Central Valley Project (CVP) south Delta export facilities (Figure 2A.2-5). From the perspective of the entire distribution of longfin smelt, an unknown percentage of the population is exposed to the influence of the export pumps. However, appreciable numbers of longfin smelt have been periodically found in salvage at the export facilities and entrainment tends to be higher in years with less outflow (reviewed by California Department of Fish and Game 2009). Recent analyses did not find statistical associations between trends in longfin smelt abundance and the volume of water exported in either winter (December to February) or spring (March to May) (Mac Nally et al. 2010; Thomson et al. 2010). Implementation of south Delta export pumping restrictions to protect Delta smelt under USFWS' biological opinion (BiOp) and as part of CDFW's incidental take permit for the operation of the south Delta export facilities has reduced entrainment risk to a very low level in most years.

There are over 2,200 small agricultural diversions in the Delta (Herren and Kawasaki 2001). Although these diversions generally take water near the bottom, the intakes may entrain water near the surface at low tide. Planktonic larval longfin smelt may have a greater vulnerability to entrainment into diversions because of their poor swimming ability. Most early stage longfin smelt larvae that rear in the Delta do so during the winter and spring months (California Department of Fish and Game 2009) but entrainment of larvae at agricultural diversions is likely to be low because diversions are low during the winter-spring larval period (Appendix 5.B, *Entrainment*). The impact of entrainment mortality at these diversions on the longfin smelt population abundance has not been quantified.

Power plants in Antioch and Pittsburg historically entrained appreciable numbers of longfin smelt, (reviewed by California Department of Fish and Game 2009), particularly because juvenile longfin smelt may be located near these facilities for much of the year (Matica and Sommer 2005). However, use of cooling water is currently low with the retirement of older units and the recent closure of the plant at Antioch. According to recent regulations by the State Water Resources Control Board, units at the Pittsburg plant must be equipped with a closed-cycle cooling system by 2017 that eliminates fish entrainment.

2A.2.6.2 Habitat Loss

2A.2.6.2.1 Reduced Spawning Habitat

Spawning of longfin smelt in California has not been observed, but is most likely similar to other populations of longfin smelt. Sand is the preferred substrate in the Lake Washington population (Moulton 1974). Spawning habitat availability may be a function of Delta outflow because it increases the spatial extent of freshwater habitats flowing over sandy substrates. The supply of sand for longfin smelt spawning substrate may be reduced as a result of the construction and/or operation of dams (Wright and Shoellhamer 2004), sand mining, and other activities that alter the flux of sediment or that change the availability of nearshore sandy habitat (e.g., bank stabilization with revetment); however, spawning substrates are not thought to be a limiting factor for longfin smelt. The possibility of spawning habitat availability affecting the longfin smelt population also was noted as a possible stressor on delta smelt (Bennett 2005; Miller et al. 2012), reflecting that both species may use similar spawning habitats.

2A.2.6.2.2 Reduced Rearing Habitat

Access to suitable rearing habitat, which for larvae is centered in the low-salinity zone of the West Delta and Suisun Bay subregions (Dege and Brown 2004), may be linked to the magnitude of net downstream flows, which have undergone long-term decreases (Cloern and Jassby 2012). The low-salinity zone, when positioned over shallow shoal areas in Suisun Bay in response to high Delta outflows, is more productive (Moyle et al. 1992; Bennett et al. 2002When located upstream, the low-salinity zone is confined to the deep river channels, is smaller in total surface area, contains very few shoal areas, may have swifter, more turbulent water currents., and may lack high zooplankton productivity. Hobbs et al. (2006) found evidence that the health and survival of juvenile longfin smelt were greater in habitats associated with shallow water habitats found in the north channel of Suisun Bay. The strong correlation between longfin smelt in the Fall Midwater Trawl index and the location of X2 (December to May) may be related to the transport of larval longfin smelt out of the Delta into suitable rearing habitats downstream (Kimmerer 2002a; Kimmerer et al. 2009). Potential mechanisms may include the extent of habitat, proximity to X2, co-occurrence of food, and changes in turbidity as related to flow (Kimmerer and Bennett 2005). Kimmerer et al. (2009) did not find strong evidence for the extent of rearing habitat being related to changes in longfin smelt abundance. The low-salinity zone also moves in response to gross hydrology (e.g., precipitation in the watershed) and SWP/CVP diversions. Outflow objectives in the State Water Resources Control Board Water Right Decision 1641 recognize the importance of the location of the low-salinity zone, and are intended to protect beneficial uses for fish and wildlife. Recent assessments conducted by mandate of the Delta Reform Act indicate that current Delta flow criteria may not be sufficient to protect public trust resources. The importance of spring outflow to longfin smelt is the subject of the spring X2 decision tree and is discussed further in the conceptual model for longfin smelt found in Chapter 5, *Effects Analysis.*

2A.2.6.3 Turbidity

Based on the similarities in life history, seasonal and geographic distribution, pelagic foraging and diet, it has been hypothesized that longfin smelt may have a similar relationship to turbidity as that observed by the following authors for delta smelt (Feyrer et al. 2007; Resources Agency 2007; Nobriga et al. 2008; Grimaldo et al. 2009). Delta smelt require turbidity for successful foraging (Baskerville-Bridges et al. 2004) and predator escape (Feyrer et al. 2007), and turbidity is an important cue for delta smelt spawning migrations (Grimaldo et al. 2009). Longfin smelt larvae hatch coincident with annual peak Delta outflows, which typically coincide with high turbidity. Also, larval and older life stages of longfin smelt possess a well-developed olfactory system, suggesting that they are well adapted to high turbidity during foraging. As a result, longfin smelt may lose their competitive advantage in foraging to other zooplanktivores when turbidity is low. Kimmerer et al. (2009) found that abundance or frequency of occurrence of longfin smelt sampled by Fall Midwater Trawl surveys and spring 20-millimeter surveys was associated with salinity and Secchi depth. Thomson et al. (2010) found that variations in long-term fall abundance of longfin smelt were most correlated with fall water clarity (and spring X2).

Turbidity levels have declined in the Bay-Delta estuary since the 1970s as a result of numerous factors (Kimmerer 2004) such as upstream sediment trapping by dams, , proliferation of invasive aquatic vegetation, and changes in hydraulic residence time, as outlined in the delta smelt species account, and reduced wind speeds (Fullerton pers.comm.).

2A.2.6.4 Food Resources

Larval and small juvenile longfin smelt feed on copepods and other small crustaceans, while juveniles and adults feed primarily on mysids (Moyle 2002; Feyer et al. 2003). Slater (2008) concluded from diet studies that young longfin smelt rely heavily on *Eurytemora* in spring. Longfin smelt, along with other POD species, have experienced a significant decline in food resources in recent decades. Efficient filter feeding and high abundance of *Potamocorbula* have dramatically reduced phytoplankton and zooplankton abundance in Suisun Bay, the west Delta, and Suisun Marsh since its introduction in the mid-1980s (Kimmerer and Orsi 1996). The introduced freshwater Asian clam, *Corbicula fluminea*, has reduced the abundance of phytoplankton in the Delta, although its effect is mainly limited to island areas flooded by fresh water (Lucas et al. 2002; Lopez et al. 2006). In Suisun Bay, the nonnative copepods *Pseudodiaptomus* and *Acanthocyclops* now dominate the diet of small juvenile smelt at low salinities in summer (Hobbs et al. 2006).

Since the decline of the native mysid *Neomysis* following the clam invasion, subadult and adult longfin smelt have fed on a broader variety of organisms, but mysids remain their primary food item (Moyle 2002; Feyrer et al. 2003). CDFW data indicate that in fall 2006, longfin smelt fed predominantly on the introduced mysid *Acanthomysis*, but consumed other mysids, as well as the copepod *Pseudodiaptomus* and amphipod *Corophium*. Baxter et al. (2010) noted that the POD coincided with lower spring abundance of mysids. Statistical analyses by Mac Nally et al. (2010) found some evidence for a positive association between longfin smelt abundance and calanoid copepod biomass in the low-salinity zone during summer. The same authors also found stronger negative associations between longfin smelt abundance and summer biomass of calanoid copepods and mysids, i.e., indications of longfin smelt limiting the abundance of these key prey species.

The changes in the zooplankton species composition have affected the quality of food resources available to longfin smelt (Resources Agency 2007; Sommer 2007. A decrease in foraging efficiency and/or the availability of suitable prey for various life stages of longfin smelt may result in reduced growth, survival, and reproductive success, contributing to an observed lower population abundance.

A number of other factors may contribute to reduced food resources, including loss of shallow-water tidal and floodplain habitat, changes in hydraulic residence time, water diversions including SWP/CVP south Delta exports, and changes in nutrient balance caused by anthropogenic sources (Lucas et al. 2002; Lehman et al. 2008; Glibert et al. 2011; Jassby 1994; Jassby and Cloern 2000).

2A.2.6.5 Exposure to Toxins

Exposure of longfin smelt to toxic substances can result from point and nonpoint sources associated with agricultural, urban, and industrial land uses. Longfin smelt can potentially be exposed to these toxic materials, including pesticides, herbicides, endocrine disrupting compounds, and metals, during their period of residence within the Bay-Delta. No studies directly link mortality of longfin smelt with exposure to toxic chemicals in the Bay-Delta estuary, although longfin smelt spawn during winter months when nonpoint runoff of pesticides tends to be the greatest (Resources Agency 2007). The pesticide diazinon is known to reduce growth and increase spinal deformities in Sacramento splittail (Teh et al. 2004), but effects of diazinon on longfin smelt have not been investigated. Histopathological and viral evaluation of young longfin smelt collected in 2006 indicated no histological abnormalities associated with toxic exposure or disease (Foott et al. 2008).

No formal risk assessment has been performed on the potential lethal and sublethal effects of toxics on longfin smelt population dynamics. However, there is growing evidence that toxics may have indirect effects on longfin smelt. For example, invertebrate prey of longfin smelt are affected by toxics (Luoma 2007; Werner 2007), reducing food availability for longfin smelt. There is also evidence that toxics may cause sublethal impacts that make fish species more vulnerable to other sources of mortality (Werner 2007; Teh et al. 2011). Most, if not all, pyrethroids are potent neurotoxicants (Shafer and Meyer 2004) and have immunosuppressive effects (Madsen et al. 1996; Clifford et al. 2005). In addition, these compounds and their breakdown products can act as endocrine-disrupting compounds (Tyler et al. 2000; Sun et al. 2007).

Exposure to copper contamination can result in significant sublethal effects on Delta fish species, with implications for their vulnerability to other stressors (Hetrick et al. 1979; Sandahl et al. 2006; Little and Finger 1990; Oros and Werner 2005). Dissolved copper causes acute toxicity to the calanoid copepod, *Eurytemora affinis*, in the north and south Delta (Teh et al. 2009). Additionally, negative synergistic effects have been documented such that the presence of copper in combination with ammonia is more toxic to aquatic organisms than either toxicant individually (Herbert and Van Dyke 1964).

The short life span of longfin smelt (less than 3 years) and location of their food source in the foodweb (zooplankton are primary food sources) may limit the ability of toxic chemicals to bioaccumulate in their tissue (Moyle 2002). Their location in the water column may further reduce the probability of some toxic impacts by those chemicals that are sequestered quickly by sediments (i.e., pyrethroids). Additional research is needed to investigate the potential risk of exposure to toxic chemicals at concentrations and exposure durations typical of Bay-Delta conditions on various life stages of longfin smelt. A recent conceptual model by Brooks et al. (2012) suggested that adult longfin smelt might be vulnerable to the effects of contaminants in winter and spring through release of toxins from fat reserves during upstream migration to the Delta from San Francisco Bay and the Pacific Ocean. The conceptual model also noted the potential for contaminant effects in winter and spring during occupation of the freshwater Delta, including acute toxicity to larvae and juveniles, direct or indirect food limitation (spring only), impaired behavior and disease susceptibility, and temperature effects on toxic thresholds (spring only).

In addition to direct effects on fish, ammonia in the form of ammonium has been shown to reduce primary production by inhibiting nitrate uptake and suppressing spring phytoplankton blooms in Suisun and Grizzly Bays (Dugdale et al. 2007). The role of ammonium nitrogen uptake inhibition in Sacramento River primary production is less certain than in the Bays. Parker et al. (2012) observed primary production in the Sacramento River decreased in the Sacramento Regional Wastewater Treatment Plant region as compared to the upper river region during the months of March and April. However, a previous study found that chlorophyll declines above the wastewater treatment plant between the Tower Bridge in Sacramento and Garcia Bend (Foe et al. 2010). The application of general ecological principles would lead us to believe that decreased primary productivity, wherever it occurs in longfin smelt habitat, is likely to lead to a decrease in copepods and other zooplankton that longfin smelt rely upon for food. A link between primary productivity and productivity in higher trophic levels has been documented in various pelagic food webs (Nixon 1988; Sobczak et al. 2005), although it has not been shown specifically in the San Francisco Bay-Delta. Kimmerer (2008) showed a statistically significant relationship between juvenile delta smelt survival and zooplankton biomass over the long term.

2A.2.6.6 Predation and Competition

The effect of nonnative predators, such as inland silversides, striped bass, , has been identified as a potential stressor on longfin smelt populations (Sommer et al. 2007; Rosenfield 2010), but the potential effect of predation on longfin smelt remains although poorly understood is most likely an important factor (Moyle 2002). Larval longfin smelt are not strong swimmers, and are thus particularly vulnerable to predation (Wang 1986). Predation has been implicated as an important factor affecting production of juvenile longfin smelt, in part because of the correspondence between freshwater flows, the volume of turbid habitat, and the young-of-year class size for longfin smelt (Rosenfield 2010). Predation would seem to be one of the mechanisms that are correlated with the amount of outflow and predictably, it is hard to quantify (Moyle 2002). Most studies have looked at known Delta piscivores and have found little evidence of longfin smelt predation (Stevens 1966; Thomas 1967; Nobriga and Feyrer 2007). Many animals including nonpiscivorous fish species can prey on smelt eggs and larvae and this may be enhanced during low outflow scenarios, so predation is thought to be one of the important mechanisms in longfin smelt and outflow correlations.

Zooplanktivores may compete for limited food resources with longfin smelt.

2A.2.6.7 Invasive Aquatic Vegetation

Egeria and water hyacinth are invasive aquatic plants that grow in dense aggregations and can indirectly affect longfin smelt by reducing dissolved oxygen and turbidity in their immediate vicinity (Grimaldo and Hymanson 1999; Brown and Michniuk 2007; Feyrer et al. 2007). Longfin smelt have limited spatial overlap with most of the known infestations of *Egeria* and water hyacinth. The spread of these plants (*Egeria* is the only one that has spread recently; Santos et al. 2011) is not likely to have influenced the population dynamics of longfin smelt.

2A.2.7 Relevant Conservation Efforts

Pursuant to the CALFED objective of ecosystem restoration, the CALFED agencies developed the Ecosystem Restoration Plan and the Environmental Water Account for the purpose of restoring habitat and recovering at-risk fish populations in the Bay-Delta estuary (CALFED Bay-Delta Program 2000). The CALFED Multi-Species Conservation Strategy (CALFED Bay-Delta Program 2000) designates longfin smelt as an "R" species and states that the goal is to "achieve recovery objectives identified for longfin smelt in the recovery plan for the Sacramento/San Joaquin Delta native fishes" (U.S. Fish and Wildlife Service 1996). However, no conservation efforts in the recovery plan specifically target longfin smelt; all are referenced to delta smelt.

In January 2005, the Interagency Ecological Program established the POD work group to investigate the causes of the recently observed rapid decline in populations of pelagic organisms, including longfin smelt, in the upper San Francisco Bay estuary (Baxter et al. 2010). The Resources Agency prepared the *Pelagic Fish Action Plan* in March 2007 to address POD (Resources Agency 2007). The action plan identifies 17 actions that are being implemented or that are under active evaluation to help stabilize the Delta ecosystem and improve conditions for pelagic fish.

Longfin smelt is included in the *Sacramento-San Joaquin Delta Native Fishes Recovery Plan* (U.S. Fish and Wildlife Service 1996), which also includes the delta smelt, Sacramento splittail, green sturgeon, Sacramento perch, and three races of Chinook salmon.

In 2007, the Federal District Court, Eastern District of California, Fresno Division (Judge Wanger) issued a court order for interim actions to protect delta smelt pending completion of a new BiOp by USFWS on SWP/CVP operations. The new opinion detailed "reasonable and prudent" alternative actions to reduce the likelihood of jeopardy that include improvements to flow conditions restoring tidal marsh and associated subtidal habitat in the Delta and Suisun Marsh, and a comprehensive monitoring plan. It is likely that the actions put in place for Delta smelt are also benefiting longfin smelt. Additionally, the "smelt workgroup" are considering longfin smelt as well as Delta smelt in their proposed actions.

Additional conservation measures that may benefit longfin smelt include the San Francisco Bay Joint Venture, San Francisco Bay and Central Valley total maximum daily loads, Suisun Marsh Plan, and the Tidal Marsh Recovery Plan. Although these plans do not specifically target longfin smelt, they might provide ecosystem services to the species.

2A.2.8 References Cited

2A.2.8.1 Literature Cited

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The Effect of Light Intensity, Alga Concentration, and Prey Density on the Feeding Behavior of Delta Smelt Larvae. In: F. Feyrer, L. Brown, R. Brown, and J. Orsi (eds.). *Early Life History of Fishes in the San Francisco Estuary and Watershed.* American Fisheries Society. Symposium 39, Bethesda, MD. Pages 219-228.

Baxter, R. D. 1999. Osmeridae. In J. Orsi (ed.). *Report on the 1980 to 1995 Fish, Shrimp and Crab Sampling in the San Francisco Estuary.* Interagency Ecological Program for the Sacramento-San Joaquin Estuary. Pages 179–216.

Baxter, R. D., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solgar, T. Sommer, and K. Souza. 2010. *Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results*. Available: <www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf>.

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* [online serial] 3(2), Article 1. Available: <http://escholarship.org/uc/item/0725n5vk>. Accessed: December 14, 2011.

Bennett, W. A., W. J. Kimmerer, and J. R. Burau. 2002. Plasticity in Vertical Migration by Native and Exotic Estuarine Fishes in a Dynamic Low-Salinity Zone. *Limnology and Oceanography* 47(5):1496–1507.

Booth, E., J. Mount, and J. Viers. 2006. Hydrologic Variability of the Cosumnes River Floodplain. *San Francisco Estuary and Watershed Science* [online serial] 4(2), Article 2.

Brooks, M., E. Fleishman, L. Brown, P. Lehman, I. Werner, N. Scholz, C. Mitchelmore, J. Lovvorn, M. Johnson, D. Schlenk, S. van Drunick, J. Drever, D. Stoms, A. Parker, and R. Dugdale. 2012. Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary, California, USA. *Estuaries and Coasts* 35(2):603–621.

Brown, L. R., and D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30(1):186–200.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2007. Evaluation of Petition: Request by Bay Institute, Center for Biological Diversity, and Natural Resources Defense Council to List the Longfin Smelt (*Spirinchus thaleichthys*) as Threatened or Endangered under the California Endangered Species Act. November 16.

California Department of Fish and Game. 2009. *Report to the Fish and Game Commission: A Status Review of the Longfin Smelt (*Spirinchus thaleichthys*) in California*. January 23. Available: <http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=10263>.

Chigbu, P. and T. h. Sibley. Feeding Ecology of Longfin Smelt (*Spirinchus thaleichthys* Ayres) in Lake Washington. *Fisheries Research* 38: 109–119.

Clifford, M. A., K .J. Eder, I. Werner, and R. P. Hendrick. 2005. Synergistic Effects of Esfenvalerate and Infectious Hematopoietic Necrosis Virus on Juvenile Chinook Salmon Mortality. *Environmental Toxicology and Chemistry* 24: 1766–1772.

Cloern, J. E., and A. D. Jassby. 2012. Drivers of Change in Estuarine-Coastal Ecosystems: Discoveries from Four Decades of Study in San Francisco Bay. *Reviews in Geophysics* 50, RG4001, doi:10.1029/2012RG000397.

Contreras, D., K. Osborn, R. Baxter, and S. Slater. 2012. 2011 Status and Trends Report for Pelagic Fishes of the Upper San Francisco Estuary. *Interagency Ecological Program Newsletter* 25(2):22–35.

Dege, M. and L. R. Brown. 2004. Effect of Outflow on Spring and Summertime Distribution and Abundance of Larval and Juvenile Fishes in the Upper San Francisco Estuary. In: F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi (eds.). Early Life History of Fishes in the San Francisco Estuary and Watershed. *American Fisheries Society Symposium* 39:49–66.

Dryfoos, R. L. 1965. *The Life History and Ecology of the Longfin Smelt in Lake Washington.* PhD dissertation. University of Washington, Tacoma.

Dugdale, R. C., F. P. Wilkerson, V. E. Hogue, and A. Marchi. 2007. The Role of Ammonium and Nitrate in Spring Bloom Development in San Francisco Bay. *Estuarine Coastal and Shelf Science* 73:17–29.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary Shifts in a Stressed Fish Assemblage: Consequences of a Bivalve Invasion in the San Francisco Estuary. *Environmental Biology of Fishes* 67(3):277–288.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Science* 64:723–734.

Foe, C., A. Ballard, and F. Stephanie. 2010. *Nutrient Concentrations and Biological Effects in the Sacramento–San Joaquin Delta*. July. Rancho Cordova, CA: California Regional Water Quality Control Board, Central Valley Region.

Foott, J. S. and R. Stone. 2008. *Histological Evaluation and Viral Survey of Juvenile Longfin Smelt (*Spirinchus thaleichthys*) and Threadfin Shad (*Dorosoma petenense*) collected from the Sacramento–San Joaquin River Delta, April–November 2007.* Anderson, CA: Health Center, U.S. Fish and Wildlife Service.

Glibert, P. M., D. Fullerton, J. M. Burkholder, J. C. Cornwell, and T. M. Kana. 2011. Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems. *Reviews in Fisheries Science* 19(4):358–417.

Grimaldo, L. F., and Z. Hymanson. 1999. What is the Impact of the Introduced Brazilian Waterweed *Egeria Densa* to the Delta Ecosystem? *Interagency Ecological Program Newsletter* 12(1):43–45.

Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, P. Smith and B. Herbold. 2009. Factors Affecting Fish Entrainment into Massive Water Diversion in a Tidal Freshwater Estuary: Can Fish Losses Be Managed? *North America Journal of Fisheries Management* 29:1253–1270.

Herbert, D. W. M. and J. M. Van Dyke. 1964. The Toxicity to Fish of Mixtures of Poisons. Copper-Ammonia and Zinc-Phenol Mixtures. *Annals of Applied Biology* 53:15–421.

Herren, J. R., and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. In R.L. Brown (ed.). Contributions to the Biology of Central Valley Salmonids. Volume 2. *California Fish and Game. Fish Bulletin* 179:343–355

Hetrick, F. M., M. D, Knittel, and J. L. Fryer. 1979. Increased Susceptibility of Rainbow Trout to Infections Hematopoietic Necrosis Virus after Exposure to Copper. *Applied and Environmental Microbiology 37*(2):198–201.

Hieb, K., and R. Baxter. 1993. Delta Outflow/San Francisco Bay. In: P. L. Herrgesell (ed.). *1991 Annual Report - Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary.* Pages101–116.

Hieb, K., M. Bryant, M. Dege, T. Greiner, S. Slater, and K. Souza. 2005. *2005 Status and Trends of Four Pelagic Fishes of the Upper San Francisco Estuary.* POD Draft Report.

Hobbs, J. A., W. A. Bennett, and J. E. Burton. 2006. Assessing Nursery Habitat for Native Smelts (*Osmeridae*) in the Low-Salinity Zone of the San Francisco Estuary. *Journal of Fish Biology* 69:907–922.

Jassby, A. D. and T. M. Powell. 1994. Hydrodynamic Influences on Interannual Chlorophyll Variability in an Estuary: Upper San Francisco Bay-Delta (California, USA). *Estuarine, Coastal and Shelf Science* 39 (6):595–618.

Jassby, A. D. and J. E. Cloern. 2000. Organic Matter Sources and Rehabilitation of the Sacramento-San Joaquin Delta (California, USA). *Aquatic Conservation: Marine and Freshwater Ecosystems*. 10:323–352.

Kimmerer, W. J. 2002a. Effects of Freshwater Flow on Abundance of Estuarine Organisms: Physical Effects of Trophic Linkages. *Marine Ecology Progress Series* 243:39–55.

Kimmerer, W. J. 2002b. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. *Estuaries* 25(6B): 1275–1290.

Kimmerer, W. J. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. *San Francisco Estuary and Watershed Science* [online serial] 2(1), Article 1.

Kimmerer, W. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *San Francisco Estuary & Watershed Science* 6(2). Available: <http://escholarship.ucop.edu/uc/item/7v92h6fs>.

Kimmerer, W., and B. Bennett. 2005. Investigating the Mechanisms Underlying the Relationships between Abundance of Estuarine Species and Freshwater Flow. *IEP Newsletter* 18(2):56–68.

Kimmerer, W. J., and J. J. Orsi. 1996. Changes in the Zooplankton of the San Francisco Bay Estuary since the Introduction of the Clam *Potamocorbula amurensis.* In J. T. Hollibaugh (ed.). *San Francisco Bay: The Ecosystem.* San Francisco, CA: Pacific Division, American Association for the Advancement of Science. Pages 403–424.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume? *Estuaries and Coasts* 32:375–389.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. *Atlas of North American Freshwater Fishes.* North Carolina Biological Survey No. 1980–12. North Carolina State Museum of Natural History, Raleigh, NC.

Lehman, P. W., T. Sommer, and L. Rivard. 2008. The Influence of Floodplain Habitat on the Quantity and Quality of Riverine Phytoplankton Carbon Produced during the Flood Season in San Francisco Estuary. *Aquatic Ecology* 42(3):363–378.

Leidy, R. A. 2007. *Ecology, Assemblage Structure, Distribution, and Status of Fishes in Streams Tributary to the San Francisco Estuary, California*. PhD dissertation. University of California, Davis. Completed in 2004.

Little E. E., and S. E. Finger. 1990. Swimming Behavior as an Indicator Of Sublethal Toxicity in Fish. *Environmental Toxicology and Chemistry* 9:13–19.

Lopez, C. B., J. E. Cloern, T. S. Schraga, A. J. Little, L. V. Lucas, J. K. Thompson, and J. R. Burau. 2006. Ecological Values of Shallow-Water Habitats: Implications for the Restoration of Disturbed Ecosystems. *Ecosystems* 9:422–440.

Lucas, L. V., J. E. Cloern, J. K. Thompson, and N. E. Monsen. 2002. Functional Variability of Habitats with the Sacramento-San Joaquin Delta: Restoration Implications. *Ecological Applications* 12(5):1528–1547.

Luoma, S. 2007. *Water Quality Issues.* Presentation at CALFED Science Workshop: Science Related to an Isolated Facility. August 22.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennet, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo. 2010. Analysis of Pelagic Species Decline In The Upper San Francisco Estuary Using Multivariate Autoregressive Modeling (MAR). *Ecological Applications* 20(5):1417–1430.

Madsen, C, H. M. H. Claesson, C. Ropke. 1996. Immunotoxicity of the Pyrethroid Insecticides Deltametrin and a-cypermetrin. *Toxicology* 107(3): 219–227.

Matica, Z., and T. Sommer. 2005. *Aquatic Impacts of the Pittsburg and Contra Costa Power Plants* Draft. Department of Water Resources, Division of Environmental Services.

Meng, L., and S. A. Matern. 2001. Native and Introduced Larval Fishes of Suisun Marsh, California: The Effects of Freshwater Outflow. *Transactions American Fisheries Society* 130:750–765.

Miller, W. J., B. F. J. Manly, D. D. Murphy, D. Fullerton, and R. R. Ramey. 2012. An Investigation of Factors Affecting the Decline of Delta Smelt (*Hypomesus transpacificus*) in the Sacramento-San Joaquin Estuary. *Reviews in Fisheries Science* 20:1–19.

Moulton, L. L. 1974. Abundance, Growth And Spawning of the Longfin Smelt in Lake Washington. *Transactions of the American Fisheries Society* 103(1):46–52.

Moyle, P. B. 2002. *Inland Fishes of California.* Revised and Expanded. University of California Press, Berkeley, CA.

Moyle, P. B., B. Herbold, D. E. Stevens, and L. W. Miller. 1992. Life History and Status of Delta Smelt in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 821:67–77.

Nixon, S. W. 1988. Physical Energy Inputs and the Comparative Ecology of Lake and Marine Ecosystems. *Limnology and Oceanography* 33 (4):1005–1025.

Nobriga, M. L., and F. Feyrer. 2007. Shallow-Water Piscivore-Prey Dynamics in California's Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science* 5(2):Article 4.

Nobriga, M. L., F. Feyrer, R. D. Baxter, and M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

Nobriga, M. L., T. R. Sommer, F. Feyrer, and D. Fleming. 2008. Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (*Hypomesus transpacificus*). *San Francisco Estuary and Watershed Science* 6(1):1–13.

Oros, D., and R. I. Werner. 2005. *Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley.* White Paper for the Interagency Ecological Program. SFEI Contribution 415. San Francisco Estuary Institute, Oakland, CA.

Parker, A. E., R. C. Dugdale, and F. P. Wilkerson. 2012. Elevated Ammonium Concentrations from Wastewater Discharge Depress Primary Productivity in the Sacramento River and the Northern San Francisco Estuary. *Marine Pollution Bulletin* 64:574–586.

Pinnix, W. D., T. A. Shaw, and N. J. Hetrick. 2004. *Fish Communities in Eelgrass, Oyster Culture, and Mud Flat Habitat of North Humboldt Bay, California Progress Report.* U.S. Fish and Wildlife Service. Arcata Fisheries Technical Report Number AFWO-F-07-04.

Resources Agency. 2007. *Pelagic Fish Action Plan*. Available: <http://www.water.ca.gov/deltainit/030507pod.pdf>.

Rosenfield, J. A. 2010. *Life History Conceptual Model and Sub-Models for Longfin Smelt, San Francisco Estuary Population for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP).* September 21.

Rosenfield, J. A., and R. D. Baxter. 2007. Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary. *Transactions of the American Fisheries Society* 136:1577–1592.

Sandahl J. F., G. Miyasaka, N. Koide, and H. Ueda. 2006. Olfactory Inhibition and Recovery In Chum Salmon (*Oncorhynchus keta*) following Copper Exposure. *Canadian Journal of Fisheries and Aquatic Sciences* 63(8):1840–1847.

Santos, M. J., L. W. Anderson, and S. L. Ustin. 2011. Effects of Invasive Species on Plant Communities: An Example Using Submersed Aquatic Plants at the Regional Scale. *Biological Invasions* 13(2):443–457.

Shafer, T. J. and D. A. Meyer. 2004. Effects of Pyrethroids on Voltage-Sensitive Calcium Channels: A Critical Evaluation of Strengths, Weaknesses, Data Needs, and Relationship to Assessment of Cumulative Neurotoxicity. *Toxicology and Applied Pharmacology* 196(2):303–318.

Shoellhamer, D. H. 2011. Sudden Clearing of Estuarine Waters upon Crossing the Threshold from Transport to Supply Regulation of Sediment Transport as an Erodible Sediment Pool is Depleted: San Francisco Bay, 1999. *Estuaries and Coasts* 34:885–899.

Slater, S. B. 2008. *Feeding Habits of Longfin Smelt in the Upper San Francisco Estuary.* Poster Session, 2008 CALFED Science Conference. Available: <http://science.calwater.ca.gov/events/conferences/index.html (2008)>.

Sobczak, W. V., J. E. Cloern, A. D. Jassby, B. E. Cole, T. S. Schraga, and A. Arnsberg. 2005. Detritus Fuels Ecosystem Metabolism but Not Metazoan Food Webs in San Francisco Estuary's Freshwater Delta. *Estuaries* 28:124–137.

Sommer, T. 2007. *The Decline of Pelagic Fishes in the San Francisco Estuary: An Update*. Presented to the California State Water Resources Control Board, Sacramento, CA, March 22, 2007. Available: <www.waterrights.ca.gov/baydelta/docs/pelagicorganism/dwr_032207sommer.pdf>.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary. *Fisheries* 32(6):270–277.

Stevens, D. E. 1966. Food Habits Of Striped Bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. In D. W. K. J. T. Turner (ed.). *Ecological Studies of the Sacramento-San Joaquin Delta.* California Department of Fish and Game. Pages 68–96.

Stillwater Sciences, 2005, Napa River Fisheries Monitoring Program Final Report, prepared for Army Corps of Engineers.

Sun, H., X.-L. Xu, L.-C. Xu, L. Song, X. Hong, J.-F. Chen, L.-B.-Cui, X.-R. Wang. 2007. Antiadrogenic Activity of Pyrethroid Pesticides and their Metabolite in Reporter Gene Assay. *Chemosphere* 66(3): 474–479.

Teh, S., I. Flores, M. Kawaguchi, S. Lesmeister, C. Teh. 2011. *Full Life-Cycle Bioassay Approach to assess Chronic Exposure of Pseudodiaptomus forbesi to Ammonia/Ammonium.* State Water Board / UC Davis Agreement No. 06-447=300. August 31.

Teh, S. J., S. Lesmeister, I. Flores, M. Kawaguchi, C. Teh. 2009. Final Report. *Acute Toxicity of Ammonia, Copper, and Pesticides to Key Copepods,*Pseudodiaptomus forbesi *and* Eurytemora affinis, *of the San Francisco Estuary.* Submitted to University of California, Davis Aquatic Toxicology Laboratory. September 29. Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/sac_rcsd/srcsd_exh1u.pdf>.

Teh, S. J., G. Zang, T. Kimball, F. and C. Teh. 2004. Lethal and Sublethal Effects of Esfenvalerate and Diazinon on Splittail Larvae. In F. Feyrer, L. R. Brown, R. L. Brown, J. J. Orsi (eds.) *Early Life History of Fishes in the San Francisco Estuary and Watershed, Symposium 39*. American Fisheries Society. Pages 243–253.

The Bay Institute, Center for Biological Diversity, Natural Resources Defense Council. 2007a. Petition to the State of California Fish and Game Commission and supporting information for listing the delta smelt (*Hypomesus transpacificus*) as an endangered species under the California Endangered Species Act. Available: <http://www.biologicaldiversity.org/swcbd/SPECIES/deltasmelt/ds-state-endangered-petition-02-07-2007.pdf>.

The Bay Institute, Center for Biological Diversity, Natural Resources Defense Council. 2007b. Petition to the State of California Fish and Game Commission and supporting information for listing the longfin smelt (*Spirinchus thaleichthys*) as an endangered species under the California Endangered Species Act. August 8, 2007. Available at: http://www.bay.org/LongfinSmeltState.pdf.

Thomas, J. L. 1967. The Diet of Juvenile and Adult Striped Bass, *Roccus Saxitilis*, in theSacramento-San Joaquin River System. *California Fish & Game* 53(1):49–62.

Thomson, J. R, W. J. Kimmerer, L. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian Change-Point Analysis of Abundance Trends for Pelagic Fishes in the Upper San Francisco Estuary. *Ecological Applications* 20:1431–1448.

Tyler, C. R., N. Beresford, M. van der Woning, J. P. Sumpter, K. Tchorpe. 2000. Metabolism and Environmental Degradationof Pyrethroid insecticides Produce Copounds with Endocrine Activities. *Environmental Toxicology and Chemistry* 19(4): 801–809.

U.S. Fish and Wildlife Service. 1996. *Sacramento-San Joaquin Delta Native Fishes Recovery Plan.* Portland, OR.

Wang, J.C.S. 1986. *Fishes of the Sacramento-San Joaquin Estuary And Adjacent Waters, California: A Guide to the Early Life Histories.* Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern*? Seminar, University of California, Davis, November 8.

Wright, S. A., and D. H. Shoellhamer. 2004. Trends in Sediment Yield of the Sacramento River, California, 1957–2001. *San Francisco Estuary and Watershed Science* [online serial] 2(2), Article 2.

2A.2.8.2 Personal Communications

Fullerton, Dave. October 1–3, 2013—Presentation at State Water Resources Control Board, Phase II Comprehensive Review of the Bay Delta Plan,Workshop 2, Pages 77–78. Available at: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/wrkshp2/dfullerton.pdf>.

2A.2.8.3 Federal Register Notices Cited

73 FR 24911. 2008. Endangered and Threatened Wildlife and Plants; Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt (*Spirinchus thaleichthys*) as Endangered. *Federal Register* 73:24911.

74 FR 16169. 2009. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt (*Spirinchus thaleichthys*) as Endangered. *Federal Register* 74:16169.

77 FR 19755. 2012. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt as Endangered or Threatened. *Federal Register* 77:19755.

Source: DFG 2007

BDCP-HCP 00343.12 (8-6-12) tm

Figure 2A.2-1
Longfin Smelt Range

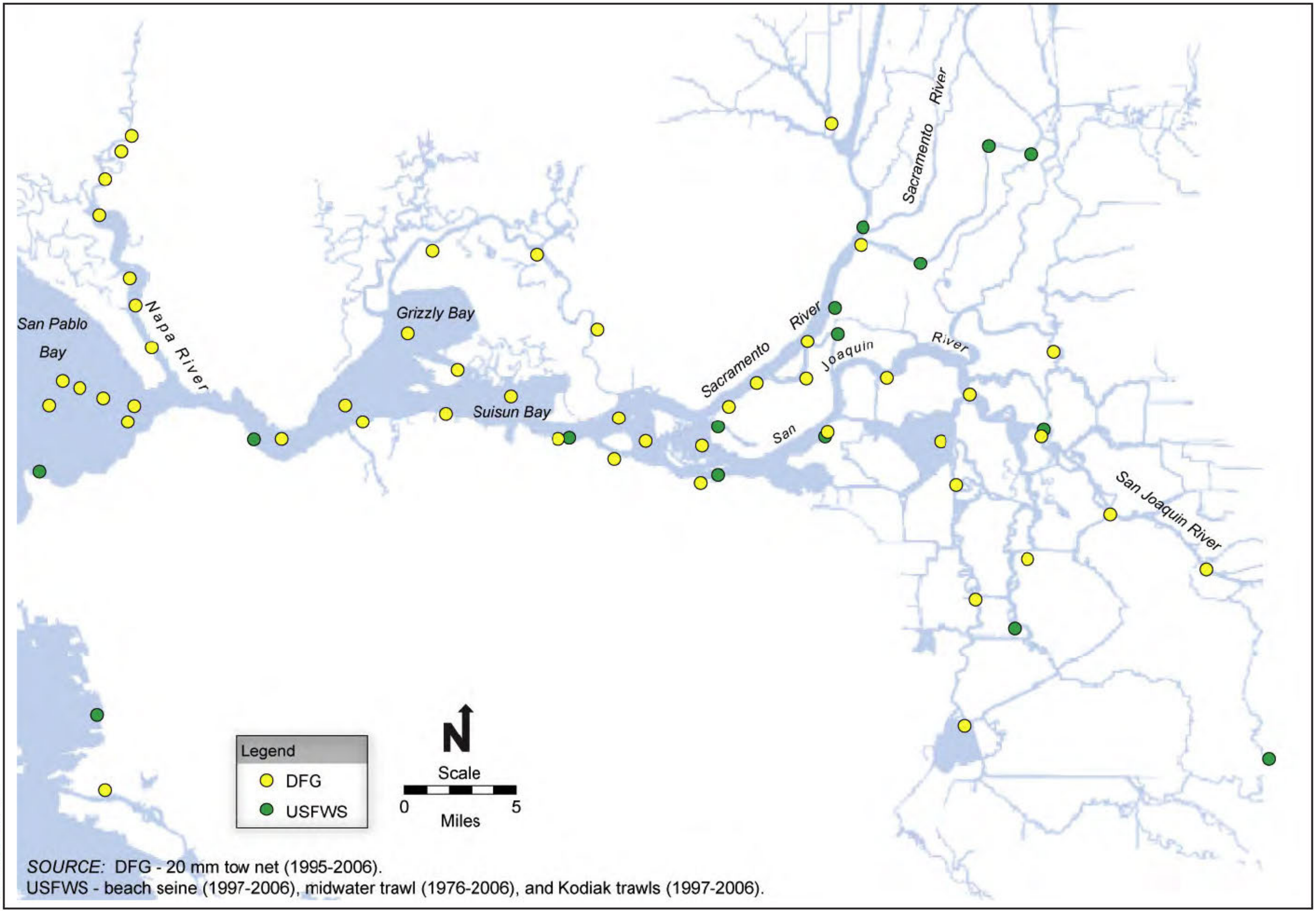
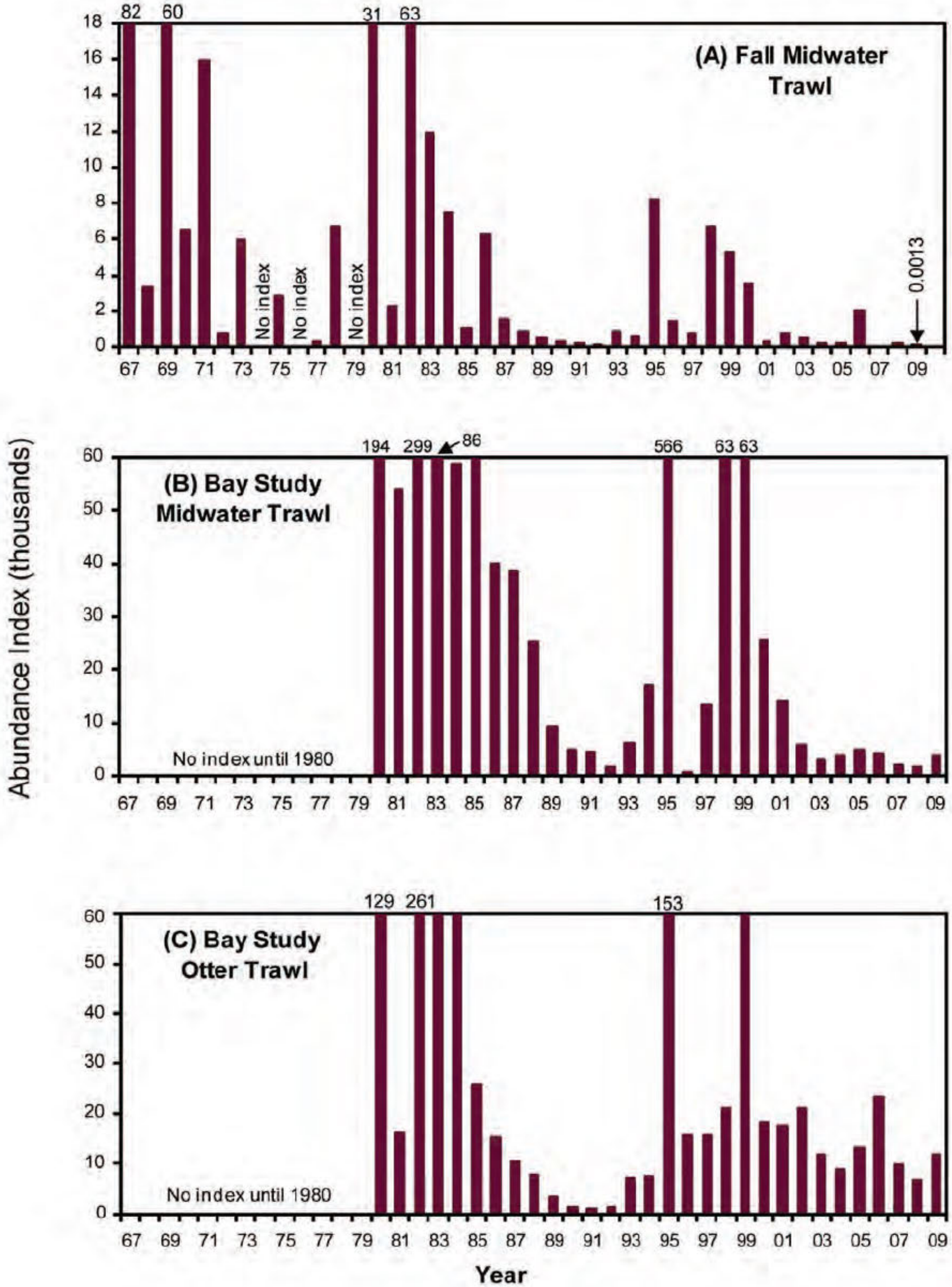
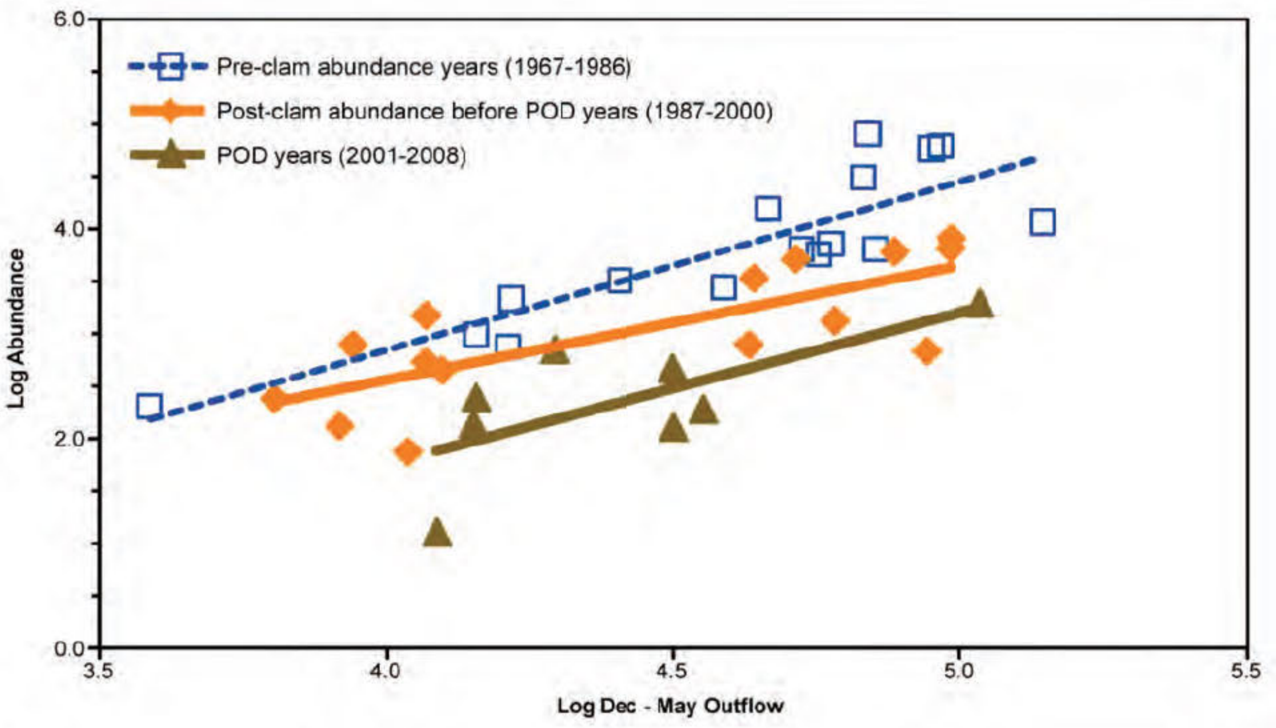


Figure 2A.2-2
Historical Sampling Locations Where Longfin Smelt Have Been Captured Since 1976



SOURCE: California Department of Fish and Game unpublished data, Interagency Ecological Program unpublished data.

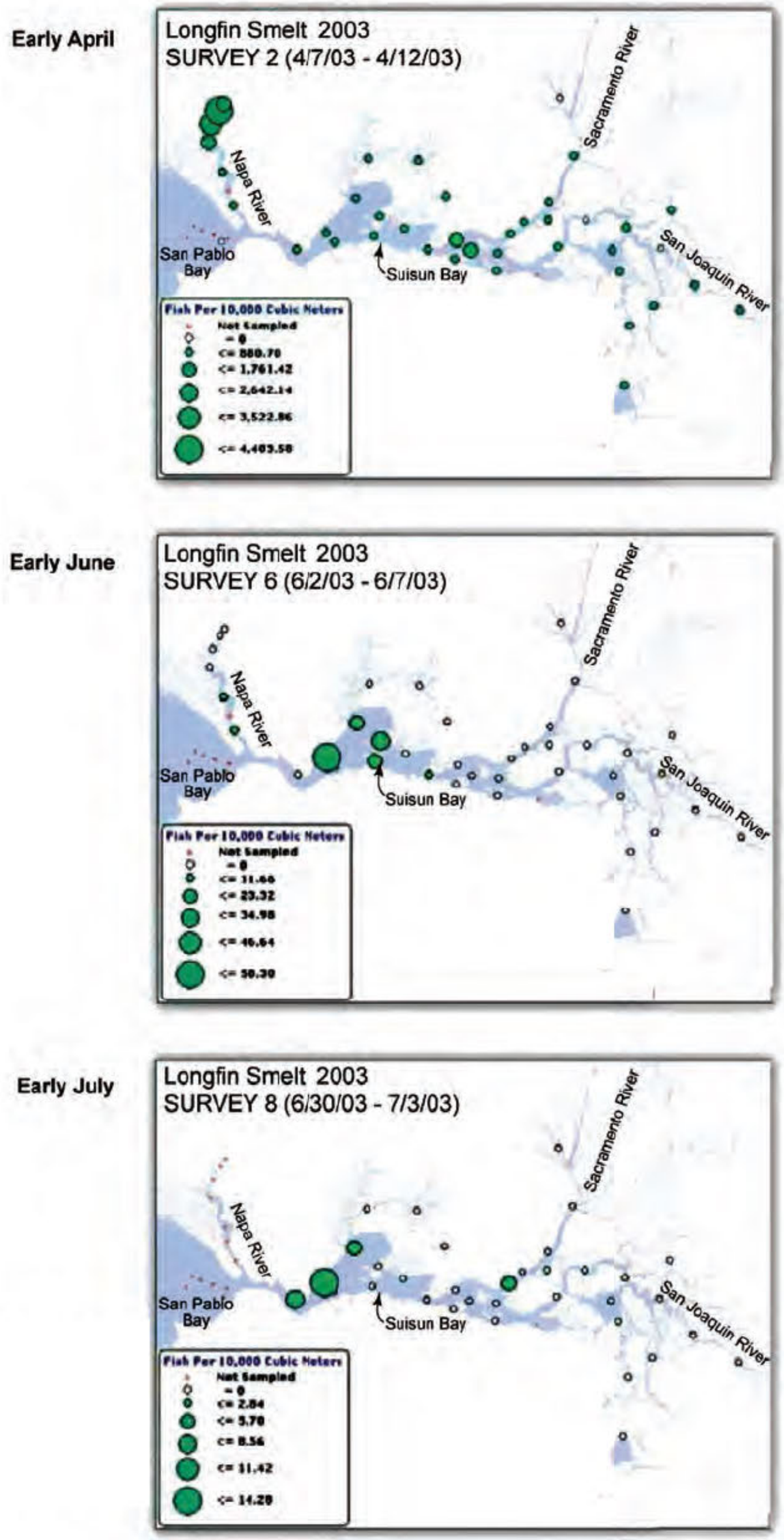
Figure 2A.2-3
Annual Abundance Indices of Longfin Smelt from 1967 to 2009



POD = pelagic organism decline

SOURCE: California Department of Fish and Game unpublished data, Interagency Ecological Program unpublished data.

Figure 2A.2-4
Longfin Smelt Abundance (log_{10}) from Fall Midwater Trawl Survey as a Function of Mean Delta Outflow from December through May (log_{10})



SOURCE: California Department of Fish and Game. 2003. 20 mm Longfin Smelt Survey. Available: <http://ww/delta.dfg.ca.gove/data/skt/l>.
This annual survey monitors post-larval and juvenile longfin smelt distribution and relative abundance every two weeks during spring and early summer throughout their historical spring range using a 1600 μm egg and larval net.

BDCP-HCP 00343.12 (10-23-12) tm

Figure 2A.2-5
Example of Distribution of Post-Larval and Juvenile Longfin Smelt in Spring-Summer of a Representative Above-Normal Water Year

Appendix 2A.3
Sacramento River Winter-Run Chinook Salmon (*Oncorhynchus tshawytscha*)

2A.3.1 Legal Status

The Sacramento River winter-run Chinook salmon evolutionary significant unit (ESU) was originally listed as a threatened species in August 1989, under emergency provisions of the federal Endangered Species Act (ESA), and was formally listed as threatened in November 1990 (55 *Federal Register* [FR] 46515). The ESU consists of only one population confined to the upper Sacramento River in California's Central Valley. The ESU was reclassified as endangered under the ESA on January 4, 1994 (59 FR 440), because of increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99% decline between 1966 and 1991. The Sacramento River winter-run Chinook salmon ESU includes all naturally spawned winter-run Chinook salmon in the Sacramento River and its tributaries, as well as two artificial propagation programs: winter-run Chinook salmon produced from the Livingston Stone National Fish Hatchery and released as juveniles into the Sacramento River and winter-run Chinook salmon held in a captive broodstock program maintained at Livingston Stone National Fish Hatchery (70 FR 37160, June 28, 2005) (Figure 2A.3-1).

The National Marine Fisheries Service (NMFS) reaffirmed the listing of the Sacramento River winter-run Chinook salmon ESU as endangered on June 28, 2005 (70 FR 37160), and included the Livingston Stone National Fish Hatchery population in the listed population. The major concerns were that there is only one extant population, which is spawning outside of its historical range, in artificially maintained habitat that is vulnerable to drought. Another concern was the rising levels of hatchery fish spawning in natural areas.

On August 15, 2011, after a second 5-year review (76 FR 50447), NMFS determined that the ESU had continued to decline since 2005, with a negative point estimate for the 10-year trend. However, the current population size still falls within the low-risk criterion, and the 10-year average introgression rate of hatchery fish (about 8%) is below the low-risk threshold for hatchery influence (National Marine Fisheries Service 2011). Winter-run Chinook salmon was listed as endangered under the California Endangered Species Act (CESA) on September 22, 1989.

2A.3.2 Species Distribution and Status

2A.3.2.1 Range and Status

The distribution of winter-run Chinook salmon spawning and rearing was limited historically to the upper Sacramento River and tributaries, where cool spring-fed streams supported successful adult holding, spawning, egg incubation, and juvenile rearing (Slater 1963; Yoshiyama et al. 1998). The headwaters of the McCloud, Pit, and Little Sacramento Rivers and Hat and Battle Creeks, provided clean, loose gravel, cold, well-oxygenated water, and year-round flow in riffle habitats for spawning and incubation (Figure 2A.3-1). These areas also provided the cold, productive waters necessary for egg and fry survival and juvenile rearing over summer. Construction of Shasta Dam in 1943 and Keswick Dam in 1950 blocked access to all of these upstream waters except Battle Creek, which is blocked by a weir at the Coleman National Fish Hatchery and other small hydroelectric facilities (Moyle et al. 1989; National Marine Fisheries Service 1997). Approximately 299 miles of tributary spawning habitat in the upper Sacramento River are inaccessible to winter-run Chinook salmon (National Marine Fisheries Service 2012).

Primary spawning and rearing habitats for winter-run Chinook salmon are now confined to the cold water areas between Keswick Dam and Red Bluff Diversion Dam. The lower reaches of the Sacramento River, Sacramento–San Joaquin River Delta (Delta), and San Francisco Bay serve as migration corridors for the upstream migration of adult and downstream migration of juvenile winter-run Chinook salmon.

Estimates of the Sacramento River winter-run Chinook salmon population (including both male and female salmon) reached nearly 100,000 fish in the 1960s before declining to under 200 fish in the 1990s (Good et al. 2005). Abundance of returning adult spawners generally increased between the mid-1990s and 2006 (Figure 2A.3-1). However, recent population estimates of winter-run Chinook salmon spawning upstream of the Red Bluff Diversion Dam have dropped off since the 2006 peak (California Department of Fish and Game 2010). The escapement estimate for 2010 was 1,533 adults, while the 2011 estimate (824 fish) was the lowest total since the 880 fish escapement estimate in 1997 (National Marine Fisheries Service 2012).

Two methods are used to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the juvenile production index method (using rotary screw traps) and the juvenile production estimate method (using carcass surveys). Average juvenile population of Sacramento River winter-run Chinook salmon inhabiting the upper Sacramento River at the Red Bluff Diversion Dam is 4,230,378 juveniles per year, using the juvenile production index method between 1995 and 2007 (excluding 2000 and 2001 when rotary screw trapping was not conducted) (Poytress and Carillo 2010). Using the juvenile production estimate method, average production is estimated to be 5,034,921 juveniles exiting the upper Sacramento River at the Red Bluff Diversion Dam between 1996 and 2007 (Poytress and Carillo 2010).

Although the abundance of the Sacramento River winter-run Chinook salmon population has, on average, been growing since the 1990s (despite recent declines since 2007), there is only one population and it depends heavily on coldwater releases from Shasta Dam (Good et al. 2005). Lindley et al. (2007) consider the Sacramento River winter-run Chinook salmon population at a moderate risk of extinction primarily because of the risks associated with only one existing population. The viability of an ESU that is represented by a single population is vulnerable to changes in the environment through a lack of spatial geographic and genetic diversity. A single catastrophic event with effects persisting for 4 or more years could extirpate the entire Sacramento River winter-run Chinook salmon ESU, which puts the population at a high risk of extinction over the long term (Lindley et al. 2007). Such potential catastrophes include volcanic eruption of Mount Lassen; prolonged drought, which depletes the coldwater pool in Lake Shasta or some related failure to manage coldwater storage; a spill of toxic materials with effects that persist for 4 years; regional declines in upwelling and productivity of near-shore coastal marine waters resulting in reduced food supplies for juvenile and sub-adult salmon, reduced growth, and/or increased mortality; or a disease outbreak. Another vulnerability to an ESU that is represented by a single population is the limitation in life history and genetic diversity that would otherwise increase the ability of individuals in the population to withstand environmental variation.

Although NMFS proposed that this ESU be downgraded from endangered to threatened status, NMFS decided in its Final Listing Determination (June 28, 2005; 70 FR 37160) to continue to list the Sacramento River winter-run Chinook salmon ESU as endangered because the population remains below the draft recovery goals established for the run (National Marine Fisheries Service 1997) and the naturally spawned component of the ESU is dependent on one extant population in the Sacramento River. NMFS reconfirmed this listing status in 2011, based on a 10-year negative trend in abundance and the continued influence of hatchery fish on the single spawning population in the ESU (National Marine Fisheries Service 2011).

2A.3.2.2 Distribution and Status in the Plan Area

The entire population of the Sacramento River winter-run Chinook salmon must pass through the Plan Area as migrating adults and emigrating juveniles. Because winter-run Chinook salmon use only the Sacramento River system for spawning, adults are likely to migrate upstream primarily along the western edge of the Delta through the Sacramento River corridor. Because juvenile winter-run salmon have been collected at various locations in the Delta (including the State Water Project [SWP] and the Central Valley Project [CVP] south Delta export facilities), juveniles likely use a wider range of the Delta for migration and rearing than adults. Studies using acoustically tagged juvenile and adult Chinook salmon are ongoing to further investigate the migration routes, migration rates, reach-specific mortality rates, and the effects of hydrologic conditions (including the effects of SWP/CVP export operations) on salmon migration through the Delta (Lindley et al. 2008; MacFarlane et al. 2008a; Michel et al. 2008; Perry et al. 2008). Juvenile winter-run Chinook salmon likely inhabit Suisun Marsh for rearing and may inhabit the Yolo Bypass when flooded, although use of these two areas is not well understood.

Results of fishery monitoring using a combination of adult counts at the Red Bluff Diversion Dam fish ladder and carcass surveys have been used to estimate annual adult escapement of winter-run Chinook salmon on the mainstem Sacramento River. The estimated annual adult escapement from 1970 through 2009 is shown in Figure 2A.3-2. During the late 1960s and throughout the 1970s, winter-run Chinook salmon abundance declined significantly from a peak of approximately 120,000 adults to several thousand adults. Population abundance remained very low through the mid-1990s, with adult abundance in some years less than 500 fish. Beginning in the mid-1990s and continuing through 2006, adult escapement has shown a trend of increasing abundance, approaching 20,000 fish in 2005 and 2006.

The following factors have contributed to this increasing trend in adult abundance.

- Improved water temperatures and temperature management in the Shasta Reservoir and the mainstem river downstream of Keswick Dam.
- Improvements in the operations of the Red Bluff Diversion Dam (keeping holding gates open for a longer period).
- Favorable hydrological and ocean rearing conditions.
- Habitat enhancements, reductions in loading of toxic chemicals.
- Improved fish screens on major water diversions.
- Changes in ocean commercial and recreational angling to reduce harvest mortality.

Based on recent escapement data, NMFS concluded that the Central Valley winter-run Chinook salmon ESU has continued to decline from a recent peak in 2006 of over 17,000 fish to less than 2,000 fish in 2010 (National Marine Fisheries Service 2011). Overall, the recent 10-year trend in abundance is negative. Adult winter-run Chinook salmon escapement to the Sacramento River declined substantially in 2007, with an estimated 2,542 adults returning to spawn (Figure 2A.3-2). As discussed below, the substantial decline in adult winter-run Chinook salmon escapement was the likely result of reduced productivity of near-shore coastal waters and reduced prey availability resulting in poor juvenile salmon growth and high mortality during the juvenile ocean rearing phase (MacFarlane et al. 2008b). A similar substantial decline in abundance of returning fall-run Chinook salmon (and other salmon populations in California) was observed in 2007. Adult escapement remained low during 2008 and 2009. In response to the low numbers of adult Chinook salmon returning to the Central Valley, commercial and recreational fishing for salmon has been curtailed since 2007, but was resumed in 2010 and full seasons were restored in 2011 and 2012.

2A.3.3 Habitat Requirements and Special Considerations

Critical habitat for the winter-run Chinook ESU was designated under the ESA on June 16, 1993 (58 FR 33212). Designated critical habitat includes the Sacramento River from Keswick Dam (river mile 302) to Chipps Island (river mile 0) at the westward margin of the Delta, all waters from Chipps Island westward to Carquinez Bridge, including Honker, Grizzly, and Suisun bays, and Carquinez Strait, all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge (59 FR 440, January 4, 1994) (Figure 2A.3-3). In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. In the areas westward of Chipps Island, critical habitat includes the estuarine water column and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration.

Habitat of Sacramento River winter-run Chinook salmon is also protected under the Magnuson-Stevens Fishery Conservation and Management Act as essential fish habitat (EFH). Those waters and substrate necessary to support Sacramento River winter-run Chinook salmon spawning, breeding, feeding, or growth are included as EFH (Figure 2A.3-4). Critical habitat and EFH are managed differently from a regulatory standpoint, but are biologically equivalent with regard to conservation.

The designated critical habitat includes primary constituent elements (PCEs) considered essential for the conservation of Sacramento River winter-run Chinook salmon. The identified PCEs are spawning habitat, freshwater rearing habitat, freshwater migration corridors, estuarine habitat, and nearshore and offshore marine habitats.

2A.3.3.1 Spawning Habitat

Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between Red Bluff Diversion Dam and Keswick Dam. Spawning sites include those stream reaches with water movement, velocity, depth, temperature, and substrate composition that support spawning, egg incubation, and larval development. Water velocity and substrate conditions are more critical to the viability of spawning habitat than depth. Incubating eggs and embryos buried in gravel require sufficient water flow through the gravel to supply oxygen and remove metabolic wastes (Resources Agency et al. 1998). Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities. The gravel must be clean and loose, yet stable for the duration of egg incubation and the larval development.

Substrate composition has other key implications to spawning success. The embryos and alevins (newly hatched fish with the yolk sac still attached) require adequate water movement through the substrate; however, this movement can be inhibited by the accumulation of fines and sand. Generally, the redd should contain less than 5% fines (Resources Agency et al. 1998).

Water velocity in Chinook salmon spawning areas typically ranges from 1.0 to 3.5 feet per second and optimum velocity is 1.5 feet per second (Resources Agency et al. 1998). Spawning occurs at depths between 1 to 5 feet with a maximum observed depth of 20 feet. A depth of less than 6 inches can be restrictive to Chinook salmon movement.

2A.3.3.2 Freshwater Rearing Habitat

Freshwater salmon rearing habitats contain sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility; suitable water quality; availability of suitable forage species that support juvenile salmon growth and development; and cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors also function as rearing habitat for juveniles, which feed and grow before and during their outmigration. Nonnatal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat value is strongly affected by habitat diversity and complexity, food supply, and fish and avian predators. Some of these more complex and productive habitats with floodplains are still found in the system (e.g., the lower Cosumnes River, Sacramento River reaches with setback levees [i.e., primarily located upstream of the City of Colusa]). The channeled, leveed, and riprapped river reaches and sloughs are common along the Sacramento River and throughout the Delta; however, they typically have low habitat complexity, have low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value as the juvenile life stage of salmonids is dependent on the function of this habitat for successful survival and recruitment into the adult population.

2A.3.3.3 Freshwater Migration Corridors

Freshwater migration corridors for winter-run Chinook salmon, including river channels, floodplains, channels through the Delta, and the Bay-Delta estuary support mobility, survival, and food supplies for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), provide favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, native aquatic vegetation, large woody debris, rocks and boulders, side channels, and undercut banks. Migratory corridors for winter-run Chinook salmon are located downstream of the spawning areas and include the lower Sacramento River, Yolo Bypass, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, limit false attraction, provide low vulnerability to predation, and not contain impediments and delays in both upstream and downstream migration.

Results of mark-recapture studies conducted using juvenile Chinook salmon (typically hatchery-reared late fall-run Chinook salmon that are considered to be representative of juvenile winter-run salmon) released into the Sacramento River have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001; Newman and Rice 2002; Hanson 2008). Mortality is typically greater in years when spring flows are reduced and water temperatures are increased. Results of survival studies have shown that closing the Delta Cross Channel gates to reduce the movement of juvenile salmon into the Central Delta, contributes to improved survival of emigrating juvenile Chinook salmon (Brandes and McLain 2001; Manly 2004; Low and White undated). Observations at the SWP/CVP fish salvage facilities have shown that very few of the marked salmon (typically less than 1% [Hanson 2008]) are entrained and salvaged at the export facilities. Results of estimating incidental take of juvenile winter-run Chinook salmon at the SWP/CVP fish salvage facilities based on comparison of the juvenile production estimates for winter-run emigrating from the upper Sacramento River rearing areas (e.g., estimated based on results of spawning carcass surveys and environmental conditions and/or fishery monitoring at Red Bluff Diversion Dam) generally show similar small direct losses of juvenile winter-run Chinook salmon at the fish salvage facilities, except in 2011 and 2012, when losses were greater than 1% (Delta Operations for Salmonids and Sturgeon Technical Working Group 2012). Although the factors contributing to the high juvenile mortality have not been quantified, results of acoustic tagging experiments and anecdotal observations suggest that exposure to adverse water quality leading to mortality (e.g., elevated water temperatures, potentially toxic chemicals) and vulnerability to predation mortality are two of the factors contributing to the high juvenile mortality observed in the Sacramento River and Delta.

2A.3.3.4 Estuarine Habitat

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, native aquatic vegetation, and side channels, provide juvenile foraging habitat and cover from predators. Tidal wetlands and seasonally inundated floodplains have also been identified as high-value foraging and rearing habitats for juvenile salmon migrating downstream through the estuary. Estuarine areas contain a high conservation value because they function to support juvenile Chinook salmon growth, smolting, and avoidance of predators, as well as provide a transition to the ocean environment.

2A.3.3.5 Marine Habitats

Although ocean habitats are not part of the critical habitat listings for Sacramento River winter-run Chinook salmon, biologically productive coastal waters are an important habitat component for the species. Juvenile Chinook salmon inhabit near-shore coastal marine waters for a period of typically 2 to 4 years before adults return to Central Valley rivers to spawn. During their marine residence, Chinook salmon forage on krill, squid, and other marine invertebrates and a variety of fish such as northern anchovy, sardines, and Pacific herring. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

The variation in ocean productivity off the West Coast can be high both within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, phytoplankton and zooplankton production, and the availability of other forage species in near-shore surface waters. Ocean conditions during a salmon's ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook and coho salmon returning to California rivers and streams (Pacific Fishery Management Council 2008). The decline has been hypothesized to be the result of decreased ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008b; Pacific Fishery Management Council 2008). The importance of changes in ocean conditions on growth, survival, and population abundance of Sacramento River Chinook salmon is currently undergoing further investigation.

2A.3.4 Life History

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). Stream-type adults enter fresh water months before spawning and juveniles reside in fresh water for a year or more following emergence, whereas ocean-type adults spawn soon after entering fresh water and juveniles migrate to the ocean as fry or parr in their first year. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter fresh water in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

Sacramento River winter-run Chinook salmon adults enter the Sacramento River basin between December and July; the peak occurring in March (Table 2A.3-1) (Yoshiyama et al. 1998; Moyle 2002). Spawning occurs from mid-April to mid-August, peaking in May and June, in the Sacramento River reach between Keswick Dam and Red Bluff Diversion Dam (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are 3 years old. Adult winter-run Chinook salmon tend to enter fresh water as sexually immature fish, migrate far upriver, and delay spawning for weeks or months. Prespawning activity requires an area of 200 to 650 square feet. The female digs a nest, called a redd, with an average size of 165 square feet, in which she buries her eggs after they are fertilized by the male (Resources Agency et al. 1998).

Table 2A.3-1. Temporal Occurrence of Adult and Juvenile Sacramento River Winter-Run Chinook Salmon in the Sacramento River and Delta

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River basin[1]	Medium / Medium	Medium / Medium	High / High	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	– / –	– / –	– / –	– / –	Medium / Medium
Sacramento River[2]	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	– / –	– / –	– / –	– / –	Medium / Medium	Medium / Medium
Juvenile												
Sacramento River at Red Bluff[3]	Low / Low	– / –	– / –	– / –	– / –	– / –	Low / Medium	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium
Sacramento River at Red Bluff[2]	Medium / Medium	Medium / Medium	– / –	– / –	– / –	– / –	Low / Low	High / High	High / High	High / High	Medium / Medium	Medium / Medium
Sacramento River at Knights Landing[4]	Medium / Medium	Medium / Medium	Medium / Medium	Low / Low	– / –	– / –	– / –	Low / Low	Low / Low	Low / Low	High / High	High / High
Lower Sacramento River (seine)[5]	High / High	High / High	Medium / Medium	Low / –	– / –	– / –	– / –	– / –	Low / Low	Low / Low	Medium / Medium	High / High
West Sacramento River (trawl)[5]	Medium / Medium	High / High	High / High	High / High	Low / –	– / –	– / –	– / –	– / –	– / –	Low / Low	Medium / Medium
Chipps Island (trawl)[5]	Medium / Medium	Medium / High	High / High	High / High	Low / Low	– / –	– / –	– / –	– / –	– / –	– / –	Low / Low

Relative Abundance: = High; = Medium; = Low

Note: Darker shades indicate months of greatest relative abundance
Sources:
[1] Yoshiyama et al. 1998; Moyle 2002
[2] Myers et al. 1998
[3] Martin et al. 2001
[4] Snider and Titus 2000
[5] U.S. Fish and Wildlife Service 2006

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994), with emergence generally occurring at night. Fry then seek lower velocity nearshore habitats with riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (National Marine Fisheries Service 1996). Emigrating juvenile Sacramento River winter-run Chinook salmon pass the Red Bluff Diversion Dam beginning as early as mid-July, typically peaking in September, and can continue through March in dry years (Vogel and Marine 1991; National Marine Fisheries Service 1997). Many juveniles apparently rear in the Sacramento River below Red Bluff Diversion Dam for several months before they reach the Delta (Williams 2006). From 1995 to 1999, all Sacramento River winter-run Chinook salmon outmigrating as fry passed the Red Bluff Diversion Dam by October, and all outmigrating presmolts and smolts passed the Red Bluff Diversion Dam by March (Martin et al. 2001).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (river mile 55) (U.S. Fish and Wildlife Service 2006), although the overall timing may extend from September to early May (National Marine Fisheries Service 2012). The timing of migration varies somewhat because of changes in river flows, dam operations, seasonal water temperatures, and hydrologic conditions (water year type). Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 millimeters and are between 5 and 10 months of age. It has been hypothesized that changes in habitat conditions in the Delta over the past century have resulted in a reduction in extended juvenile salmon rearing when compared to periods when habitat for juvenile salmon rearing was more suitable. The reduction of floodplain habitat may have significant negative impacts on winter-run Chinook salmon. The shallow water habitat occurring in floodplains provide for higher abundances of food and warmer temperatures, which promotes rapid growth. Presumably resulting in larger out-migrants which have higher survival rates in the ocean (Sommer et al. 2001). Emigration to the ocean begins as early as November and continues through May (Fisher 1994; Myers et al. 1998). The importance of the Delta in the life history of Sacramento River winter-run Chinook salmon is not well understood.

Data from the Pacific States Marine Fisheries Commission Regional Mark Information System database indicate that Sacramento River winter-run Chinook salmon adults are not as broadly distributed along the Pacific Coast as other Central Valley Chinook salmon runs and concentrate in the region between San Francisco and Monterey. This localized distribution may indicate a unique life history strategy related to the fact that Sacramento River winter-run Chinook salmon also mature at a relatively young age (Myers et al. 1998). Sacramento River winter-run Chinook salmon remain in the ocean environment for 2 to 4 years.

2A.3.5 Threats and Stressors

NMFS issued a final listing determination on June 28, 2005, concluding that the ESU was still "in danger of extinction" due to risks associated with its reduced diversity and spatial structure. The major concerns were that there is only one extant population, and it is spawning outside of its historical range, in artificially maintained habitat that is vulnerable to drought, climate change, and other catastrophes. There was also a concern over the increasing number of Livingston Stone National Fish Hatchery fish spawning in natural areas, although the duration and extent of this possible introgression was still consistent with a low extinction risk as of 2004 (National Marine Fisheries Service 2011). Since 2000, the proportion of hatchery-origin fish spawning in the Sacramento River has generally ranged between 5–10% of the total population, except for in 2005 when it reached approximately 20% of the population, which is consistent with the goals of the hatchery program (National Marine Fisheries Service 2011).

The following conditions have been identified as important threats and stressors to winter-run Chinook salmon.

2A.3.5.1 Reduced Staging and Spawning Habitat

Access to much of the historical upstream spawning habitat for winter-run Chinook salmon (Figure 2A.3-1) has been eliminated or degraded by artificial structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). The construction and operation of Shasta Dam reduced the winter-run Chinook salmon ESU from four independent populations to just one. The remaining available habitat for natural spawners is currently maintained with cool water releases from Shasta and Keswick dams, thereby significantly limiting spatial distribution of this ESU in the reach of the mainstem Sacramento River immediately downstream of the dam.

Issues resulting from dam operation for water storage arise when flows are suddenly dropped back to baselines after water has been released to make room in Shasta Reservoir for floodwater storage. If 10,000 cubic feet per second (cfs) are being delivered during a spawning period, which then dropped to 3,500 cfs, there would be a 29.5% redd dewatering (U.S. Fish and Wildlife Service 2006). Upstream diversions and dams have decreased downstream flows and altered seasonal hydrologic patterns, which have been identified as factors resulting in delayed upstream migration by adults and increased mortality of out-migrating juveniles (Yoshiyama et al. 1998; California Department of Water Resources 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced the flushing of sediments from existing gravel beds, reducing and degrading natal spawning grounds. Furthermore, reduced flows can lower attraction cues for adult spawners, causing straying and delays in spawning (California Department of Water Resources 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999).

The Red Bluff Diversion Dam, located on the Sacramento River, has been identified as a barrier and impediment to adult winter-run Chinook salmon upstream migration. Although the Red Bluff Diversion Dam is equipped with fish ladders, migration delays occur when the dam gates are closed. Mortality, as a result of increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder, has also been identified as a factor affecting abundance of salmon produced on the Sacramento River (Hallock 1991). The construction and operation of the Red Bluff Diversion Dam has been identified as one of the primary factors contributing to the decline in winter-run Chinook salmon abundance that led to listing of the species under the ESA. However, the dam gates were placed in a permanent open position in September 2011, and a new pump facility with a state-of-the-art fish screen was subsequently constructed. The project is expected to benefit both upstream and downstream migration and contribute to a reduction in juvenile predation mortality.

The Battle Creek Salmon and Steelhead Restoration Project is currently modifying facilities at Battle Creek Hydroelectric Project diversion dam sites located on the North and South Forks of Battle Creek and Baldwin Creek. Modifications include the removal of five dams on Battle Creek, installation of fish screens and ladders on three dams, and termination of water diversions from the North Fork to the South Fork. When the program is completed, about 48 miles of additional habitat will be accessible to winter-run Chinook salmon. While a reintroduction plan is currently under development, a few adult spawners have already been observed returning to Battle Creek (National Marine Fisheries Service 2011).

2A.3.5.2 Reduced Rearing and Out-Migration Habitat

Juvenile winter-run Chinook salmon prefer natural stream banks, floodplains, marshes, and shallow water habitats for rearing during out-migration. Channel margins throughout the Delta have been leveed, channelized, and fortified with riprap for flood protection and island reclamation, reducing and degrading the value of natural habitat available for juvenile Chinook salmon rearing (Brandes and McLain 2001). Artificial barriers further reduce and degrade rearing and migration habitat and delay juvenile out-migration. Juvenile out-migration delays can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening and altering the seasonal timing of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488; Sommer et al. 2001; California Department of Water Resources 2005).

Recovery of floodplain habitat in the Central Valley has been found to contribute to increased production in fall-run Chinook salmon (Sommer et al. 2001), but little is known about the potential benefits of recovered floodplains during the migration period for winter-run fish, although Sommer et al. (2001) noted that the reduction of floodplain habitat might have significant negative impacts on winter-run Chinook salmon. Reductions in flow rates have resulted in increased seasonal water temperatures. The potential adverse effects of dam operations and reductions in seasonal river flows, such as delays in juvenile emigration and exposure to a higher proportion of agricultural return flows, have all been identified as factors that could affect the survival and success of winter-run Chinook salmon inhabiting the Sacramento River in the future.

Tidal areas form important rearing habitat for foraging juvenile salmonids. Studies have shown that foraging salmonids may spend 2 to 3 months in the Delta (e.g., fall-run Chinook salmon [Kjelson et al. 1982], winter-run Chinook salmon [Del Rosario et al. in review]). Loss of tidal habitat because of land reclamation facilitated by levee construction is considered to be a major stressor on juvenile salmonids in the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual model (Williams 2009).

Channel margins have been considerably reduced because of the construction of levees and the armoring of their banks with riprap (Williams 2009). These shallow-water habitat areas provide refuge from unfavorable hydraulic conditions and predation, as well as foraging habitat for out-migrating juvenile salmonids. Recent research has focused on the use of channel margin habitat by Chinook salmon fry (McLain and Castillo 2009; H.T. Harvey & Associates with PRBO Conservation Science 2010). Benefits for larger Chinook salmon migrant juveniles and steelhead may be somewhat less than for foraging Chinook salmon fry, although the habitat may serve an important function as holding areas during downstream migration (Burau et al. 2007), thereby improving connectivity along the migration route.

2A.3.5.3 Predation by Nonnative Species

Predation on juvenile salmon by nonnative fish has been identified as an important threat to winter-run Chinook salmon in areas with high densities of nonnative fish (e.g., smallmouth and largemouth bass, striped bass, and catfish) that prey on out-migrating juveniles (Lindley and Mohr 2003). On the main stem Sacramento River, high rates of predation are known to occur at the Anderson-Cottonwood and Glenn Colusa Irrigation District diversion facilities, areas where rock revetment has replaced natural river bank vegetation, and at South Delta water diversion structures (e.g., Clifton Court Forebay) (California Department of Fish and Game 1998).

Water temperatures are generally lower during out-migration of winter-run compared to other salmonids, and may ameliorate predation pressures that can increase with increasing water temperature. In addition, nonnative aquatic vegetation, such as Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*), provide suitable habitat for nonnative predators (Nobriga et al. 2005; Brown and Michniuk 2007). Predation risk may also vary with increased temperatures. Metabolic rates of nonnative, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009; Miranda et al. 2010). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways in the

Sacramento River and Delta reduces refuge space of salmon from predators (Raleigh et al. 1984; Missildine et al. 2001; 70 FR 52488).

2A.3.5.4 Harvest

Commercial and recreational harvest of winter-run Chinook salmon in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and the Pacific Fishery Management Council. The primary concerns focus on the effects of harvest on wild Chinook salmon produced in the Central Valley, as well as the incidental harvest of winter-run Chinook salmon as part of the fall- and late fall-run salmon fisheries. Naturally reproducing winter-run Chinook salmon are less able to withstand high harvest rates when compared to hatchery-based stocks. This intolerance is attributed to differences in survival rates for incubating eggs and rearing and emigrating juvenile salmon produced in streams and rivers (relatively low survival rates) compared to Central Valley salmon hatcheries (relatively high survival rates) (Knudsen et al. 1999).

Commercial fishing for salmon in west coast ocean waters is managed by the Fishery Management Council and is constrained by time and area closures to meet the Sacramento River winter-run ESA consultation standard and restrictions that require minimum size limits and the use of circle hooks by anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of winter-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). Major restrictions in the commercial fishing industry in California and Oregon were enforced to protect Klamath River coho salmon stocks. Because the fishery is mixed, these restrictions have likely reduced harvest of winter-run Chinook salmon as well. The California Department of Fish and Wildlife (CDFW), NMFS, and Pacific Fishery Management Council continually monitor and assess the effects of the harvest of winter-run Chinook salmon, such that regulations can be refined and modified as new information becomes available. However, previous harvest practices are the likely cause of the predominance of 3-year-old spawners, with few (if any) 4- and 5-year-old fish surviving the additional years in the ocean to return as spawners (National Marine Fisheries Service 2012).

Since 2005, NMFS has issued a new biological opinion (National Marine Fisheries Service 2010) addressing the ocean harvest impacts on this ESU from commercial and sport fisheries. The biological opinion concluded the fisheries jeopardized the species, and therefore, imposed further restrictions on the minimum retention size and fishing effort that are expected to further reduce ocean harvest impacts. In summary, the available information indicates that the level of ocean fishery impacts on this ESU have not changed appreciably since the 2005 status review (Good et al. 2005), although they are expected to be much reduced in 2008 and 2009 because of ocean fishery closures (National Marine Fisheries Service 2011).

Because adult winter-run Chinook salmon hold in the mainstem Sacramento River until spawning during the summer months, they are particularly vulnerable to illegal (poaching) harvest. Various watershed groups have established public outreach and educational programs in an effort to reduce poaching. In addition, CDFW wardens have increased enforcement against illegal harvest of winter-run Chinook salmon. The level and effect of illegal harvest on adult winter-run Chinook salmon abundance and population reproduction is unknown.

2A.3.5.5 Reduced Genetic Diversity and Integrity

Artificial propagation programs conducted for winter-run Chinook salmon conservation purposes (i.e., Livingston Stone National Fish Hatchery) were developed to increase the abundance and diversity of winter-run Chinook salmon and to protect the species from extinction in the event of a catastrophic failure of the wild population. It is unclear what the effects of the hatchery propagation program are on the productivity and spatial structure of the winter-run Chinook salmon ESU (i.e., genetic fitness and productivity). One of the primary concerns with hatchery operations is the genetic introgression by hatchery origin fish that spawn naturally and interbreed with local natural populations (U.S. Fish and Wildlife Service 2001; Bureau of Reclamation 2004; Goodman 2005). It is now recognized that Central Valley hatcheries are a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (National Marine Fisheries Service 2009a). Such introgression introduces maladaptive genetic changes to the wild winter-run stocks and may reduce overall fitness (Myers et al. 2004; Araki et al. 2007). Taking egg and sperm from a large number of individuals is one method to ameliorate genetic introgression, but artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are unavoidable (Bureau of Reclamation 2004).

Hatchery-origin winter-run Chinook salmon from Livingston Stone National Fish Hatchery represent more than 5% of the natural spawning run in recent years and as high as 18% in 2005 (National Marine Fisheries Service 2012). Lindley et al. (2007) recommended reclassifying the winter-run Chinook population extinction risk as moderate, rather than low, if hatchery introgression exceeds about 15% over multiple generations of spawners. Since 2005, however, the percentage of hatchery fish has been consistently below 15% of the spawning run (National Marine Fisheries Service 2012).

Investigations are continuing to evaluate the genetic characteristics of winter-run Chinook salmon, improve genetic management of the artificial propagation program, evaluate the minimum viable population size that would maintain genetic integrity in the population, and explore methods for establishing additional independent winter-run Chinook salmon populations as part of recovery planning and conservation of the species.

2A.3.5.6 Entrainment

The vulnerability of juvenile winter-run Chinook salmon to entrainment and salvage at SWP/CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon in the Delta, operation of Delta Cross Channel gates, hydrodynamic conditions occurring in the central and southern regions of the Delta (e.g., Old and Middle Rivers), and export rates. The loss of fish to entrainment mortality has been identified as an impact on Chinook salmon populations (Kjelson and Brandes 1989). Juvenile winter-run Chinook salmon tend to be distributed in the central and southern Delta where they have an increased risk of entrainment and salvage between February and April (Table 2A.3-1), with nearly half of the average annual salvage occurring in March (National Marine Fisheries Service 2012).

The effect of changing hydrodynamics in Delta channels, such as reversed flows in Old and Middle rivers resulting from SWP/CVP export operations, has the potential to increase attraction of emigrating juveniles into false migration pathways, delay emigration through the Delta, and directly or indirectly increase vulnerability to entrainment at unscreened diversions. In addition, there is an increase in the risk of predation and duration of exposure to seasonally elevated water temperatures and other water quality conditions. SWP/CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects vary in response to a variety of factors including tidal stage and magnitude of ebb and flood tides, the rate of SWP/CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from the upstream tributaries.

Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Changes in these hydraulic cues as a result of SWP/CVP export operations during the period that salmon are migrating through Delta channels may contribute to the use of false migration pathways, delays in migration, or increased movement of migrating salmon toward the export facilities leading to an increase in entrainment risk. During the past several years, additional investigations have been designed using radio or acoustically tagged juvenile Chinook salmon to monitor migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP/CVP export operations on migration (Holbrook et al. 2009; Perry et al. 2010, San Joaquin River Group Authority 2010). These studies are ongoing.

Incidental take of juvenile winter-run Chinook salmon at the SWP/CVP export fish salvage facilities is routinely monitored and reported as part of export operations. Salvage monitoring and the protocol for identifying juvenile winter-run Chinook salmon from other Central Valley Chinook salmon have been refined over the past decade. Run identification was originally determined based on the length of each fish and the date it was collected. Subsequent genetic testing has been used to refine species identification. Methods for estimating juvenile winter-run Chinook salmon production each year (year class strength) have been developed that take into account the number of adults spawning in the river from carcass surveys, hatching success based on a consideration of water temperatures and other factors, and estimated juvenile survival. Authorized incidental take can then be adjusted each year (1% to 2% of juvenile production) to reflect the relative effect of take at a population level rather than based on a predetermined level that does not reflect year-to-year variation in juvenile production in the Sacramento River.

In addition to SWP/CVP exports, there are more than 2,200 small water diversions throughout the Delta, including unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978; Schneeberger and Jude 1981; Zeitoun et al. 1981; Weisberg et al. 1987). Many juvenile winter-run Chinook salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile winter-run Chinook salmon also migrate primarily in the upper part of the water column, reducing their vulnerability to unscreened diversions located near the channel bottom. No quantitative estimates have been developed to assess the potential magnitude of entrainment losses for juveniles migrating through the rivers and Delta, or the effects of these losses on the overall population abundance of returning adult Chinook salmon. The effect of entrainment mortality on the population dynamics and overall adult abundance of winter-run Chinook salmon is not well understood.

Power plants in the Plan Area have the ability to impinge and entrain juvenile Chinook salmon on the existing cooling water system intake screens. However, use of cooling water is currently low with the retirement of older units. Furthermore, newer units are being equipped with a closed-cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

Besides mortality, salmon fitness may be affected by delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration resulting from water management related to SWP/CVP operations can make juvenile salmonids more susceptible to many of the threats and stressors discussed in this section, such as predation, entrainment, angling, exposure to poor water quality, and disease. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risk associated with other threats is unknown, but is currently the subject of a number of investigations and analyses.

2A.3.5.7 Exposure to Toxins

Inputs of toxins into the Delta watershed include agricultural drainage and return flows, municipal wastewater treatment facilities, and other point and nonpoint discharges (Moyle 2002). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to affect fish health and condition, and adversely affect salmon distribution and abundance. Toxic chemicals have the potential to be widespread throughout the Sacramento River and Delta, or may occur on a more localized scale in response to episodic events (e.g., stormwater runoff and point source discharges). Agricultural return flows are widely distributed throughout the Sacramento River and the Delta, although dilution flows from the rivers may reduce chemical concentrations to sublethal levels. Toxic algae (e.g., Microcystis) have also been identified as a potential factor adversely affecting salmon and other fish. Exposure to these toxic materials has the potential to directly and indirectly adversely affect salmon distribution and abundance.

Concern regarding exposure to toxic substances for Chinook salmon includes both waterborne chronic and acute exposure, but also bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in agricultural drainage water return flows from the San Joaquin River that is then dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon has been shown to result in toxic effects (Saiki 1986; Saiki and Lowe 1987; Hamilton et al. 1986, 1990; Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage in the San Joaquin River basin and petroleum refining operations adjacent to San Pablo and San Francisco Bays.

Other contaminants of concern for Chinook salmon include, but are not limited to, mercury, copper, oil and grease, pesticides, herbicides, ammonia, and localized areas of depressed dissolved oxygen (e.g., Stockton Deep Water Ship Channel and return flows from managed freshwater wetlands). As a result of the extensive agricultural development in the Central Valley, exposure to pesticides and herbicides has been identified as a significant concern for salmon and other fish species in the Plan Area (Bennett et al. 2001). In recent years, changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and discharges related to agricultural wastewater discharges (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Ammonia released from the City of Stockton Wastewater Treatment Plant contributes to the low dissolved oxygen conditions in the adjacent Stockton Deep Water Ship Channel. In addition to the adverse effects of the lowered dissolved oxygen on salmonid physiology, ammonia is toxic to salmonids at low concentrations. Actions have been implemented to remedy this source of ammonia, by modifying the treatment train at the wastewater facility (National Marine Fisheries Service 2012). Concerns remain, however, regarding the toxicity of contaminants such as pyrethroids that adsorb to sediments and other chemicals (e.g., including selenium and mercury, as well as other contaminants) on salmon.

Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish, as a result of direct toxicity and impacts related to acid mine runoff from sites such as Iron Mountain Mine (U.S. Environmental Protection Agency 2006). The potential problems include tissue bioaccumulation that may adversely affect the fish, but also represent a human health concern (Gassel et al. 2008). These materials originate from a variety of sources including mining operations, municipal wastewater treatment, agricultural drainage in the tributary rivers and Delta, nonpoint runoff, natural runoff and drainage in the Central Valley, agricultural spraying, and a number of other sources.

The State Water Resources Control Board (State Water Board), Central Valley Regional Water Quality Control Board (CVRWQCB), U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), California Department of Water Resources (DWR), and others have ongoing monitoring programs designed to characterize water quality conditions and identify potential toxins and contaminant exposure to Chinook salmon and other aquatic resources in the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) program, as well as programs to establish and reduce total daily maximum loads of various constituents entering the Delta. Changes in regulations have also been made to help reduce chemical exposure and reduce the adverse impacts on aquatic resources and habitat conditions in the Plan Area. These monitoring and regulatory programs are ongoing. Regulations and changes in monitoring and management of agricultural pesticide and herbicide chemicals and their application, education on the effects of urban runoff and chemical discharges, and refined treatment processes have been adopted over the past several decades in an effort to reduce the adverse effects of chemical pollutants on salmon and other aquatic species.

In the final listing determination of the ESU, acid mine runoff from Iron Mountain Mine, located adjacent to the upper Sacramento River, was identified as one of the main threats to winter-run Chinook salmon (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Acid mine drainage, including elevated concentrations of metals, produced from the abandoned mine degraded spawning habitat of winter-run Chinook salmon and resulted in high mortality. Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (Bureau of Reclamation 2004). EPA's Iron Mountain Mine remediation program and 2002 restoration plan has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s. Pollution from Iron Mountain Mine is no longer considered to be a main factor threatening the winter-run Chinook salmon ESU.

Concern has been expressed regarding the potential to resuspend toxic materials into the water column where they may adversely affect salmon through seasonal floodplain inundation, habitat construction projects, channel and harbor maintenance dredging, and other means. For example, mercury deposits exist at a number of locations in the Central Valley and Delta, including the Yolo Bypass. Seasonal inundation of floodplain areas, such as in the Yolo Bypass, has the potential to create anaerobic conditions that contribute to the methylation of mercury, which increases toxicity. Additionally, there are problems with scour and erosion of these mercury deposits by increased seasonal flows. Similar concerns exist regarding creating aquatic habitat by flooding Delta islands or disturbance created by levee setback construction or other habitat enhancement measures. The potential to increase toxicity as a result of habitat modifications designed to benefit aquatic species is one of the factors that needs to be considered when evaluating the feasibility of habitat enhancement projects in the Central Valley.

Sublethal concentrations of toxics may interact with other stressors on salmonids, such as increasing their vulnerability to mortality as a result of exposure to seasonally elevated water temperatures, predation or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to the infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on winter-run Chinook salmon, a similar response is likely.

2A.3.5.8 Increased Water Temperature

Water temperature is among the physical factors that affect the value of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive life stages, such as during incubation or rearing. The Central Valley is the southern limit of Chinook salmon geographic distribution and increased water temperatures are often recognized as an important stressor to California populations. Water temperature criteria for various life stages of salmonids in the Central Valley have been developed by NMFS (2009a).

The tolerance of winter-run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors, such as predator avoidance (Myrick and Cech 2004; Bureau of Reclamation 2004). Higher water temperatures can lead to physiological stress, reduced growth rates, prespawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur as a result of reductions in flow, as a result of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation.

The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool in Shasta Reservoir, has reduced many of the temperature issues on the Sacramento River. Water temperature management on the Sacramento River has been specified in the NMFS biological opinion and has been identified as one of the factors contributing to the observed increase in adult winter-run Chinook salmon abundance in some recent years. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest temperatures and best areas for winter-run Chinook salmon spawning and rearing are typically located immediately downstream of Keswick Dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily from actions upstream of the

Delta. As a result of the relatively wide channels that occur in the Delta, the effects of additional riparian vegetation on reducing water temperatures in the Delta are minimal.

The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future, have been identified as important factors that may adversely affect the health and long-term viability of Sacramento River winter-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential future environmental changes, and their effect of habitat value and availability for winter-run Chinook salmon, however, are subject to a high degree of uncertainty.

2A.3.6 Relevant Conservation Efforts

Since the listing of Sacramento River winter-run Chinook salmon, several habitat and harvest-related problems that were identified as factors contributing to the decline of the species have been addressed and improved through restoration and conservation actions. The impetus for initiating restoration actions stems primarily from the following actions.

- ESA Section 7 consultation Reasonable and Prudent Alternatives on temperature, flow, and operations of the CVP and SWP (National Marine Fisheries Service 2009b).
- Regional Water Quality Control Board decisions requiring compliance with Sacramento River water temperature objectives which resulted in the installation of the Shasta Temperature Control Device in 1998.
- A 1992 amendment to the authority of the CVP through the Central Valley Improvement Act to give fish and wildlife equal priority with other CVP objectives.
- Fiscal support of habitat improvement projects from the CALFED Bay-Delta Program (CALFED) (e.g., installation of a fish screen on the Glenn-Colusa Irrigation District diversion, Battle Creek Restoration Project).
- Establishment of the CALFED Environmental Water Account.
- EPA actions to control acid mine runoff from Iron Mountain Mine.
- Ocean harvest restrictions implemented in 1995.

Results of monitoring at the CVP and SWP fish salvage facilities and extensive experimentation over the past several decades have led to the identification of a number of management actions designed to reduce or avoid the potentially adverse effects of SWP/CVP export operations on salmon. Many of these actions have been implemented through State Water Board water quality permits (D-1485, D-1641), biological opinions issued on project export operations by NMFS, U.S. Fish and Wildlife Service (USFWS), and CDFW, as part of CALFED programs (e.g., Environmental Water Account), and as part of Central Valley Project Improvement Act actions. These requirements support multiple conservation efforts to enhance habitat and reduce entrainment of Chinook salmon by the SWP/CVP export facilities.

The artificial propagation program for winter-run Chinook salmon at Livingston Stone National Fish Hatchery, located on the mainstem of the Sacramento River, has operated for conservation purposes since the early 1990s. In 2010, about 12% of the spawning population consisted of hatchery fish, and only wild (not fin-clipped) fish are currently being spawned in the hatchery to reduce genetic introgression of the population (National Marine Fisheries Service 2011).

Biological opinions for SWP/CVP operations (National Marine Fisheries Service 2009b) and other federal projects involving irrigation and water diversion and fish passage have improved or minimized adverse impacts on salmon in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act gave protection of fish and wildlife equal priority with other CVP objectives. From this act arose several programs that have benefited listed salmonids. The Anadromous Fish Restoration Program is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the Anadromous Fish Restoration Program include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. Despite these and other conservation efforts, the program has fallen short of the goal of doubling the natural production of Sacramento River winter-run Chinook salmon (National Marine Fisheries Service 2011).

The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon, with the primary focus on listed Chinook salmon and steelhead, including winter-run Chinook salmon, by maintaining or increasing instream flows (e.g., Environmental Water Account) on the Sacramento River at critical times, and to reduce salmonid entrainment at the SWP/CVP export facilities through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses. However, impacts from factors such as drought, climate change and poor survival conditions have increased in recent years and are likely to be substantial contributing factors to the declining abundance of the ESU (National Marine Fisheries Service 2011).

Two programs included under CALFED, the Ecosystem Restoration Program and the Environmental Water Account, were created to improve conditions for fish, including winter-run Chinook salmon, in the Central Valley. As part of developing the program, a series of conceptual models (DRERIP) have been constructed to provide a framework for identifying and assessing the benefits and/or consequences of potential restoration actions. The DRERIP models are being used to evaluate proposed conservation measures, as well as restoration actions as part of the program. Restoration actions implemented by the program include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors and stressors affecting listed salmonids. Additional ongoing actions include efforts to enhance fishery monitoring and improvements to hatchery management to support salmonid production through hatchery releases.

A major CALFED Ecosystem Restoration Program action currently under way is the Battle Creek Salmon and Steelhead Restoration Project. Although winter-run Chinook salmon do not currently inhabit Battle Creek, they occurred there historically. CALFED is funding the establishment of a second independent population of winter-run Chinook salmon in the upper Battle Creek watershed using the artificial propagation program as a source of fish. The project will restore 77 kilometers (48 miles) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. This restoration effort is thought to be the largest coldwater restoration project to date in North America. Other than the potential benefits of the Battle Creek restoration effort, there has been very limited habitat expansion, but no substantial changes in habitat condition or availability since the ESU was listed (National Marine Fisheries Service 2011).

As part of CALFED and Central Valley Project Improvement Act programs, many of the largest water diversions located on the Sacramento River and Delta (e.g., Glenn Colusa Irrigation District, Bureau of Reclamation [Reclamation] District 1001 Princeton diversion, RD 108 Wilkins Slough Pumping Plant, Sutter Mutual Water Company Tisdale Pumping Plant, Contra Costa Water District's Old River and Alternative Intake Project intake, and others) have been equipped with positive barrier fish screens, although the majority of smaller water diversions located on the Sacramento River and Delta remain unscreened. Reclamation District 108 has also designed and constructed a new fish screen and pumping plant (Poundstone Pumping Plant) located on the Sacramento River that consolidates and eliminates three existing unscreened water diversions. These fish-screening projects are specifically intended to reduce and avoid entrainment losses of juvenile winter-run Chinook salmon and other fish inhabiting the river.

The DRERIP was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements in the Delta (California Department of Fish and Game 2007). The DRERIP team has created a suite of ecosystem and species conceptual models, including winter-run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed conservation measures.

The Central Valley Salmonid Project Work Team, an interagency technical working group led by CDFW, drafted a proposal to develop a Chinook salmon escapement monitoring plan that was selected by the CALFED Ecosystem Restoration Program Implementing Agency Managers for directed action funding.

Recent habitat restoration initiatives sponsored primarily by the CALFED Ecosystem Restoration Program have funded 29 projects (approximately $24 million) designed to restore ecological function to 9,543 acres (8,091 acres in the Bay Area and the remaining acres located in the Delta and Eastside Tributaries Regions of the CALFED action area) of shallow-water tidal and marsh habitats in the Delta. Over the last 11 years, the CALFED Ecosystem Restoration Program has provided funding for about 580 projects, totaling over $700 million, and is currently managing 74 previously funded projects and 18 newly funded projects totaling about $24 million (California Department of Fish and Game et al. 2011). The majority of the funding has been spent on projects focusing on riparian habitat restoration, fish screen installations, water and sediment quality improvements, and stream hydrodynamic enhancements.

EPA's Iron Mountain Mine remediation involves removing toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine, and other mining operations, has shown measurable reductions since the early 1990s. Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows to dilute heavy metal contaminants being spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

In 2001, a new fish screen was constructed at the Anderson Cottonwood Irrigation District Diversion Dam and a state-of-the-art fish ladder was installed to address the threats caused by the dam. As described in the final listing determination for the ESU (70 FR 37160), the flashboard gates and inadequate fish ladders at the diversion dam blocked passage for winter-run Chinook salmon migrating upstream. Seasonal operation of the dam created unsuitable habitat upstream of the dam by reducing flow velocity over the incubating eggs, reducing egg survival. Evaluation of the fish ladder is ongoing.

To eliminate an impediment to migration of adult and juvenile winter-run Chinook salmon and other species, operation of the Red Bluff Diversion Dam ceased in 2011 and dam gates were placed in a permanent open position. A new pumping facility was built that includes a state-of-the-art fish screen.

Since 1986, DWR's Delta Fish Agreement Program has approved approximately $49 million for projects that benefit salmon and steelhead production in the Sacramento and San Joaquin River basins and Delta. Delta Fish Agreement projects that benefit Sacramento River winter-run Chinook salmon include enhanced law enforcement efforts from San Francisco Estuary upstream into the Sacramento River, spawning gravel augmentations, and habitat enhancement projects. Through the Delta-Bay Enhanced Enforcement Program initiated in 1994, a team of 10 wardens focus their enforcement efforts on salmon, steelhead, and other species of concern from the San Francisco Estuary upstream into the Sacramento and San Joaquin River basins. Enhanced enforcement programs are believed to have had significant benefits on Chinook salmon attributed to CDFW, although results have not been quantified.

Harvest protective measures for Sacramento River winter-run Chinook salmon include seasonal constraints on sport and commercial fisheries south of Point Arena in an effort to reduce harvest of winter-run Chinook salmon. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of winter-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). The average 2000 to 2007 harvest index was reduced to 0.17, and the closure of the primary ocean fishery on this stock in 2008 and 2009 is expected to reduce the harvest index to substantially below this level (National Marine Fisheries Service 2011). The state of California has also established specific in-river fishing regulations and no-retention prohibitions designed to protect Sacramento River winter-run Chinook salmon. CDFW has implemented enhanced enforcement efforts to reduce illegal harvests.

2A.3.7 Recovery Goals

The draft recovery plan for Central Valley salmonids, including Sacramento River winter-run Chinook salmon, was released on October 19, 2009 (National Marine Fisheries Service 2009a). Although not final, the overarching goal in the public draft is the removal of Sacramento River winter-run Chinook salmon, among other listed salmonids, from the federal list of Endangered and Threatened Wildlife (National Marine Fisheries Service 2009a). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations in each historical diversity group, as well as other measurable biological criteria.

2A.3.8 References Cited

2A.3.8.1 Literature Cited

Araki, H., B. Cooper, M.S. Blouin. 2007. Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild. *Science* 318:100–103.

Bennett, J., J. Hofius, C. Johnson, T. Maurer. 2001. *Tissue Residues and Hazards of Water-Borne Pesticides for Federally Listed and Candidate Fishes of the Sacramento-San Joaquin River Delta, California: 1993–1995*. July. Sacramento, CA: U.S. Fish and Wildlife Service. Environmental Contaminants Division.

Brandes, P. L., J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. In: Brown, R.L. (ed.). *Contributions to the Biology of Central Valley Salmonids.* Volume 2. California Department of Fish and Game. *Fish Bulletin* 179:39–136.

Brown L. R., D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30:186–200.

Burau, J., A. Blake, and R. Perry. 2007. *Sacramento/San Joaquin River Delta Regional Salmon Outmigration Study Plan: Developing Understanding for Management and Restoration.* Available: <http://www.science.calwater.ca.gov/pdf/workshops/workshop_outmigration_reg_study_plan_011608.pdf> Accessed: March 27, 2012.

Bureau of Reclamation. 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan, Biological Assessment.* Mid-Pacific Region. Available: <http://www.usbr.gov/mp/cvo/ocap/OCAP_6_30_04.pdf>.

California Department of Fish and Game. 1998. *A Status Review of the Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage*. Candidate Species Status Report 98-01. Sacramento, CA: Fish and Game Commission.

California Department of Fish and Game. 2007. *Delta Regional Ecosystem Restoration Implementation Plan.* Available<http://www.delta.dfg.ca.gov/erpdeltaplan>. Accessed: February 25, 2008.

California Department of Fish and Game. 2010. *GrandTab Database.* Unpublished data. Summaries of salmon and steelhead populations in the Central Valley of California.

California Department of Fish and Game, U.S. Fish and Wildlife Service, and NOAA Fisheries Service. *Ecosystem Restoration Program Plan. Year 12 Annual Report (State FYs 2011-12; Federal FY 2012).* July 1. Available: <http://www.dfg.ca.gov/ERP/mypp.asp>.

California Department of Water Resources. 2005. *Fish Passage Improvement.* Bulletin 250. Available: <http://www.watershedrestoration.water.ca.gov/fishpassage/b250/content.html>.

Clifford, M. A., K. J. Eder, I. Werner, R. P. Hendrick. 2005. Synergistic Effects of Esfenvalerate and Infectious Hematopoietic Necrosis Virus on Juvenile Chinook Salmon Mortality. *Environmental Toxicology and Chemistry* 24:1766–1772.

Crozier, L. G., P. W. Lawson, T. P. Quinn, A. P. Hendry, J. Battin, N .J. Mantua, W. Eldridge, R. G. Shaw. 2008. Potential Responses to Climate Change in Organisms with Complex Life Histories: Evolution and Plasticity in Pacific Salmon. *Evolutionary Applications*1: 252–270.

Del Rosario, R., Y. J. Redler, K. Newman, P. L. Brandes, T. Sommer, K. Reece, and R. Vincik. 2013. Migration Patterns of Juvenile Winter-Run-Sized Chinook Salmon (*Oncorhynchus tshawytscha*) Through the Sacramento–San Joaquin Delta. *San Francisco Estuary and Watershed Science* 11(1). Available: <http://www.escholarship.org/uc/item/36d88128>.

Delta Operations for Salmonids and Sturgeon Technical Working Group (DOSS). 2012. Annual Report of Activities, October 1, 2011 to September 30, 2012. Available: <http://www.swr.noaa.gov/ocap/doss/DOSS_annual_report_2012_Final.pdf>.

Fisher, F. W. 1994. Past and Present Status of Central Valley Chinook Salmon. *Conservation Biology* 8:870–873.

Gassel, M., S. A. Klasing, R. K. Btodberg, S. Roberts. 2008. *Mercury in Fish and Shellfish in the Sacramento River and Northern Delta.* Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. April.

Good, T. P., R. S. Waples, P. Adams(eds.). 2005. *Updated Status of Federally Listed ESU of West Coast Salmon and Steelhead.* U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-66,

Goodman, D. 2005. Selection Equilibrium for Hatchery and Wild Spawning Fitness in Integrated Breeding Programs. *Canadian Journal of Fisheries and Aquatic Sciences* 62:374–389.

H.T. Harvey & Associates with PRBO Conservation Science. 2010. *Critical Erosion Levee Repair Sites, Fish and Habitat Monitoring, Year-3 (2010) Monitoring Report.* December 29. Sacramento, CA: California Department of Water Resources.

Hallock, R. J. 1991. The Red Bluff Diversion Dam. In: A. Lufkin (ed.). *California's Salmon And Steelhead. The Struggle to Restore an Imperiled Resource.* Berkeley, CA: University of California Press. Pages 96–104.

Hamilton, S .J., K. J. Buhl. 1990. Acute Toxicity of Boron, Molybdenum, and Selenium to Fry of Chinook Salmon and Coho Salmon. *Archives of Environmental Contamination and Toxicology* 19(3):366–373.

Hamilton, S. J., A. N. Palmisano, G. A. Wedemeyer, and W. T. Yasutake. 1986. Impacts of Selenium on Early Life Stages and Smoltification of Fall Chinook Salmon. *Transactions of the Fifty First North American Wildlife and Natural Resources Conference.* Washington, DC: Wildlife Management Institute. Pages 343–356.

Hamilton, S. J., K. J. Buhl, N. L. Faerber, R. H. Wiedmeyer, F. A. Bullard. 1990. Toxicity of Organic Selenium in the Diet of Chinook Salmon. *Environmental Toxicology and Chemistry* 9:347–358.

Hanson, C. H. 2008. Declaration of Charles H. Hanson, Ph.D. in support of defendant-intervenor State Water Contractors' status report. United States District Court. Eastern District of California, Fresno Division. August 28.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). In: C. Groot, L. Margolis (eds.). *Pacific Salmon Life-Histories*. Vancouver, British Columbia: UBC Press. Pages 313–393.

Herren, J. R., S. S. Kawasaki. 2001. Inventory of Water Diversion in Four Geographic Areas in California's Central Valley. Contributions to the Biology of Central Valley Salmonids. *Fish Bulletin 179* (2):343–355.

Holbrook, C. M., R. W. Perry, N. S. Adams. 2009. *Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008.* Open-File Report 2009-1204. Available: < http://pubs.usgs.gov/of/2009/1204/>.

Kjelson, M. A. and P. Brandes. 1989. The Use of Smolt Survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. In: Levings, C., L. Holtby, and M. Henderson (eds.). Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publication of Fisheries and Aquatic Sciences* 105:100–115.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life History of Fall-Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary, California. In: V. S. Kennedy (ed.), *Estuarine Comparisons*. New York: Academic Press. Pages 393–411.

Knudsen, E. E., C. R. Steward, D. MacDonald, J. E. Williams, D. E. Reiser. 1999. *Sustainable Fisheries Management: Pacific Salmon.* CRC Press.

Lindley, S. L., C. Michel, P. T. Sandstrom. 2008. *Estimating Reach-Specific Smolt Survival Rates and the Factors Influencing Them from Acoustic Tagging Data.* 5th Biennial CALFED Science Conference. October 22-24.Sacramento, CA.

Lindley, S. T., M. S. Mohr. 2003. Modeling the Effect of Striped Bass on the Population Viability of Sacramento River Winter-Run Chinook Salmon. *Fishery Bulletin* 101:321–331.

Lindley, S. T., R. S. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. McEwan, R. B. MacFarlane, C. Swanson, J. G. Williams. 2007. Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. *San Francisco Estuary and Watershed Science* 5(1): Article 4. Available: <http://repositories.cdlib.org/jmie/sfews/vol5/iss1/art4>.

Loboschefsky, E., G. Benigno, T. Sommer, T. Ginn, A. Massoudieh, K. Rose, and F. Loge. 2009. *Bioenergetic Modeling of Striped Bass Predation in California from 1969-2004.* Unpublished manuscript.

Low, A. F., J. White. Undated*. Relationship Of Delta Cross Channel Gate Operations to Loss of Juvenile Winter-Run Chinook Salmon at the CVP/SWP Delta Facilities*. Available: <www.science.calwater.ca.gov/pdf/ewa/support_docs../Relationship%20of%20Delta%20Cross%20Channel%20Gate%>.

MacFarlane, R. B., A. P. Klimley, S. L. Lindley, A. J. Ammann, P. T. Sandstrom, C. J. Michel, and E. D. Chapman. 2008a. *Survival and Migratory Patterns of Central Valley Juvenile Salmonids: Progress Report.* 5th Biennial CALFED Science Conference. October 22-24, Sacramento, CA.

MacFarlane, R. B., S. Hayes, B. Wells. 2008b. Coho and Chinook Salmon Decline in California during the Spawning Seasons of 2007/08. Paper distributed at 2/8/2008 BDCP Steering Committee meeting, February 8. Available: <http://www.resources.ca.gov/bdcp/docs/2.8.08_HO_Decline_of_salmon_in_California_in_2007.pdf>.

Manly, B. F. J. 2004. *Analysis Of Data from the Salmon Smolt Experiments.* November 24.

Martin, C. D., P. D. Gaines, and R. R. Johnson. 2001. *Estimating the Abundance of Sacramento River Juvenile Winter Chinook Salmon with Comparisons to Adult Escapement*. Final Report, Report Series: Volume 5. July. Prepared by U.S. Fish and Wildlife Service, Red Bluff, CA. Prepared for U.S. Bureau of Reclamation, Red Bluff, CA.

McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Seattle, WA: U.S. Environmental Protection Agency, Region 10.

McLain, J., and G. Castillo. 2009. Nearshore Areas Used by Fry Chinook Salmon, *Oncorhynchus tshawytscha*, in the Northwestern Sacramento-San Joaquin Delta, California. *San Francisco Estuary & Watershed Science* 7(2). Available: <http://escholarship.ucop.edu/uc/item/4f4582tb>.

Michel, C. J., A. Ammann, P. Sandstrom, E. Chapman, S. Lindley, P. Klimley, R. MacFarlane. 2008*. A High-Resolution Account of the Survival and Movement Rates of Acoustically Tagged Juvenile Chinook Salmon during the 2007 and 2008 Season.* 5th Biennial CALFED Science Conference. October 22-24, Sacramento, CA.

Miranda J, R. Padilla, J. Morinaka, J. DuBois, M. Horn. 2010. *Release Site Predation Study.* California Department of Water Resources.

Missildine, B., R. Peters, R. Piaskowski, and R. Tabor. 2001. *Habitat Complexity, Salmonid Use, and Predation of Salmonids at the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington*. Miscellaneous report. Lacey, WA: U.S. Fish and Wildlife Service, Western Washington Office.

Moyle, P. B. 2002. *Inland Fishes of California*, Revised and Expanded. Berkeley, CA: University of California Press.

Moyle, P. B., J. E. Williams, E. D. Wikramanayake. 1989. *Fish Species of Special Concern of California.* Wildlife and Fisheries Biology Department, University of California, Davis. Rancho Cordova, CA: California Department of Fish and Game.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, R. S. Waples. 1998. *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.* U.S. Department Commerce, NOAA Technical Memorandum NMFS-NWFSC-35.

Myers, R. A., S. A. Levin, R. Lande, F. C. James, W. W. Murdoch, R. T. Paine. 2004. Hatcheries and Endangered Salmon. *Science* 303:1980.

Myrick, C. A., J. J. Cech Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations.* Bay-Delta Modeling Forum Technical Publication 01-1. Available: <http://www.cwemf.org/Pubs/TempReview.pdf>.

Myrick, C. A., J. J. Cech, Jr. 2004. Temperature Effects on Juvenile Anadromous Salmonids in California's Central Valley: What Don't We Know? *Reviews in Fish Biology and Fisheries* 14:113–123.

National Marine Fisheries Service. 1996. *Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act*. Portland, OR and Long Beach, CA: Protected Resource Division.

National Marine Fisheries Service. 1997. *NMFS Proposed Recovery Plan for the Sacramento River Winter-run Chinook Salmon*. August. Long Beach, CA: Southwest Region.

National Marine Fisheries Service. 2009a. *Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter–Run Chinook Salmon and Central Valley Spring–Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead*. October. Sacramento, CA: Sacramento Protected Resources Division.

National Marine Fisheries Service. 2009b. *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. June 4. Long Beach, CA. Available: <http://www.swr.noaa.gov/ocap/NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the _CVP_and_SWP.pdf>.

National Marine Fisheries Service. 2010. *Biological Opinion on the Authorization of Ocean Salmon Fisheries Pursuant to the Pacific Coast Salmon Fishery Management Plan and Additional Protective Measures as it Affects Sacramento River Winter Chinook Salmon.* Southwest Region, Protected Resources Division.

National Marine Fisheries Service. 2011. *Central Valley Recovery Domain. 5-Year Review: Summary and Evaluation of Sacramento River Winter-Run Chinook Salmon ESU.* Southwest Region.

National Marine Fisheries Service. 2012. *Biological Opinion: Formal Consultation for the California Department of Water Resources, 2012 Georgiana Slough Non-Physical Barrier Study.* Southwest Region. February 2012.

Newman, K. B. and J. Rice. 2002. Modeling the Survival of Chinook Salmon Smolts Outmigrating through the Lower Sacramento River System. *Journal of the American Statistical Association* 97.

Nichols, F. H., J. E. Cloern, S. N. Luoma, D. H. Peterson. 1986. The Modification of an Estuary. *Science* 231:567–573. Available: <http://www.jstor.org/stable/1696456>.

Nobriga, M. L., F. Feyrer, R. D, Baxter, M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

Pacific Fishery Management Council. 2008. *Pacific Council News.* Spring 32(1):1, 17–23. Available: <http://www.pcouncil.org/newsletters/2008/Spring_2008_newsletter.pdf>.

Perry, R. W., P. Brandes, and J .R. Skalski. 2008. *Migration Routes and Survival of Juvenile Late-Fall Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta*. Fifth Biennial CALFED Science Conference. October 22-24. Sacramento, CA.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, B. MacFarlane. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Poytress, W. R., and F. D. Carillo. 2010. *Brood-Year 2007 Winter Chinook Juvenile Production Indices with Comparisons to Juvenile Production Estimates Derived from Adult Escapement*. Final Annual Report 2007. Grant Number P0685507. May. Prepared for California Department of Fish and Game, Sacramento, CA, and California Bay Delta Authority, Sacramento, CA. Prepared by U.S. Fish and Wildlife Service, Red Bluff, CA.

Raleigh R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. *Habitat Suitability Information: Rainbow Trout*. Washington, DC: U.S. Fish and Wildlife Service, FWS/OBS-82/10.60.

Resources Agency, State of California, California State Water Resources Control Board, U.S. Fish and Wildlife Service. 1998. *Deer Creek Watershed Management Plan, Existing Conditions Report.* Prepared by the Deer Creek Watershed Conservancy. June.

Saiki, M. K. 1986. A Field Example of Selenium Contamination in an Aquatic Food Chain. *Selenium in the Environment – Proceedings.* Fresno, CA: California Agricultural Technology Institute. Pages 67–76.

Saiki, M. K., T. P. Lowe. 1987. Selenium in Aquatic Organisms from Subsurface Agricultural Drainage Water, San Joaquin Valley, California. *Archives Environmental Contamination and Toxicology* 16:657–670.

San Joaquin River Group Authority. 2010. *On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.* 2009 Annual Technical Report.

Schneeberger, P. J., D. J. Jude. 1981. Use of Fish Larva Morphometry to Predict Exclusion Capabilities of Small-Mesh Screens at Cooling-Water Intakes. *Transactions of the American Fisheries Society* 110:246–252.

Slater, D. W. 1963. *Winter-Run Chinook Salmon in the Sacramento River, California with Notes on Water Temperature Requirements at Spawning.* Special Science Report No. 461.

Snider, B., and R. G. Titus. 2000. *Timing, Composition, and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing, October 1996-September 1997.* California Department of Fish and Game, Habitat Conservation Division, Stream Evaluation Program Technical Report No. 00-04.

Sommer, T. R., M. L. Nobriga, W. C. Harrel, W. Batham, W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Tomljanovich, D. A., J. H. Heuer, C. W. Voigtlander, 1978. *Concept for Protecting Fish Larvae at Water Intakes.* 1978 Winter Meeting of American Nuclear Society, Washington, DC, USA. 30:105–107.

U.S. Environmental Protection Agency. 2006. *Abandoned Mine Lands Case Study: Iron Mountain Mine.* March.

U.S. Fish and Wildlife Service. 2001. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary: 1997 and 1998*. Annual progress report Sacramento-San Joaquin Estuary.

U.S. Fish and Wildlife Service. 2006. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary: 2000.* Annual progress report Sacramento-San Joaquin Estuary.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. *Upper Sacramento River Fisheries and Riparian Habitat Management Plan.* A report prepared for the California Resources Agency by the Action Team. Sacramento.

Vogel, D. A. and K. R. Marine. 1991. *Guide to Upper Sacramento River Chinook Salmon Life History.* Prepared for the Bureau of Reclamation, Central Valley Project. July.

Waples, R. S., R. W. Zabel, M. D. Scheuerell, B. L. Sanderson. 2008. Evolutionary Responses by Native Species to Major Anthropogenic Changes to Their Ecosystems: Pacific Salmon in the Columbia River Hydropower System. *Molecular Ecology* 17:84–96.

Watanabe, M., R. M. Adams, J. Wu, J. Bolte, M. M. Cox, S. Johnson, W. J. Liss, W. G. Boggess, J. L. Ebersole. 2005. Toward Efficient Riparian Restoration: Integrating Economic, Physical, and Biological Models. *Journal of Environmental Management* 75(2):93–104.

Weisberg, S. B., W. H. Burton, F. Jacobs, E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge-Wire Screens. *North American Journal of Fisheries Management* 7:386–393.

Wells, B. K., C. B. Grimes, J. C. Field, C .S. Reiss. 2006. Co-variation Between the Average Lengths of Mature Coho (*Oncorhynchus kisutch*) and Chinook Salmon (*O. tshawytscha*) and the Ocean Environment. *Fisheries Oceanography* 15:67–79.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern?* Seminar, University of California, Davis. November 8.

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* [online serial] 4(3): Article 2.

Williams, J. G. 2009. *Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan: Life-history Conceptual Model for Chinook Salmon and (*Oncorhynchus tshawytscha *and* O. mykiss*). Sacramento-San Joaquin Delta, Regional Ecosystem* Restoration Implementation Plan.

Yoshiyama, R. M., F. W. Fisher, P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. *North American Journal of Fisheries Management* 18:487–521.

Zeitoun I. H., J. A. Gulvas, D. B. Roarabaugh, 1981. Effectiveness of Fine Mesh Cylindrical Wedge-Wire Screens in Reducing Entrainment of Lake Michigan Ichthyoplankton. *Canadian Journal of Fisheries and Aquatic Sciences* 38(1):120–125.

2A.3.8.2 Federal Register Notices Cited

55 FR 46515. 1990. Final Rule: Endangered and Threatened Species; Sacramento River Winter-Run Chinook Salmon. *Federal Register*. 55:46515.

58 FR 33212. 1993. Designation of ESA Critical Habitat for Sacramento River Winter-Run Chinook. *Federal Register*. 58:33212.

59 FR 440. 1994. Final Rule: Endangered and Threatened Species; Status of Sacramento River Winter-Run Chinook Salmon. *Federal Register*. 59:440.

70 FR 37160. 2005. Final Rule: Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register*. 70:37160.

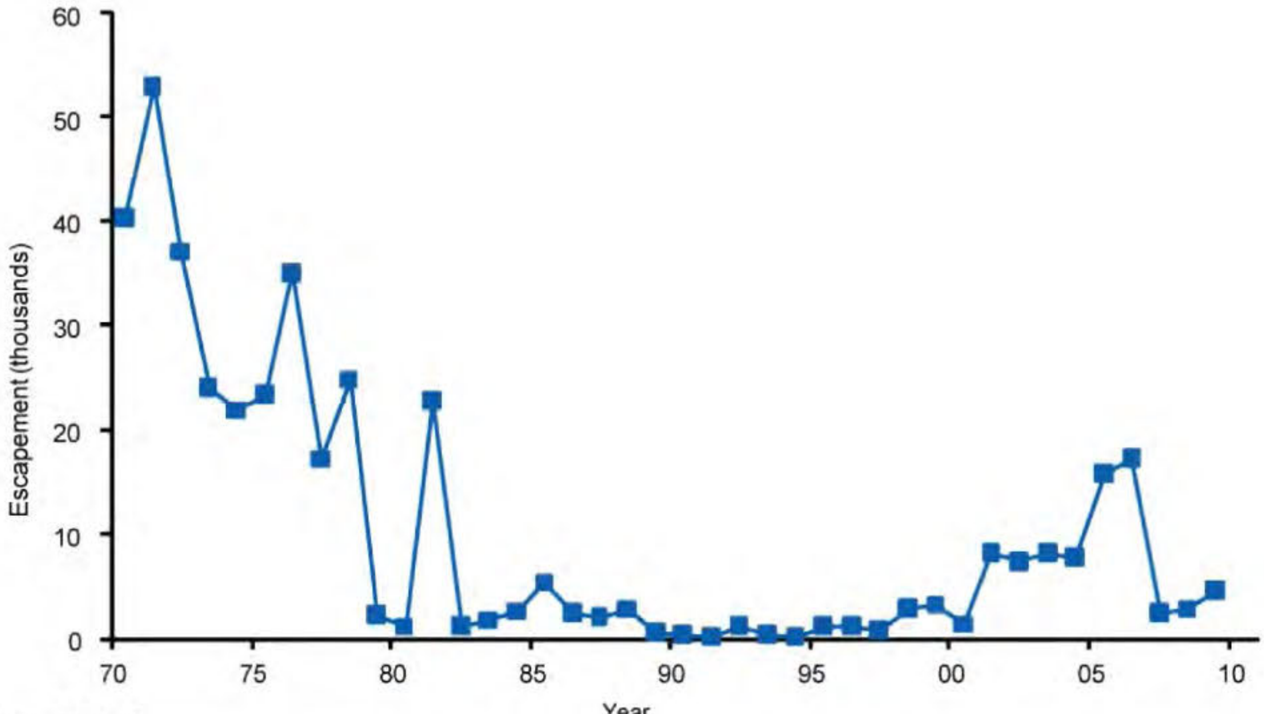
70 FR 52488. 2005. Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. *Federal Register.* 70:52488.

76 FR 50447. 2011. Endangered and Threatened Species; 5-Year Reviews for 5 Evolutionarily Significant Units of Pacific Salmon and 1 Distinct Population Segment of Steelhead in California *Federal Register*. 76:50447

Source: NOAA-NMFS 2005

BDCP-HCP 00343.12 (8-7-12) tm

Figure 2A.3-1
Sacramento River Winter-Run Chinook Salmon Inland Range



Source: DFG 2010

SOURCE: California Department of Fish and Game. 2010. Annual spawner escapement estimates for all rivers in the Central Valley. September. Available: <http://www.calfish.org/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/ItemId/123/Default.aspx>.

BDCP-HCP 00343.12 (10-23-12) tm

Figure 2A.3-2
Estimated Historical Spawner Escapement of Sacramento River Winter-Run Chinook Salmon (1970–2009)

BDCP-HCP 00343.12 (8-6-12) tm

Figure 2A.3-3
Sacramento River Winter-Run Chinook Salmon Inland Designated Critical Habitat

BDCP-HCP 00343.12 (8-7v-12) tm

Figure 2A.3-4
Sacramento River Winter-Run Chinook Salmon Inland Essential Fish Habitat

Appendix 2A.4
Central Valley Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*)

2A.4.1 Legal Status

The Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) is listed as a threatened species under the federal Endangered Species Act (ESA). The ESU includes all naturally spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries in California, including the Feather River (Figure 2A.4-1). The ESU was listed as threatened on September 16, 1999 (64 *Federal Register* [FR] 50394) for the following reasons:

- The species occurred in only a small portion of its historical range.
- From 70 to 90% of spawning and rearing habitats had been lost.
- Abundance declined to low levels (5-year average of 8,500 fish, compared with 40,000 fish in 1940s).
- There is a potential for hybridization between spring- and fall-run fish in hatcheries and the mainstem Sacramento River.

In June 2004, the National Marine Fisheries Service (NMFS) proposed that Central Valley spring-run Chinook salmon remain listed as threatened (69 FR 33102). This proposal was based on the recognition that, although Central Valley spring-run Chinook salmon productivity trends were positive, the ESU continued to face risks from having a limited number of remaining populations (i.e., three existing populations from an estimated 17 historical populations), a limited geographic distribution, and potential hybridization with Feather River Hatchery spring-run Chinook salmon. Until recently, Feather River Hatchery spring-run Chinook salmon were not included in the ESU, yet these fish are genetically distinct from other populations in Mill, Deer, and Butte Creeks.

On June 28, 2005, NMFS issued its final decision to retain the status of Central Valley spring-run Chinook salmon as threatened (70 FR 37160). This decision also included the Feather River Hatchery spring-run Chinook salmon population as part of the Central Valley spring-run Chinook salmon ESU.

On August 15, 2011, after a second 5-year review, NMFS determined that the ESU had an increased extinction risk (National Marine Fisheries Service 2011). With a few exceptions, escapements have declined over the past 10 years, particularly since 2006, placing the Mill and Deer Creek populations at high risk of extinction because of their rate of decline (National Marine Fisheries Service 2011). While the Butte Creek population continues to meet the low extinction risk criteria, the rate of decline is close to triggering the population decline criterion for high risk. Overall, the recent declines have been significant but not severe enough to qualify as a catastrophe under the criteria of Lindley et al. (2007). In addition, spring-run Chinook salmon appear to be repopulating Battle Creek, home to a historical independent population (National Marine Fisheries Service 2011).

Spring-run Chinook salmon was listed as a threatened species under the California Endangered Species Act (CESA) on February 5, 1999.

2A.4.2 Species Distribution and Status

2A.4.2.1 Range and Status

Historically, spring-run Chinook salmon were predominant throughout the Central Valley occupying the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit Rivers, with smaller populations in most tributaries with sufficient habitat for adult salmon holding over the summer months (Figure 2A.4-1) (Stone 1874; Rutter 1904; Clark 1929). Completion of Friant Dam extirpated the native spring-run Chinook salmon population from the San Joaquin River and its tributaries. Naturally spawning populations of Central Valley spring-run Chinook salmon with consistent spawning returns are currently restricted to Butte Creek, Deer Creek, and Mill Creek (Good et al. 2005).

A small spawning population has been documented in Clear Creek (Newton and Brown 2004). In addition, the upper Sacramento River and Yuba River support small populations, but their status is not well documented. The Feather River Hatchery produces spring-run Chinook salmon on the Feather River.

Central Valley spring-run Chinook salmon were once the most abundant run of salmon in the Central Valley (Campbell and Moyle 1992). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (California Department of Fish and Game 1998). More than 500,000 Central Valley spring-run Chinook salmon were caught in the Sacramento-San Joaquin commercial fishery in 1883 (Yoshiyama et al. 1998). Population estimates of returning spring-run Chinook salmon for the years immediately preceding and after the closure of Friant Dam in February 1944 are as follows (Fry 1961; Yoshiyama et al. 1998):

- 35,000 in 1943
- 5,000 in 1944
- 56,000 in 1945
- 30,000 in 1946
- 6,000 in 1947
- 2,000 in 1948

There were occasional records of returning spring-run Chinook salmon during the 1950s and 1960s in wet years. The San Joaquin River population was essentially extirpated by the late 1940s. Populations in the upper Sacramento, Feather, and Yuba Rivers were eliminated with the construction of major dams from the 1940s through the 1960s.

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance between 1960 and 2009 (Figure 2A.4-2). Adult spring-run salmon escapement to the Sacramento River system in 2009 was 3,802 fish. Sacramento River tributary populations in Mill, Deer, and Butte Creeks are probably the best trend indicators for the Central Valley spring-run Chinook ESU as a whole because these streams contain the primary independent populations in the ESU. Generally, there was a positive trend in escapement in these waterways between 1992 and 2005, after which there was a steep decline (Figure 2A.4-3). Adult spring-run salmon escapement to Mill, Deer, and Butte Creeks in 2009 was estimated to be between 2,492 and 2,561 fish. Escapement numbers are dominated by Butte Creek returns, which typically represent nearly 75% of fish returning to these three creeks, although the escapement to Butte Creek in 2009 was approximately 2,059 fish, or 80 to 83% of escapement to these three creeks.

Between 1992 and 2009 there were significant habitat improvements in these watersheds, including the removal of several small dams, increases in summer flows, reduced ocean salmon harvest ,and a favorable terrestrial and marine climate. The significant recent declines in adult fall-run Chinook salmon escapement have resulted in significant curtailment of the commercial and recreational salmon fisheries, which is expected also to increase the level of protection and benefit the Central Valley spring-run Chinook salmon population.

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Hatchery. However, coded-wire tag information from these hatchery returns and results of genetic testing indicate that substantial introgression has occurred between fall-run and spring-run Chinook salmon populations in the Feather River because of hatchery practices and the geographic and temporal overlap with spawning fall-run Chinook salmon in the river.

Although recent Central Valley spring-run Chinook salmon population trends are negative, annual abundance estimates display a high level of variation. The overall number of Central Valley spring-run Chinook salmon remains well below estimates of historical abundance. Central Valley spring-run Chinook salmon have some of the highest population growth rates in the Central Valley, but other than Butte Creek and the hatchery-influenced Feather River, population sizes are very small relative to fall-run Chinook salmon populations (Good et al. 2005).

An ESU that is essentially represented by three populations located in the same ecoregion is vulnerable to changes in the environment because it lacks spatial geographic diversity. The current geographic distribution of viable populations makes the Central Valley spring-run Chinook salmon ESU vulnerable to catastrophic disturbance (Lindley et al. 2007; National Marine Fisheries Service 2011). Such potential catastrophes include volcanic eruption of Mt. Lassen, prolonged drought conditions reducing coldwater pool adult holding habitat, and a large wildfire (approximately 30 kilometers maximum diameter) encompassing the Deer, Mill and Butte Creek watersheds. The Central Valley spring-run Chinook salmon ESU remains at a moderate to high risk of extinction for the following reasons:

- The ESU is spatially confined to relatively few remaining streams in its historical range.
- The population continues to display broad fluctuations in abundance.
- A large proportion of the population (in Butte Creek) faces the risk of high mortality rates resulting from high water temperatures during the adult holding period.

2A.4.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley spring-run Chinook salmon ESU must pass through the Plan Area as migrating adults and emigrating juveniles. Adult Central Valley spring-run Chinook salmon migrate primarily along the western edge of the Sacramento–San Joaquin River Delta (Delta) through the Sacramento River corridor, and juvenile spring-run Chinook salmon use the Delta, Suisun Marsh, and Yolo Bypass for migration and rearing. With the goal of returning spring-run Chinook salmon to the San Joaquin River, the San Joaquin corridor will presumably become an important migration route, with juveniles also using the south, central and west Delta areas as migration and rearing corridors.

2A.4.3 Habitat Requirements and Special Considerations

Critical habitat for spring run Chinook salmon ESU was updated on September 2, 2005, with an effective date of January 2, 2006 (70 FR 52488). Designated critical habitat includes 1,158 miles of stream habitat in the Sacramento River basin and 254 square miles of estuarine habitat in the San Francisco-San Pablo-Suisun Bay complex (70 FR 52488, Figure 2A.4-4). Critical habitat includes stream reaches such as those of the Feather and Yuba Rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear Creeks, and the Sacramento River and Delta.

This habitat is composed of physical and biological features considered essential to the conservation of the species, including space for individual and population growth and for normal behavior; cover; sites for breeding, reproduction, and rearing of offspring; and habitats protected from disturbance or are representative of the historical, geographical, and ecological distribution of the species.

Central Valley spring-run Chinook salmon habitats are also protected under the Magnuson-Stevens Fishery Conservation and Management Act as essential fish habitat (EFH). Those waters and substrate that are necessary to spring-run Chinook salmon for spawning, breeding, feeding, or growth to maturity are included as EFH (Figure 2A.4-5). Critical habitat and EFH are managed differently from a regulatory standpoint, but are biologically equal for the conservation of Central Valley spring-run Chinook salmon.

The critical habitat designation identified the following primary constituent elements considered essential for the conservation of the ESU.

- Freshwater spawning habitat
- Freshwater rearing habitat
- Freshwater migration corridors
- Estuarine habitat
- Nearshore and offshore marine habitats

2A.4.3.1 Freshwater Spawning Habitat

Freshwater spawning sites are those stream reaches with water quantity (instream flows) and quality conditions (e.g., water temperature and dissolved oxygen) and substrate suitable to support spawning, egg incubation, and larval development. Most spawning habitat in the Central Valley for spring-run Chinook salmon is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Historically, spring-run Chinook salmon migrated upstream into high-elevation steep gradient reaches of the rivers and tributaries for spawning. Access to the majority of these historical spawning areas has been blocked by construction of major Central Valley dams and reservoirs. Currently, Central Valley spring-run Chinook salmon spawn on the mainstem Sacramento River between the Red Bluff Diversion Dam and Keswick Dam, and in tributaries such as the Feather River, Mill, Deer, Clear, Battle and Butte

Creeks. There is currently an effort under way to reestablish a self-sustaining population of spring-run Chinook salmon on the San Joaquin River downstream of Friant Dam. Spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

2A.4.3.2 Freshwater Rearing Habitat

Freshwater rearing sites have sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; suitable water quality; availability of suitable prey and forage to support juvenile growth and development; and natural cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large woody debris, rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration.

Juveniles also rear in nonnatal, intermittent tributaries. Rearing habitat condition is strongly affected by habitat diversity and complexity, food supply, and presence of predators. Some of these more complex, productive habitats with floodplain connectivity are still present in limited amounts in the Central Valley (e.g., the lower Cosumnes River, Sacramento River reaches with setback levees [primarily located upstream of the City of Colusa]). However, the channeled, leveed, and riprapped river reaches and sloughs that are common along the Sacramento and San Joaquin Rivers and throughout the Delta typically have low habitat complexity, low abundance of food organisms, and offer little protection from predatory fish and birds. Freshwater rearing habitat also has a high conservation value, as the juvenile life stage of salmonids is dependent on the function of this habitat for successful survival and recruitment to the adult population.

2A.4.3.3 Freshwater Migration Corridors

Freshwater migration corridors for spring-run Chinook salmon, including river channels, channels through the Delta, and the Bay-Delta estuary support mobility, survival, and food supplies for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), have favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, native aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors for spring-run Chinook salmon are located downstream of the spawning areas and include the lower Sacramento River, lower Feather River, tributaries providing suitable adult holding and spawning habitat, the Delta, and the San Francisco Bay complex extending to coastal marine waters. Efforts are currently under way to reestablish a spring-run salmon population on the San Joaquin River downstream of Friant Dam that would use the lower river and Delta as part of the migration corridor. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value.

Results of mark-recapture studies conducted using juvenile Chinook salmon (typically fall-run or late fall-run Chinook salmon, which are considered to be representative of juvenile spring-run salmon) released into both the Sacramento and San Joaquin Rivers have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001; Newman and Rice 2002; Manly 2004; San Joaquin River Group Authority 2007; Hanson 2008; Low and White undated). Mortality for juvenile salmon is typically greater in the San Joaquin River than in the Sacramento River (Brandes and McLain 2001). Results of survival studies have shown that closing the Delta Cross Channel gates and installing the Head of Old River Barrier to reduce the movement of juvenile salmon into the Delta contribute to improved survival of emigrating juvenile Chinook salmon (Brandes and McLain 2001; Manly 2004; San Joaquin River Group Authority 2007; Low and White undated). Observations at the State Water Project (SWP) and Central Valley Project (CVP) fish salvage facilities have shown that very few of the marked salmon (typically fewer than 1%) are entrained and salvaged at the export facilities (San Joaquin River Group Authority 2007; Hanson 2008). Although the factors contributing to high juvenile mortality have not been quantified, results of acoustic tagging experiments and anecdotal observations suggest that exposure to adverse water quality (e.g., elevated water temperatures, toxic chemicals) and vulnerability to predation are two of the factors contributing to the high juvenile mortality observed in the rivers and Delta (San Joaquin River Group Authority 2007). Additional acoustic tagging experiments are currently under way to better assess factors affecting migration pathways, migration rates, effects of SWP/CVP exports on migration, and reach-specific survival rates for emigrating juvenile Chinook salmon (Lindley et al. 2008; MacFarlane et al. 2008a; Michel et al. 2008; Perry et al. 2008).

2A.4.3.4 Estuarine Habitat

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. Natural cover, such as submerged and overhanging large wood, native aquatic vegetation, and side channels provide juvenile foraging habitat and cover from predators. Tidal wetlands and seasonally inundated floodplains are identified as high-value foraging and rearing habitats for juvenile salmon migrating downstream through the estuary. Estuarine areas have a high conservation value as they support juvenile Chinook salmon growth, smolting, avoidance of predators, and the transition to the ocean environment.

2A.4.3.5 Marine Habitats

Although ocean habitats are not part of the critical habitat listing for Central Valley spring-run Chinook salmon, biologically productive coastal waters are an important habitat component for the ESU. Juvenile Chinook salmon inhabit near-shore coastal marine waters for a period of typically 2 to 4 years before adults return to Central Valley rivers to spawn. During their marine residence, Chinook salmon forage on krill, squid, and other marine invertebrates as well as a variety of fish such as northern anchovy and Pacific herring. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown the variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling are significant factors affecting nutrient availability, phytoplankton and zooplankton production, and the availability of other forage species in nearshore surface waters. Ocean conditions during the salmon’s ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams (Pacific Fishery Management Council 2008). These declines are believed to be the result of decreases in ocean productivity and associated high mortality rates during the period when these fish were rearing in nearshore coastal waters (MacFarlane et al. 2008b; Pacific Fishery Management Council 2008). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley Chinook salmon is currently undergoing further investigation.

2A.4.4 Life History

Chinook salmon typically mature between 2and 6 years of age, although more commonly from 2 to 4 years (Myers et al. 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated based on adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime, and flow characteristics of their spawning site, and the actual time of spawning (Myers et al. 1998). Spring-run Chinook salmon tend to enter fresh water as immature fish, migrate far upriver, hold in cool-water pools for a period of months during the spring and summer, and delay spawning until the early fall.

Adult Central Valley spring-run Chinook salmon begin their upstream migration in late January and early February (California Department of Fish and Game 1998) and enter the Sacramento River between February and September, primarily in May and June (Table 2A.4-1) (Yoshiyama et al. 1998; Moyle 2002). Lindley et al. (2006) reported that adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. Typically, spring-run Chinook salmon use mid- to high-elevation streams that provide appropriate seasonal water temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama et al. 1998).

Table 2A.4-1. Temporal Occurrence of Adult and Juvenile Central Valley Spring-Run Chinook Salmon in the Sacramento River

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Sacramento River basin[1,2]			M/M	M/M	H/H	H/H	M/M	M/M	M/M			
Sacramento River[3]			M/M	M/M	M/M	M/M	M/M					
Mill Creek[4]			L/L	M/H	H/H	H/M	M/L	L/L				
Deer Creek[4]			L/L	M/H	H/H	H/M	M/L	L/L				
Butte Creek[4,9]		M/M	M/M	M/M	M/M	M/M	M/L	L/L				
Juvenile												
Sacramento River Tributaries[5]	M/M	M/M	M/M							M/M	H/H	H/H
Upper Butte Creek[6]	H/H	H/H	M/M	M/M	M/M	L/L				L/L	L/L	H/H
Mill, Deer, Butte Creeks[4]	H/H	H/H	M/M	M/M	M/M	L/L				L/L	L/L	L/L
Sacramento River at Red Bluff Diversion Dam[3]	H/H	L/L	L/L	L/L							H/H	H/H
Sac. River at Knights Landing[7]	H/H	L/L	L/L	L/L							H/H	H/H
Chipps Island (trawl)[8*]	H/H	L/L	L/L	L/L							H/H	H/H
Lower Sacramento River/Delta[10]	H/H	L/L	L/L	L/L	L/L	L/L	L/L	L/L			H/H	H/H

Relative Abundance: H = High; M = Medium; L = Low

Note: Darker shades indicate months of greatest relative abundance

* By the time spring-run Chinook salmon yearlings reach Chipps Island they cannot be distinguished with confidence from fall-run Chinook salmon yearlings

Sources:

[1] Yoshiyama et al. 1998

[2] Moyle 2002

[3] Myers et al. 1998

[4] Lindley et al. 2006

[5] California Department of Fish and Game 1998

[6] McReynolds et al. 2005; Ward et al. 2002, 2003

[7] Snider and Titus 2000

[8] U.S. Fish and Wildlife Service 2001

[9] National Marine Fisheries Service 2009a

[10] U.S. Fish and Wildlife Service 2012

Chinook salmon spawn in clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper reaches where suitable water temperature, depth, and velocity favor redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds located at the tails of holding pools (U.S. Fish and Wildlife Service 1995). Fry emergence generally occurs at night. Upon emergence, fry swim or are displaced downstream (Healey 1991).

The daily migration of juvenile spring-run Chinook salmon passing Red Bluff Diversion Dam is highest in the 4-hour period prior to sunrise (Martin et al. 2001).

Fry may continue downstream to the estuary and rear, or may take up residence in the stream for a period from weeks to a year (Healey 1991). Fry seek streamside habitats containing beneficial characteristics such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates, predator avoidance cover, and slower water velocities for resting (National Marine Fisheries Service 1996).

Spring-run Chinook salmon fry emerge from the gravel from September to April (Moyle 2002; Harvey 1995; Bilski and Kindopp 2009) and the emigration timing is highly variable, as they may migrate downstream as young-of-the-year or as juveniles or yearlings. The modal size of fry migrants at approximately 40 millimeters between December and April in Mill, Butte, and Deer Creeks reflects a prolonged emergence of fry from the gravel (Lindley et al. 2006). Studies in Butte Creek found that the majority of Central Valley spring-run Chinook salmon migrants are fry occurring primarily during December, January, and February, and that fry movements appeared to be influenced by flow (Ward et al. 2002, 2003; McReynolds et al. 2005). Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer Creeks are very similar to patterns observed in Butte Creek, with the exception that juveniles from Mill and Deer creeks typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley et al. 2006).

Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac (Moyle 2002). Many also disperse downstream during high-flow events. As is the case with other salmonids, there is a shift in microhabitat use by juveniles to deeper, faster water as they grow. Microhabitat use can be influenced by the presence of predators, which can force juvenile salmon to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). Peak movement of yearling Central Valley spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and young-of-the-year juveniles occur in March and April; however, juveniles were also observed between November and the end of May (Snider and Titus 2000).

As juvenile Chinook salmon grow, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the U.S. Fish and Wildlife Service (USFWS) (1997) showed that larger juvenile salmon were captured in the main channel and smaller fry were typically captured along the channel margins. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit surface waters (Healey 1980). Stream flow changes and/or turbidity increases in the upper Sacramento River watershed are thought to stimulate juvenile emigration (Kjelson et al. 1982; Brandes and McLain 2001).

Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and shallow water areas with emergent aquatic vegetation (Meyer 1979; Healey 1980). Cladocerans, copepods, amphipods, and larval dipterans, as well as small arachnids and ants are common prey items (Kjelson et al. 1982; Sommer et al. 2001a; MacFarlane and Norton 2002). Although the bulk of production in Butte and Big Chico Creeks emigrate as fry, yearlings can enter the Delta as early as February and as late as June (California Department of Fish and Game 1998). Yearling-sized spring-run Chinook salmon migrants appear at Chipps Island (entrance to Suisun Bay) between October and December (Brandes and McLain 2001; U.S. Fish and Wildlife Service 2001).

While there have been few studies of estuarine habitat use by juvenile spring-run Chinook, the low numbers of juveniles encountered throughout the bays and lower tidal marshes, and the lack of growth observed in those reaches reflect the immense changes and habitat alteration that have taken place in those areas over the last century (MacFarlane and Norton 2002). Over this period, the bulk of the tidal marsh and creek habitats had been leveed, channelized, and dredged, for navigation and other anthropogenic purposes. In addition, water transfers at the Delta pump facilities have drastically altered hydrology, salinity, and turbidity in the lower Delta. These changes in habitat conditions in the Delta over the past century may have resulted in a reduction in extended juvenile salmon rearing when compared to periods when habitat for juvenile salmon rearing was more suitable.

Central Valley spring-run Chinook salmon begin their ocean life in the coastal marine waters of the Gulf of the Farallones. Upon reaching the ocean, juveniles feed on larval and juvenile forage fishes, plankton, and other marine invertebrates (Healey 1991; MacFarlane and Norton 2002). Juveniles grow rapidly in the ocean environment with growth rates dependent on water temperatures and food availability (Healey 1991). The first year of ocean life is considered a critical period of high mortality for Chinook salmon that largely determines survival to harvest or spawning (Beamish and Mahnken 2001; Quinn 2005).

2A.4.5 Threats and Stressors

In the last status review, Good et al. (2005) described the threats to the Central Valley spring-run Chinook salmon ESU as falling into three broad categories: loss of historical spawning habitat, degradation of remaining habitat, and genetic threats from the Feather River Hatchery spring-run Chinook salmon program. Other likely important threats and stressors include nonnative predators, commercial and recreational harvest, entrainment at water withdrawal facilities, toxin exposure, and increased water temperatures.

2A.4.5.1 Reduced Staging and Spawning Habitat

Access to most of the historical upstream spawning habitat for spring-run Chinook salmon (Figure 2A.4-1) has been eliminated or degraded by artificial structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). Current spawning and juvenile rearing habitat is restricted to the mainstem and a few tributaries to the Sacramento River. Suitable summer water temperatures for adult and juvenile spring-run Chinook salmon holding and rearing are thought to occur at elevations from 492 to 1,640 feet (150 to 500 meters), most of which are now blocked by impassible dams. Habitat loss has resulted in a reduction in the number of natural spawning populations from an estimated 17 to 3 (Good et al. 2005).

Upstream diversions and dams have decreased downstream flows and altered the seasonal hydrologic patterns. These factors have been identified as resulting in delayed upstream migration by adults, increased mortality of outmigrating juveniles, and are responsible for making some streams uninhabitable by spring-run salmon (Yoshiyama et al. 1998; California Department of

Water Resources 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced flushing of sediments from existing gravel beds, thereby reducing and degrading natal spawning grounds. Further, reduced flows may decrease attraction cues for adult spawners, causing migration delays and increases in straying (California Department of Water Resources 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999).

Dams and other passage barriers also limit the geographic locations where spring-run Chinook salmon can spawn. In the Sacramento and Feather Rivers, restrictions to upstream movement and spawning site selection for spring-run salmon may increase the risk of hybridization with fall-run salmon, as co-occurrence contributes to an increased risk of redd superimposition. In creeks that are not affected by large dams, such as Deer and Mill Creeks, adult spring-run Chinook salmon have a greater opportunity to migrate upstream into areas where geographic separation from fall-run salmon reduces the risk of hybridization.

The Red Bluff Diversion Dam, located on the Sacramento River, is a barrier and impediment to adult spring-run Chinook salmon upstream migration. Although the dam is equipped with fish ladders, migration delays were reported when the dam gates are closed. Mortality from increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder also affects abundance of salmon produced on the Sacramento River (Hallock 1991). The dam gates were placed in a permanent open position beginning in September 2011, and a new pump facility with a state-of-the-art fish screen was subsequently constructed. The elimination of dam operations is expected to benefit both upstream and downstream migration and contribute to a reduction in juvenile predation mortality.

Since the ESU was listed as threatened in 1999, very little expansion of spawning habitat has occurred, particularly compared to the hundreds of miles of habitat blocked by dams. The removal of Seltzer Dam on Clear Creek in 2000 opened up 10 miles of habitat, and the removal of a partial low-flow barrier on Cottonwood Creek in 2010 improved access to 30 miles of habitat (National Marine Fisheries Service 2011). Additionally, the removal of Wildcat Dam in 2010 along with the completion of fish ladders at Eagle Canyon Dam and North Battle Feeder Dam opened up about 10 miles of habitat on Battle Creek. The Battle Creek Salmon and Steelhead Restoration Project will eventually remove five dams on Battle Creek, install fish screens and ladders on three dams, and end the diversion of water from the North Fork to the South Fork. When the program is completed, a total of 42 miles of mainstem habitat and 6 miles of tributary habitat will be accessible to anadromous salmonids, including Central Valley spring run Chinook salmon (National Marine Fisheries Service 2011).

The 2009 SWP/CVP biological opinion (BiOp) includes a phased fish passage program, intended to expand spring-run Chinook salmon habitat to areas upstream of Shasta Dam. Phases of the fish passage program include habitat evaluations through January 2012, pilot reintroductions through January 2015, and implementation of the long-term program by January 2020 (National Marine Fisheries Service 2011).

2A.4.5.2 Reduced Rearing and Out-Migration Habitat

Juvenile spring-run Chinook salmon prefer natural stream banks, floodplains, marshes, and shallow water habitats as rearing habitat during out-migration. Channel margins throughout the Delta have been leveed, channelized, and fortified with riprap for flood protection and island reclamation, reducing and degrading the quality of natural habitat available for juvenile Chinook salmon rearing (Brandes and McLain 2001). Artificial barriers further reduce and degrade rearing and migration habitat and delay juvenile out-migration. Juvenile out-migration delays can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening and altering the seasonal timing of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488) (Sommer et al. 2001a; California Department of Water Resources 2005). Recovery of floodplain habitat in the Central Valley has been found to contribute to increases in production in Chinook salmon (Sommer et al. 2001b), but little is known about the potential benefit available to migrating spring-run salmon.

The potential adverse effects of dam operations include reductions in seasonal river flows, delays in juvenile emigration, and increased seasonal water temperature. In addition, exposure to a higher proportion of agricultural return flows, and exposure to reduced dissolved oxygen concentrations (e.g., Stockton Deep Water Ship Channel) likely affect the survival and success of reestablishing spring-run Chinook salmon on the San Joaquin River in the future (Regional Water Resources Control Board 2003).

2A.4.5.3 Predation by Nonnative Species

Predation on juvenile salmon by nonnative fish has been identified as an important threat to spring-run Chinook salmon in areas with high densities of nonnative fish (e.g., small and largemouth bass, striped bass, and catfish) that prey on out-migrating juveniles (Lindley and Mohr 2003). Nonnative aquatic vegetation, such as Brazilian waterweed (*Egeria dense*) and water hyacinth (*Eichhornia crassipes*), provide suitable habitat for nonnative predators (Nobriga et al. 2005; Brown and Michniuk 2007). Predation risk may covary with increased temperatures. Metabolic rates of nonnative, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009; Miranda et al. 2010). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways in the rivers and Delta reduces refugia from predators (70 FR 52488) (Raleigh et al. 1984; Missildine et al. 2001; California Department of Water Resources 2005).

Increased predation mortality by native fish species, such as Sacramento pikeminnow at the Red Bluff Diversion Dam, is a factor affecting the survival of juvenile salmon in the rivers and Delta. Predation at the dam should decrease as the dam gates are in for shorter periods of time, and particularly in 2012 when the dam gates will be out year-round (National Marine Fisheries Service 2011). Although reducing predation at the Red Bluff Diversion Dam will benefit spring-run Chinook salmon at that location, it is unclear whether the reduction will substantially decrease the overall level of predation throughout the Sacramento River and Delta.

2A.4.5.4 Harvest

Commercial and recreational harvest of spring-run Chinook salmon in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and Pacific Fishery Management Council. The primary concerns focus on the effects of harvest on wild Chinook salmon produced in the Central Valley as well as the incidental harvest of listed salmon as part of the fall-run and late fall-run salmon fisheries. Because survivorship has been reduced in incubating eggs and rearing and emigrating wild salmon relative to hatchery-reared individuals, naturally reproducing populations are less able to withstand high harvest rates compared to hatchery-based stocks (Knudsen et al. 1999). National Marine Fisheries Service (2011) reports that ocean harvest had not changed appreciably since the 2005 status review (Good et al. 2005), except for extreme reductions in 2008 through 2010. The ocean salmon fisheries were closed in 2008 and 2009 and substantially restricted in 2010.

Commercial fishing for salmon in west coast ocean waters is managed by the Pacific Fishery Management Council, and is constrained by time and area closures to meet the Sacramento River winter-run ESA consultation standard and restrictions that require minimum size limits and use of circle hooks by anglers. Ocean harvest restrictions since 1995 have led to reduced ocean harvest of spring-run Chinook salmon (i.e., Central Valley Chinook salmon ocean harvest index, ranged from 0.55 to nearly 0.80 from 1970 to 1995, and was reduced to 0.27 in 2001). The California Department of Fish and Wildlife (CDFW), NMFS, and Pacific Fishery Management Council continue to monitor and assess the effects of harvest of spring-run Chinook salmon, such that regulations can be refined and modified as new information becomes available.

Because adult spring-run Chinook salmon hold in a pool habitat in a stream during the summer months, they are vulnerable to illegal harvest (poaching). Various watershed groups have established public outreach and educational programs in an effort to reduce poaching. In addition, CDFW wardens have increased enforcement against illegal harvest of spring-run Chinook salmon. The level and effect of illegal harvest on adult spring-run Chinook salmon abundance and population reproduction is unknown.

2A.4.5.5 Reduced Genetic Diversity and Integrity

Interbreeding of wild spring-run Chinook salmon with both wild and hatchery fall-run Chinook salmon has the potential to dilute and eventually eliminate the adaptive genetic distinctiveness and diversity of the few remaining naturally reproducing spring-run Chinook salmon populations (California Department of Fish and Game 1995; Sommer et al. 2001b; Araki et al. 2007). Central Valley spring- and fall-run Chinook salmon spawning areas were historically isolated in time and space (Yoshiyama et al. 1998). However, the construction of dams has eliminated access to historical upstream spawning areas of spring-run salmon in the upper tributaries and streams of many river systems. Restrictions to upstream access, particularly on the Sacramento and Feather Rivers, has forced spring-run individuals to spawn in lower elevation areas also used by fall-run individuals, potentially resulting in hybridization of the two races. Hybridization between spring- and fall-run salmon is a particular concern on the Feather River, where both runs co-occur, and is a potential concern for restoration of salmon on the San Joaquin River downstream of Friant Dam.

Management of the Feather River hatchery and brood stock selection practices have been modified in recent years (e.g., tagging early returning adult salmon showing phenotypic and run timing characteristics of spring-run Chinook salmon for subsequent use as selected brood stock and genetic testing of potential brood stock) in an effort to reduce potential hybridization as a result of hatchery operations. Consideration has also been given to using a physical weir to help segregate and isolate adults showing spring-run characteristics and later-arriving fish showing characteristics of fall-run fish to reduce the risk of hybridization and redd superimposition in spawning areas of the river.

Habitat quality and availability for spring-run Chinook salmon spawning and juvenile rearing in the reaches of the Feather River upstream of Oroville Dam could be used to expand the geographic range of spring-run salmon using trap and haul techniques. On many of the other Central Valley tributaries, such as Deer and Mill Creeks, the risk of hybridization is reduced by the ability of the runs to segregate geographically in the watersheds.

Further, in an effort to improve juvenile survival and the contribution of the Feather River Hatchery to the adult spring-run Chinook salmon population, the spring-run salmon program at the hatchery has released juvenile spring-run salmon downstream of the hatchery (San Pablo Bay) in the past. This increased the rate of straying adults migrating back upstream (California Department of Fish and Game 2001). Recent changes in hatchery management by CDFW, however, have modified juvenile planting with a greater number of juvenile fish released into the Feather River in an effort to improve imprinting and reduce straying, which may reduce potential for hybridization with spring-run salmon in other watersheds (McReynolds et al. 2006). Half of the juvenile spring-run Chinook salmon produced at the hatchery are now released in the Feather River at Live Oak as part of an experimental program designed to improve hatchery management.

2A.4.5.6 Entrainment

The vulnerability of juvenile spring-run Chinook salmon to entrainment and salvage at the SWP/CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon in the Delta, operation of Delta Cross Channel gates, hydrodynamic conditions occurring in the central and southern regions of the Delta (Old and Middle Rivers), and export rates. The loss of fish to entrainment mortality affects Chinook salmon populations (Kjelson and Brandes 1989). Juvenile spring-run Chinook salmon tend to be distributed in the central and southern Delta where they have an increased risk of entrainment/salvage between February and May. The effect of changing hydrodynamics in Delta channels, such as reversed flows in Old and Middle Rivers resulting from SWP/CVP export operations, may result in the following effects:

- Increase attraction of emigrating juveniles into false migration pathways.
- Delay emigration through the Delta.
- Directly or indirectly increase vulnerability to entrainment at unscreened diversions.
- Increase the risk of predation.
- Increase movement of migrating salmon toward the export facilities.
- Increase the risk that these fish will be entrained into the fish salvage facilities.
- Increase the duration of exposure to seasonally elevated water temperatures and other adverse water quality conditions.

SWP/CVP exports affect the tidal hydrodynamics (e.g., water current velocities and direction), and the magnitude of these effects varies in response to a variety of factors, including tidal stage and magnitude of ebb and flood tides, the rate of SWP/CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from the upstream tributaries. Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Over the past several years, additional investigations have been designed using radio or acoustically tagged juvenile Chinook salmon to monitor their migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP/CVP export operations on migration. These studies are continuing (San Joaquin River Group Authority 2007; Brandes et al. 2008; Lindley et al. 2008; MacFarlane et al. 2008a; Michel et al. 2008; North Delta Hydrodynamic and Juvenile Salmon Migration Study 2008; Perry et al. 2008).

In addition to SWP/CVP exports, over 2,200 small water diversions exist throughout the Delta, along with unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978; Schneeberger and Jude 1981; Zeitoun et al. 1981; Weisberg et al. 1987). Many of the juvenile salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile salmon also migrate primarily in the upper part of the water column and are less vulnerable to an unscreened diversion located near the channel bottom. While unscreened diversions used to flood agricultural fields (e.g., rice fields) during the winter have the potential to divert and strand juvenile salmonids, there are no quantitative estimates of the potential magnitude of entrainment losses for juvenile Chinook salmon migrating through the rivers and Delta. Draining these fields can also provide flow attractions to upstream migrating adult salmon, resulting in migration delays or stranding losses, although the loss of adult fish and the effects of these losses on the overall population abundance of returning adult Chinook salmon are also unknown. Despite these potential detrimental effects, flooding agricultural fields can increase nutrient loading to downstream habitats and increase productivity, and increase base flows during low stream flow periods. Many of the larger water diversions located in the Central Valley and Delta (e.g., Glenn Colusa Irrigation District, Reclamation District 108 Wilkins Slough, Poundstone, and Sutter Mutual Water Company Tisdale Pumping Plants, Contra Costa Water District Old River and Alternative Intake Project, and others) have been equipped with positive barrier fish screens to reduce and avoid the loss of juvenile Chinook salmon and other fish species.

Power plants in the Plan Area may impinge juvenile Chinook salmon on the existing cooling water system intake screens. However, use of cooling water is currently low with the retirement of older units. Newer units are equipped with a closed-cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

Besides mortality, salmon fitness may be affected by entrainment at these diversions and delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration due to management of the SWP/CVP operations can make juvenile salmonids more susceptible to many of the threats and stressors, such as predation, entrainment, angling, exposure to poor water quality and toxics, and disease. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risk associated with other threats are unknown, but are the subject of a number of investigations and analyses.

2A.4.5.7 Exposure to Toxins

Toxic chemicals have the potential to be widespread throughout the Delta, or may occur on a more localized scale in response to episodic events (stormwater runoff, point source discharges). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to affect fish health and condition, and adversely affect salmon distribution and abundance. Chinook salmon may experience both waterborne chronic and acute exposure, but also bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in the return flow of agricultural drainage water from the San Joaquin River that is then dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon results in toxic effects (Saiki 1986; Saiki and Lowe 1987; Hamilton et al. 1986, 1990; Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage in the San Joaquin River basin and petroleum refining operations adjacent to San

Pablo and San Francisco Bays. Other contaminants of concern for Chinook salmon include, but are not limited to, mercury, copper, oil and grease, pesticides, herbicides, ammonia[1], and localized areas of depressed dissolved oxygen (e.g., Stockton Deep Water Ship Channel, return flows from managed freshwater wetlands). As a result of the extensive agricultural development in the Central Valley, exposure to pesticides and herbicides is a significant concern for salmon and other fish species in the Plan Area (Bennett et al. 2001). In recent years, changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and agricultural wastewater discharges (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Concerns remain, however, regarding the toxicity of contaminants such as pyrethroids that adsorbed to sediments and other chemicals (selenium and mercury, as well as other contaminants) on salmon.

Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish as a result of direct toxicity and impacts such as those related to acid mine runoff from sites such as Iron Mountain Mine (U.S. Environmental Protection Agency 2006). Tissue bioaccumulation may adversely affect the fish, but also represents a human health concern (Gassel et al. 2008). These materials originate from a variety of sources, including mining operations, municipal wastewater treatment, agricultural drainage in the tributary rivers and Delta, nonpoint runoff, natural runoff and drainage in the Central Valley, agricultural spraying, and a number of other sources. The State Water Resources Control Board (State Water Board), Central Valley Regional Water Quality Control Board, U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), California Department of Water Resources (DWR), and others have ongoing monitoring programs designed to characterize water quality conditions and identify potential toxicants and contaminant exposure to Chinook salmon and other aquatic resources in the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) program as well as efforts to establish and reduce total daily maximum loads (TMDL) of various constituents entering the Delta. Regulations have been updated to help reduce chemical exposure and adverse effects on aquatic resources and habitat conditions in the Plan Area. These monitoring and regulatory programs are ongoing.

Sublethal concentrations of toxics may interact with other stressors on salmonids, possibly increasing their vulnerability to mortality because of exposure to seasonally elevated water temperatures, predation, or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on spring-run Chinook salmon, a similar response is likely due to the physiological similarity.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements and metals that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (Bureau of Reclamation 2004). The EPA's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

2A.4.5.8 Increased Water Temperature

Water temperature is among the physical factors that affect the value of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive life stages, such as during incubation or rearing. The Central Valley is the southern limit of spring-run Chinook salmon geographic distribution, so increased water temperatures are often recognized as an important stressor to California populations. Water temperature criteria for various life stages of salmonids in the Central Valley have been developed (National Marine Fisheries Service 2009a). The tolerance of spring-run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004; Bureau of Reclamation 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, prespawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur because of reductions in flow, upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest temperatures and best areas for salmon spawning and rearing are typically located immediately downstream of the dam. Climate change modeling predicts that the Butte Creek run of spring-run Chinook (the largest population of spring-run Chinook) will be extirpated as a result of warming temperature, even with the cessation of water and power operations (Thompson et al. 2011).

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue results from actions upstream of the Delta. The relatively wide channels of the Delta minimize the effects of additional riparian vegetation on reducing water temperatures.

Adult and juvenile spring-run Chinook salmon hold and rear in pools at higher elevations in the watershed. On several tributaries, prespawning adult mortality has been reported for adults that accumulate in high densities in a pool and are then exposed to elevated summer water temperatures. Flow reductions, resulting from natural hydrologic conditions during the summer, evapotranspiration, or surface and groundwater extractions may all contribute to exposure to elevated temperatures and increased levels of stress or mortality. In some areas, groundwater wells have been used to pump cooler water into the stream to reduce summer temperatures. Dense riparian vegetation, streams incised into canyons that provide shading, cool water springs, and availability of deep holding pools are factors that affect summer holding and rearing conditions for spring-run Chinook salmon.

The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future are important factors that may adversely affect the health and long-term viability of Central Valley spring-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential future environmental changes, and their effect on habitat value and availability for spring-run Chinook salmon, however, are subject to a high degree of uncertainty.

2A.4.6 Relevant Conservation Efforts

Results of salvage monitoring and extensive experimentation over the past several decades have led to the identification of a large number of management actions designed to reduce or avoid the potentially adverse effects of SWP/CVP export operations on salmon. Many of these actions have been implemented through State Water Board water quality permits (D-1485, D-1641), BiOps issued on project export operations by NMFS, USFWS, and CDFW, as part of CALFED programs (e.g., Environmental Water Account), and as part of actions associated with Central Valley Project Improvement Act. These requirements support multiple conservation efforts to enhance habitat and reduce entrainment of Chinook salmon by the SWP/CVP export facilities.

Several habitat problems that contributed to the decline of Central Valley salmonid species are being addressed and improved through restoration and conservation actions. Such actions include reasonable and prudent alternatives from ESA Section 7 consultations on the SWP/CVP projects, including the reasonable and prudent alternatives addressing temperature, flow, and operations; the Central Valley Regional Water Quality Control Board decisions requiring compliance with Sacramento River water temperature objectives that resulted in installation of the Shasta Temperature Control Device in 1998; and EPA actions to control acid mine runoff from Iron Mountain Mine.

BiOps for SWP/ CVP operations (e.g., National Marine Fisheries Service 2009a) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse effects on salmon in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act was enacted to give protection of fish and wildlife equal priority with other CVP objectives. From this act arose several programs that have benefited listed salmonids.

- The Anadromous Fish Restoration Program is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the program include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment.
- The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River.
- The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon, with the

primary focus on listed Chinook salmon and steelhead, by maintaining or increasing instream flows on the Sacramento River at critical times, and to reducing salmonid entrainment at the SWP/CVP export facilities through reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program and the Environmental Water Account, were created to improve conditions for fish, including spring-run Chinook salmon, in the Central Valley. The Ecosystem Restoration Program Implementing Agency Managers selected a proposal for directed action funding written by the Central Valley Salmonid Project Work Team, an interagency technical working group led by CDFW, to develop a spring-run Chinook salmon escapement-monitoring plan. Long-term funding for implementation of the monitoring plan must still be secured.

A major CALFED Ecosystem Restoration Program action currently under way is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 48 miles (77 kilometers) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest coldwater restoration project to date in North America.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Program elements in the Delta (California Department of Fish and Game 2007). The DRERIP team has created a suite of ecosystem and species conceptual models, including for spring-run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Program for implementation. DRERIP conceptual models were used in the analysis of proposed conservation measures.

Recent habitat restoration initiatives sponsored and funded primarily by the Ecosystem Restoration Program have resulted in plans to restore ecological function to 9,543 acres of shallow-water tidal and marsh habitats in the Delta. Restoration of these areas primarily involves flooding lands previously used for agriculture, thereby creating additional rearing habitat for juvenile salmonids. Similar habitat restoration is adjacent to Suisun Marsh (at the confluence of Montezuma Slough and the Sacramento River) as part of the Montezuma Wetlands project, which is intended to provide for commercial disposal of material dredged from San Francisco Estuary in conjunction with tidal wetland restoration.

The Vernalis Adaptive Management Program has implemented migration flow augmentation for the San Joaquin River basin to improve juvenile and adult migration for fall-run Chinook salmon (San Joaquin River Group Authority 2007). The program also includes seasonal reductions in SWP/CVP export rates that may benefit juvenile spring-run Chinook salmon during their emigration period. The program was designed in the framework of adaptive management to improve the survival of juvenile salmonids migrating from the river through the Delta while providing an experimental framework to quantitatively evaluate the contribution of each action to salmonid survival. The incremental contribution of the program conditions to overall spring-run salmon survival and adult abundance is uncertain. The program’s experimental design and results of survival testing conducted to date are currently undergoing peer review and will be the subject of a review conducted by the State Water Board. Based on results and recommendations from these technical reviews, the experimental design and testing program are expected to be refined.

The EPA's Iron Mountain Mine remediation involves the removal of toxic metals in acidic mine drainage from the Spring Creek Watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s. Decreasing the heavy metal contaminants that enter the Sacramento River should increase the survival of salmonid eggs and juveniles. However, during periods of heavy rainfall upstream of the Iron Mountain Mine, Reclamation substantially increases Sacramento River flows to dilute heavy metal contaminants spilled from the Spring Creek debris dam. This rapid change in flows can cause juvenile salmonids to become stranded or isolated in side channels below Keswick Dam.

To eliminate an impediment to migration of adult and juvenile spring-run Chinook salmon and other species, operation of the Red Bluff Diversion Dam ceased in 2011 and dam gates were placed in a permanent open position. A new pumping facility was built that includes a state-of-the-art fish screen.

Since 1986, DWR's Delta Fish Agreement Program has approved approximately $49 million for projects that benefit salmon and steelhead production in the Sacramento-San Joaquin basins and Delta. The Delta Fish Agreement projects that benefit Central Valley spring-run Chinook salmon include water exchange programs on Mill and Deer Creeks; enhanced law enforcement from San Francisco Estuary upstream to the Sacramento and San Joaquin Rivers and their tributaries; design and construction of fish screens and ladders on Butte Creek; and screening of diversions in Suisun Marsh and San Joaquin River tributaries. The Spring-Run Salmon Increased Protection Project provides overtime wages for CDFW wardens to focus on reducing illegal take and illegal water diversions on upper Sacramento River tributaries and adult holding areas, where the fish are vulnerable to poaching. This project covers Mill, Deer, Antelope, Butte, Big Chico, Cottonwood, and Battle Creeks, and has been in effect since 1996. Through the Delta-Bay Enhanced Enforcement Program, initiated in 1994, ten wardens focus their enforcement efforts on salmon, steelhead, and other species of concern from the San Francisco Estuary upstream into the Sacramento and San Joaquin River basins. These two enhanced enforcement programs have likely had significant benefits to spring-run Chinook salmon attributed to CDFW, although results have not been quantified.

The Mill and Deer Creek Water Exchange projects will provide new wells that enable diverters to bank groundwater in place of stream flow, thus leaving water in the stream during critical migration and oversummering periods. On Mill Creek, several agreements between Los Molinos Mutual Water Company, Orange Cove Irrigation District, CDFW, and DWR allows DWR to pump groundwater from two wells into the Los Molinos Mutual Water Company canals to pay back Los Molinos Mutual Water Company water rights for surface water released downstream for fish. Although the Mill Creek Water Exchange project was initiated in 1990 and the agreement allows for a well capacity of 25 cubic feet per second (cfs), only 12 cfs has been developed to date. In addition, it has been determined that a base flow of greater than 25 cfs is needed from April through June for upstream passage of adult spring-run Chinook salmon in Mill Creek. In some years, water diversions from the creek are curtailed by amounts sufficient to provide for passage of upstream migrating adult spring-run Chinook salmon and downstream migrating juvenile steelhead and spring-run Chinook salmon.

The Feather River Hatchery is making efforts to segregate spring-run from fall-run Chinook salmon to enhance and restore the genotype of spring-run Chinook salmon in the Feather River (California Department of Fish and Game 2001; McReynolds et al. 2006).

To help reduce the effects of the Red Bluff Diversion Dam operation on migration of adult and juvenile salmonids and other species, the dam gates are now maintained in the open position for a longer period, thereby facilitating greater upstream and downstream migration. Changes in dam operations have benefited both upstream and downstream migration by salmon and have contributed to a reduction in juvenile predation mortality. In 2009, the Bureau of Reclamation (Reclamation) received funding for the Fish Passage Improvement Project at the Red Bluff Diversion Dam to build a pumping facility to provide reliable water supply for high-valued crops in Tehama, Glenn, Colusa, and northern Yolo Counties while providing year-round unimpeded fish passage. This project, which is expected to be completed in late 2012, will eliminate passage issues for spring-run Chinook salmon and other migratory species.

Seasonal constraints on sport and commercial fisheries south of Point Arena benefit spring-run Chinook salmon. CDFW has implemented enhanced enforcement efforts to reduce illegal harvests. Central Valley spring-run Chinook salmon is a state-listed fish that is protected by specific in-river fishing regulations.

2A.4.7 Recovery Goals

The draft recovery plan for Central Valley salmonids, including spring-run Chinook salmon, was released by NMFS on October 19, 2009. Although not final, the overarching goal is the removal of, among other listed salmonids, spring-run Chinook salmon from the federal list of endangered and threatened wildlife (National Marine Fisheries Service 2009b). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations in each historical diversity group, as well as other measurable biological criteria.

2A.4.8 References Cited

2A.4.8.1 Literature Cited

Araki, H., B. Cooper, and M.S. Blouin. 2007. Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild. *Science* 318:100–103.

Beamish, R. J., C. Mahnken. 2001. A Critical Size and Period Hypothesis to Explain Natural Regulation of Salmon Abundance and Linage to Climate and Climate Change. *Progress in Oceanography* 49:423–437.

Bennett, J., J. Hofius, C. Johnson, T. Maurer. 2001. *Tissue Residues and Hazards of Water-Borne Pesticides for Federally Listed and Candidate Fishes of the Sacramento-San Joaquin River Delta, California: 1993–1995*. July. Sacramento, CA: U.S. Fish and Wildlife Service. Environmental Contaminants Division.

Bilski, R. and J. Kindopp. 2009. *Emigration of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Feather River, 2005-2007.* Oroville, CA: California Department of Water Resources.

Brandes, P. L., J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. In Brown, R. L. (ed.). *Contributions to the Biology of Central Valley Salmonids.* Volume 2. California Department of Fish and Game Fish Bulletin 179:39–136.

Brandes, P. L., R. W. Perry, M. Marshall. 2008. *Use of Acoustic Tag Technology to Estimate Relative Juvenile Chinook Salmon Survival and the Proportion Of Salmon Migrating into the Interior Sacramento-San Joaquin Delta.* 5th Biennial CALFED Science Conference. October 22–24. Sacramento, CA.

Brown, L. R., D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980–1983 and 2001–2003. *Estuaries and Coasts* 30:186–200.

Bureau of Reclamation. 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan, Biological Assessment.* Available: <http://www.usbr.gov/mp/cvo/ocap/OCAP_6_30_04.pdf>.

California Department of Fish and Game. 1995. *Fish Species of Special Concern in California, Spring-Run Chinook Salmon.* Habitat Conservation Planning Branch. Available: <http://www.dfg.ca.gov/hcpb/species/ssc/sscfish/sprngrnchnok.htm>. Accessed: June 21, 2007.

California Department of Fish and Game. 1998. *Report to the Fish and Game Commission. A Status Review of the Spring-Run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage.* Candidate species status report 98-01.

California Department of Fish and Game. 2001. *Final Report on Anadromous Salmonid Fish Hatcheries in California.* Technical report with National Marine Fisheries Service, Southwest Region. Available: <http://swr.nmfs.noaa.gov/14HatcheryReviewPublicDraft2.pdf>.

California Department of Fish and Game. 2007. *Delta Regional Ecosystem Restoration Implementation Plan.* Available: <http://www.delta.dfg.ca.gov/erpdeltaplan>. Accessed: February 25, 2008.

California Department of Water Resources. 2005. Bulletin 250. *Fish Passage Improvement.* Available <http://www.watershedrestoration.water.ca.gov/fishpassage/b250/content.html>.

Campbell, E. A., P. B. Moyle. 1992. *Effects of Temperature, Flow, and Disturbance on Adult Spring-Run Chinook Salmon.* University of California. Water Resources Center. Technical Completion Report.

Clark, G. H. 1929. Sacramento-San Joaquin Salmon (*Oncorhynchus tshawytscha*) Fishery of California. *California Fish and Game Bulletin* 17:73.

Clifford, M. A., K. J. Eder, I. Werner, R. P. Hendrick. 2005. Synergistic Effects of Esfenvalerate and Infectious Hematopoietic Necrosis Virus on Juvenile Chinook Salmon Mortality. *Environmental Toxicology and Chemistry* 24:1766–1772.

Crozier, L. G., P. W. Lawson, T. P. Quinn, A. P. Hendry, J. Battin, N .J. Mantua, W. Eldridge, R. G. Shaw. 2008. Potential Responses to Climate Change in Organisms with Complex Life Histories: Evolution and Plasticity in Pacific Salmon. *Evolutionary Applications* 1:252–270.

Fry, D. H., Jr. 1961. King Salmon Spawning Stocks of the California Central Valley, 1940-1959. *California Fish and Game* 47(1):55–71.

Gassel, M., S. A. Klasing, R. K. Brodberg, S. Roberts. 2008. *Mercury in Fish and Shellfish in the Sacramento River and Northern Delta.* Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. April.

Good, T. P., R. S. Waples, P. Adams (eds.). 2005. *Updated Status of Federally Listed ESU Of West Coast Salmon And Steelhead.* U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-66.

Hallock, R. J. 1991. The Red Bluff Diversion Dam. In: A. Lufkin (ed.). *California's Salmon And Steelhead. The Struggle to Restore an Imperiled Resource.* Berkeley, CA: University of California Press. Pages 96–104.

Hamilton, S. J., and K. J. Buhl. 1990. Acute Toxicity of Boron, Molybdenum, and Selenium to Fry of Chinook Salmon and Coho Salmon. *Archives of Environmental Contamination and Toxicology* 19(3):366–373.

Hamilton, S. J., A. N. Palmisano, G. A. Wedemeyer, and W. T. Yasutake. 1986. Impacts of Selenium on Early Life Stages and Smoltification of Fall Chinook Salmon. *Transactions of the Fifty First North American Wildlife and Natural Resources Conference.* Washington, DC: Wildlife Management Institute. Pages 343–356.

Hamilton, S. J., K. J. Buhl, N. L. Faerber, R. H. Wiedmeyer, and F. A. Bullard. 1990. Toxicity of organic Selenium in the Diet of Chinook salmon. *Environmental Toxicology and Chemistry* 9: 347–358.

Hanson, C. H. 2008. Declaration of Charles H. Hanson, Ph.D. in support of defendant-intervenor State Water Contractors' status report. United States District Court. Eastern District of California, Fresno Division. August 28, 2008.

Harvey, C. 1995. *Juvenile Spring-Run Chinook Salmon Emergence, Rearing and Outmigration Patterns in Deer Creek and Mill Creek, Tehama County for the 1993 Broodyear*. Redding, CA: California Department of Fish and Game, Inland Fisheries Division.

Healey, M. C. 1980. Utilization of the Nanaimo River Estuary by Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*. *U.S. Fisheries Bulletin* 77: 653–668.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). In: C. Groot, L. Margolis (eds.). *Pacific Salmon Life-Histories*. Vancouver, British Columbia: UBC Press. Pages 313–393.

Herren, J .R., S. S. Kawasaki. 2001. Inventory of Water Diversion in Four Geographic Areas in California's Central Valley. Contributions to the Biology of Central Valley Salmonids. *Fish Bulletin 179* (2):343–355.

Kjelson, M. A., and P. Brandes. 1989. The Use of Smolt Survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. In Levings C, Holtby L, Henderson M (eds.). Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publication of Fisheries and Aquatic Sciences* 105:100–115.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life History of Fall-Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary, California. In: V. S. Kennedy (ed.), *Estuarine Comparisons*. New York: Academic Press. Pages 393–411.

Knudsen, E. E., C. R. Steward, D. MacDonald, J. E. Williams, D. E. Reiser. 1999. *Sustainable Fisheries Management: Pacific Salmon.* CRC Press.

Lindley, S. L., C. Michel, P. T. Sandstrom. 2008. *Estimating Reach-Specific Smolt Survival Rates and the Factors Influencing Them from Acoustic Tagging Data.* 5th Biennial CALFED Science Conference. October 22–24. Sacramento, CA.

Lindley, S. T., M. S. Mohr. 2003. Modeling the Effect of Striped Bass on the Population Viability of Sacramento River Winter-Run Chinook Salmon. *Fishery Bulletin* 101:321–331.

Lindley, S. T., R. Schick, A. Agrawal, M. Goslin, T. E. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, J. G. Williams. 2006. *Historical Population Structure of Central Valley Steelhead and Its Alteration by Dams.* San Francisco Estuary and Watershed Science [online serial] 4(2).

Lindley, S.T., R. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. R. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. *Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science* [online serial] 5(1).

Loboschefsky, E., G. Benigno, T. Sommer, T. Ginn, A. Massoudieh, K. Rose, and F. Loge. 2009. B*ioenergetic Modeling of Striped Bass Predation in California from 1969–2004.*

Low, A. F., J. White. Undated. *Relationship Of Delta Cross Channel Gate Operations to Loss Of Juvenile Winter-Run Chinook Salmon at the CVP/SWP Delta Facilities.* Available: <www.science.calwater.ca.gov/pdf/ewa/support_docs.../Relationship%20of%20Delta%20Cross%20Channel%20Gate%>.

MacFarlane, B .R., A. P. Klimley, S. L. Lindley, A. J. Ammann, P. T. Sandstrom, C .J. Michel, E. D. Chapman. 2008a. *Survival and Migratory Patterns of Central Valley Juvenile Salmonids: Progress Report*. 5th Biennial CALFED Science Conference. October 22–24. Sacramento, CA.

MacFarlane, B. R., E. C. Norton. 2002. Physiological Ecology of Juvenile Chinook Salmon (Oncorhynchus tshawytscha) at the Southern End of Their Distribution, the San Francisco Estuary and Gulf of the Farallones, California. *Fisheries Bulletin* 100:244–-257.

MacFarlane, B. R., S. Hayes, B. Wells. 2008b. *Coho and Chinook Salmon Decline in California During the Spawning Seasons of 2007/08.* Paper distributed at BDCP Steering Committee meeting, February 8. Available: <http://www.resources.ca.gov/bdcp/docs/2.8.08_HO_Decline_of_salmon_in_California_in_2007.pdf>.

Manly, B. F. 2004. *Analysis of Data from the Salmon Smolt Experiments.* November 24.

Martin, C. D., P. D. Gaines, and R. R. Johnson. 2001. *Estimating the Abundance of Sacramento River Juvenile Winter Chinook Salmon with Comparisons to Adult Escapement*. Final Report, Report Series: Volume 5. July. Prepared by U.S. Fish and Wildlife Service, Red Bluff, CA. Prepared for U.S. Bureau of Reclamation, Red Bluff, CA.

McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Seattle, WA: U.S. Environmental Protection Agency, Region 10.

McReynolds, T. R., C. E. Garman, P. D. Ward., M. C. Schommer. 2005. *Butte and Big Chico Creeks Spring-Run Chinook Salmon,* Oncorhynchus tshawytscha *Life History Investigation, 2003-2004.* California Department of Fish and Game, Inland Fisheries Administrative Report No. 2005-1.

McReynolds, T. R., C. E. Garman, P. D. Ward., M. C. Schommer. 2006. *Butte And Big Chico Creeks Spring-Run Chinook Salmon,* Oncorhynchus tshawytscha *Life History* Investigation, 2004-2005. California Department of Fish and Game, Inland Fisheries Administrative Report No. 2006-4.

Meyer, J. H. 1979. *A Review of the Literature on the Value of Estuarine and Shoreline Areas to Juvenile Salmonids in Puget Sound, Washington*. Olympia, WA: U.S. Fish and Wildlife Service. Fisheries Assistance Office,

Michel, C. J., A. Ammann, P. Sandstrom, E. Chapman, S. Lindley, P. Klimley, R. MacFarlane. 2008. *A High-Resolution Account of the Survival and Movement Rates of Acoustically Tagged Juvenile Chinook Salmon during the 2007 and 2008 Season.* 5th Biennial CALFED Science Conference. October 22–24. Sacramento, CA.

Miranda J, R. Padilla, J. Morinaka, J. DuBois, M. Horn. 2010. *Release Site Predation Study.* California Department of Water Resources.

Missildine, B., R. Peters, R. Piaskowski, and R. Tabor. 2001. *Habitat Complexity, Salmonid Use, and Predation of Salmonids at the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington*. Miscellaneous report. Lacey, WA: U.S. Fish and Wildlife Service, Western Washington Office.

Moyle, P. B. 2002. *Inland Fishes of California*, Revised and Expanded. Berkeley, CA: University of California Press.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, R. S. Waples. 1998. *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.* U.S. Department Commerce, NOAA Technical Memorandum NMFS-NWFSC-35.

Myrick C. A., J. J. Cech, Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations.* Bay-Delta Modeling Forum Technical Publication 01-1. Available: <http://www.cwemf.org/Pubs/TempReview.pdf>.

Myrick C. A., J. J. Cech, Jr. 2004. Temperature Effects on Juvenile Anadromous Salmonids in California's Central Valley: What Don't We Know? *Reviews in Fish Biology and Fisheries* 14: 113–123.

National Marine Fisheries Service. 1996. *Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act*. Portland, OR and Long Beach, CA: Protected Resource Division.

National Marine Fisheries Service. 2009a. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project And State Water Project.* Southwest Region. June.

National Marine Fisheries Service. 2009b. *Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead.* Sacramento Protected Resources Division. October.

National Marine Fisheries Service. 2011. *Central Valley Recovery Domain, 5-Year Review: Summary and Evaluation of Central Valley Spring-Run Chinook Salmon ESU.* Southwest Region, Long Beach CA.

Newman, K. B., J. Rice. 2002. Modeling the Survival of Chinook Salmon Smolts Outmigrating through the Lower Sacramento River System. *Journal of the American Statistical Association* 97.

Newton, J. M. and M. R. Brown. 2004. *Adult Spring Chinook Salmon Monitoring in Clear Creek, California, 1999-2002.* Red Bluff, CA: U.S. Fish and Wildlife Service.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The Modification of an Estuary. *Science* 231:567–573.

Nobriga, M. L., F. Feyrer, R. D, Baxter, M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

North Delta Hydrodynamic and Juvenile Salmon Migration Study. 2008. Available: <baydeltaoffice.water.ca.gov/ndelta/salmon/documents/North%20Delta%20Study%20overview%205-20-2008.pdf>.

Pacific Fishery Management Council. 2008 *Pacific Council News* 32(1):1, 17–23. Available: <http://www.pcouncil.org/newsletters/2008/Spring_2008_newsletter.pdf>.

Perry, R. W., P. Brandes, and J .R. Skalski. 2008. *Migration Routes and Survival of Juvenile Late-Fall Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta. 5th* Biennial CALFED Science Conference. October 22–24. Sacramento, CA.

Quinn, T. P. 2005. *The Behavior and Ecology of Pacific Salmon and Trout.* University of Washington Press, Seattle.

Raleigh R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. *Habitat Suitability Information: Rainbow Trout*. Washington, DC: U.S. Fish and Wildlife Service, FWS/OBS-82/10.60.

Regional Water Resources Control Board. 2003. *Total Maximum Daily Load for Low Dissolved Oxygen In The San Joaquin River.* Available: <http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/san_joaquin_oxygen/low_do_report_6-2003/do_tmdl_rpt.pdf>. Accessed: June 2003.

Rutter, C. 1904. Natural History of the Quinnat Salmon. Investigation on Sacramento River, 1896-1901. *Bulletin U.S. Fisheries Commission* 22:65–141.

Saiki, M. K. ,T. P. Lowe. 1987. Selenium in Aquatic Organisms from Subsurface Agricultural Drainage Water, San Joaquin Valley, California. *Archives Environmental Contamination and Toxicology* 16:657–670.

Saiki, M. K. 1986. A Field Example of Selenium Contamination in an Aquatic Food Chain. In *Selenium in the Environment – Proceedings, California Agricultural Technology Institute*. Fresno, CA. Pages 67–76.

San Joaquin River Group Authority. 2007. *On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.* 2006 Annual Technical Report.

Schneeberger, P. J., D. J. Jude. 1981. Use of Fish Larva Morphometry to Predict Exclusion Capabilities of Small-Mesh Screens at Cooling-Water Intakes. *Transactions of the American Fisheries Society* 110:246–252.

Snider, B. and R. G. Titus. 2000. *Timing, Composition, and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River near Knights Landing, October 1996-September 1997.* California Department of Fish and Game, Habitat Conservation Division, Stream Evaluation Program Technical Report No. 00-04.

Sommer, T. R., D. McEwan, R. Brown. 2001b. Factors Affecting Chinook Salmon Spawning in the Lower Feather River. California Department of Fish and Game. *Fish Bulletin* 179:269–297.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, W. J. Kimmerer. 2001a. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Stone, L. 1874. *Report of Operations During 1872 at the U.S. Salmon-Hatching Establishment on the McCloud River, and on the California Salmonidae Generally; with a List Of Specimens Collected.* Report of U.S. Commissioner of Fisheries for 1872–1873. 2:168–215.

Thompson, L. C., M. I. Escobar, C. M. Mosser, D. R. Purkey, D. Yates, P. B. Moyle. 2011. Water Management Adaptations to Prevent Loss of Spring-Run Chinook Salmon in California Under Climate Change. *Journal of Water Resource, Planning and Management.* Doi:10.1061/(ASCE)WR. 1943-5452.0000194.

Tomljanovich, D. A., J. H. Heuer, C. W. Voigtlander, 1978. *Concept for Protecting Fish Larvae at Water Intakes.* 1978 Winter Meeting of American Nuclear Society, Washington, DC, USA. 30:105–107.

U.S. Environmental Protection Agency. 2006. *Abandoned Mine Lands Case Study: Iron Mountain Mine.* March.

U.S. Fish and Wildlife Service. 1995. *Working Paper: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California*. Volume 2. May 9. Prepared under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

U.S. Fish and Wildlife Service. 1997. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary 1994.* Annual progress report. Stockton, CA.

U.S. Fish and Wildlife Service. 2001. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary: 1997 and 1998.* Annual progress report.

U.S. Fish and Wildlife Service. 2012. *Delta Juvenile Fish Monitoring Program Database.* Pacific Southwest Region, Stockton Fish and Wildlife Office. Available: <http://www.fws.gov/stockton/jfmp/>.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. *Upper Sacramento River Fisheries and Riparian Habitat Management Plan*. Prepared for the California Resources Agency by the Action Team. Sacramento.

Waples, R. S., R. W. Zabel, M. D. Scheuerell, B. L. Sanderson. 2008. Evolutionary Responses by Native Species to Major Anthropogenic Changes to Their Ecosystems: Pacific Salmon in the Columbia River Hydropower System. *Molecular Ecology* 17:84–96.

Ward, P. D., T. R McReynolds, C. E. Garman. 2002. *Butte and Big Chico Creeks Spring-Run Chinook Salmon,* Oncorhynchus tshawytscha *Life History Investigation, 2000-2001.* California Department of Fish and Game, Inland Fisheries Administrative Report.

Ward, P. D., T. R McReynolds, C. E. Garman. 2003. *Butte and Big Chico Creeks Spring-Run Chinook Salmon,* Oncorhynchus tshawytscha *Life History Investigation, 2001-2002.* California Department of Fish and Game, Inland Fisheries Administrative Report.

Watanabe, M., R. M. Adams, J. Wu, J. Bolte, M. M. Cox, S. Johnson, W. J. Liss, W. G. Boggess, J. L. Ebersole. 2005. Toward Efficient Riparian Restoration: Integrating Economic, Physical, and Biological Models. *Journal of Environmental Management* 75(2):93–104.

Weisberg, S. B., W. H. Burton, F. Jacobs, E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge-Wire Screens. *North American Journal of Fisheries Management* 7:386–393.

Wells, B. K., C. B. Grimes, J. C. Field, C. S. Reiss. 2006. Covariation Between the Average Lengths of Mature Coho (*Oncorhynchus kisutch*) and Chinook Salmon (*O. tshawytscha*) and the Ocean Environment. *Fisheries Oceanography* 15:67–79.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern?* Seminar, University of California, Davis. November 8.

Yoshiyama, R. M., F. W. Fisher, and P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. *North American Journal of Fisheries Management* 18:487–521.

Zeitoun I. H., J. A. Gulvas, D. B. Roarabaugh, Effectiveness of Fine Mesh Cylindrical Wedge-Wire Screens in Reducing Entrainment of Lake Michigan Ichthyoplankton. *Canadian Journal of Fisheries and Aquatic Sciences* 38(1):120–125.

2A.4.8.2 Federal Register Notices Cited

64 FR 50394. 1999. Final Rule; Notice of Determination: Endangered and Threatened Species; Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. *Federal Register* 64:50394.

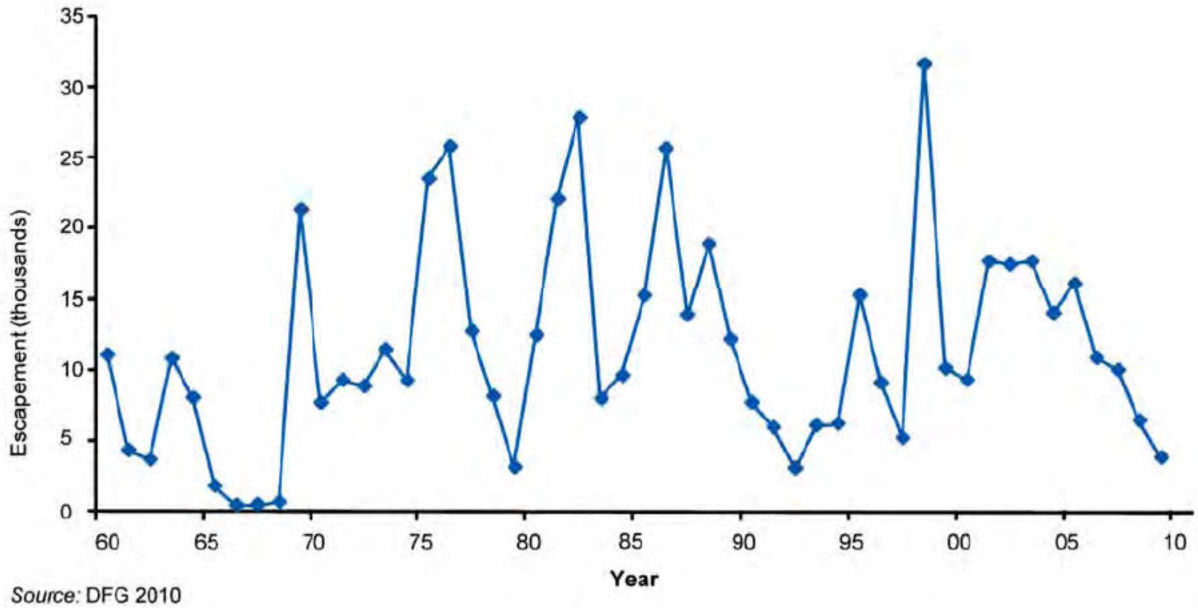
69 FR 33102. Proposed Rule: Threatened and Endangered Species; Proposed Listing Determinations for 27 West Coast Salmonid ESUs, and Proposed Amendments to 4(d) Protective Regulations for threatened ESUs. *Federal Register* 69:33102.

70 FR 37160. 2005. Final Rule: Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. *Federal Register* 70:37160.

70 FR 52488. 2005. Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. *Federal Register* 70:52488.

BDCP-HCP 00343.12 (8-6-12) tm

Figure 2A.4-1
Central Valley Spring-Run Chinook Salmon Inland Range

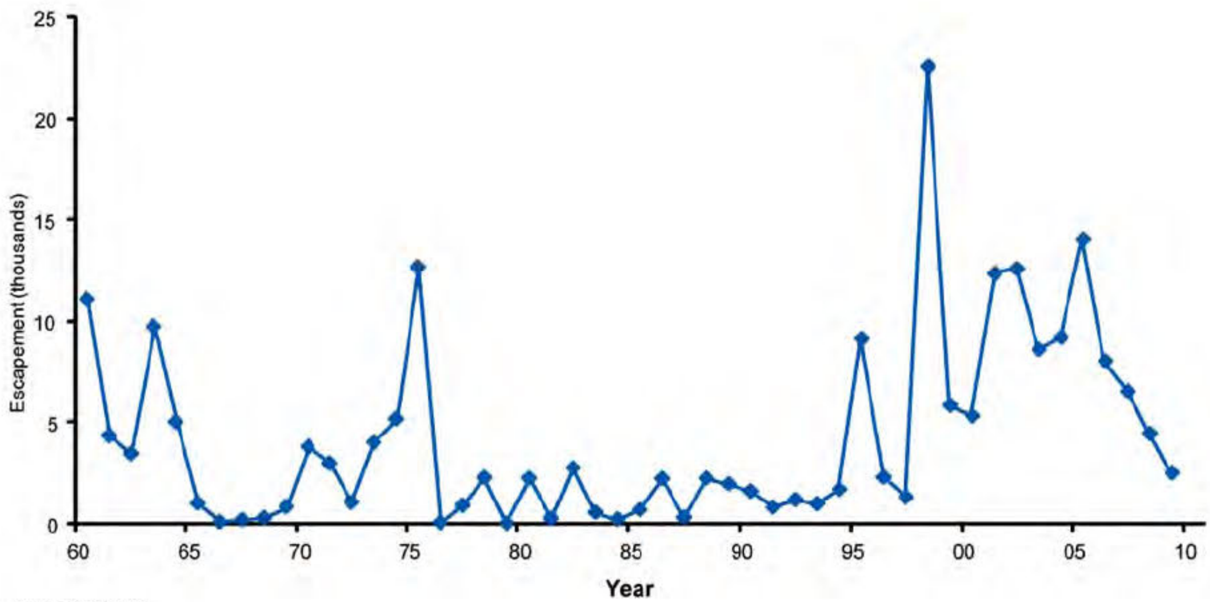


Source: DFG 2010

SOURCE: California Department of Fish and Game. 2010. Annual spawner escapement estimates for all rivers in the Central Valley. September. Available: <http://www.calfish.org/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/ItemId/123/Default.aspx>.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.4-2
Estimated Historical Spawner Escapement of Spring-Run Chinook Salmon Throughout the Central Valley (1960-2009)



Source: DFG 2010

SOURCE: California Department of Fish and Game. 2010. Annual spawner escapement estimates for all rivers in the Central Valley. September. Available: <http://www.calfish.org/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/ItemId/123/Default.aspx>.

Figure 2A.4-3
Estimated Historical Spawner Escapement of Spring-Run Chinook Salmon in Mill, Deer, and Butte Creeks (1960-2009)

BDCP-HCP 00343.12 (12-3-12) tm

Figure 2A.4-4
Central Valley Spring-Run Chinook Salmon
Inland Designated Critical Habitat

BDCP-HCP 00343.12 (8-8-12) tm

Figure 2A.4-5
Central Valley Spring-Run Chinook Salmon Inland Essential Fish Habitat

Appendix 2A.5
Central Valley Fall- and Late Fall–Run Chinook Salmon (*Oncorhynchus tshawytscha*)

2A.5.1 Legal Status

The Central Valley fall- and late fall–run Chinook salmon evolutionary significant unit (ESU) includes all naturally spawned populations of fall- and late fall–run Chinook salmon in the Sacramento and San Joaquin River basins and their tributaries east of Carquinez Strait, California (64 *Federal Register* [FR] 50394) (Figure 2A.5-1 and Figure 2A.5-2, respectively). On September 16, 1999, after reviewing the best available scientific and commercial information, the National Marine Fisheries Service (NMFS) determined that listing Central Valley fall- and late fall–run Chinook salmon was not warranted. On April 15, 2004, the Central Valley fall- and late fall–run Chinook salmon ESU was identified by NMFS as a Species of Concern (69 FR 19975). The rationale for this determination included the following items.

- The average 5-year escapement was above 190,000 fish from natural production, although 20–40% of these natural spawners were of hatchery origin.
- Long-term trends were generally stable or increasing, but it was unclear if natural populations were self-sustaining because of the influence of hatchery production.
- Short-term trends for San Joaquin River tributaries were stable or increasing.
- Concerns remained over impacts from high hatchery production and harvest levels, although ocean and freshwater harvest rates have been recently reduced.
- Approximately 40 to 50% of spawning and rearing habitats have been lost or degraded.

In a subsequent 5-year status review of California ESUs (76 FR 50447), NMFS concluded that several Chinook salmon populations identified through genetic sampling, should be included in the Central Valley fall- and late fall–run Chinook salmon ESU (Williams et al. 2011). This includes populations in the Napa and Guadalupe Rivers, along with future populations found in basins inclusive of the San Francisco/San Pablo Bay complex, which express a fall-run timing,

The Central Valley fall- and late fall–run Chinook salmon ESU are not listed under the California Endangered Species Act (CESA). Fall- and late fall–run Chinook salmon are identified as a California Species of Special Concern (Moyle et al. 1995).

2A.5.2 Species Distribution and Status

2A.5.2.1 Range and Status

Central Valley fall-run Chinook salmon historically spawned in all major tributaries, as well as the mainstem of the Sacramento and San Joaquin Rivers (Figure 2A.5-1). The historical geographic distribution of Central Valley late fall–run Chinook salmon is not well understood, but is thought to be less extensive than that of fall-run (Figure 2A.5-2). The late fall–run fish most likely spawned in the upper Sacramento and McCloud Rivers in reaches now blocked by Shasta Dam, as well as in sections of major tributaries where there was adequate cold water in summer. There is also some evidence they once spawned in the San Joaquin River in the Friant region and in other large San Joaquin tributaries (Yoshiyama et al. 1998). A large percentage of fall-run Chinook spawning areas in the Sacramento and San Joaquin Rivers historically inhabited the lower gradient reaches of the rivers downstream of sites now occupied by major dams, such as Shasta and Friant Dams. As a result of the geographic distribution of spawning and juvenile rearing areas, fall-run Chinook salmon populations in the Central Valley were not as severely affected by early water projects that blocked access to upstream areas, as were spring and winter runs of Chinook salmon and steelhead that used higher elevation habitat for spawning and rearing (Reynolds et al. 1993; McEwan 2001). Changes in seasonal hydrologic patterns resulting from operation of upstream reservoirs for water supplies, flood control, and hydroelectric power generation have altered instream flows and habitat conditions for fall-run Chinook salmon and other species downstream of the dams (Williams 2006).

The abundance of Central Valley fall- and late fall–run Chinook salmon escapement before 1952 is poorly documented. Reynolds et al. (1993) estimated that production of fall- and late fall–run Chinook salmon on the San Joaquin River historically approached 300,000 adults and probably averaged approximately 150,000 adults. Calkins et al. (1940) estimated fall- and late fall–run Chinook salmon abundance at 55,595 adults in the Sacramento River basin from 1931 to 1939. In the early 1960s, adult fall- and late fall–run Chinook salmon escapement was estimated to be 327,000 fish in the Sacramento River basin (California Department of Fish and Game 1965). In the mid-1960s, fall- and late fall–run Chinook salmon escapement to the San Joaquin River basin was estimated to be about 2,400 fish, which spawned in the San Joaquin River tributaries—the Stanislaus, Tuolumne, and Merced Rivers.

Long-term trends in adult fall-run Chinook salmon escapement indicate that abundance in the Sacramento River has been consistently higher than abundance in the San Joaquin River (Figure 2A.5-3). Escapement on the Sacramento River has been characterized by relatively high interannual variability ranging from approximately 100,000 to over 800,000 fish. Sacramento River escapement showed a marked increase in abundance between 1990 and 2003 followed by a decline in abundance from 2004 to present. In 2009, adult fall-run Chinook salmon returns to the Central Valley rivers showed a substantial decline in both the Sacramento and San Joaquin River systems. Similar declines in adult escapement were also observed for coho salmon and Chinook salmon returning to other river systems in California (MacFarlane et al. 2008).

A variety of factors are thought to have influenced adult escapement on both rivers, including hydrological conditions for migration, spawning, and juvenile rearing; ocean conditions; and management actions. Measures have been implemented since the early 1990s to improve seasonal water temperatures, streamflows, modifications to Red Bluff Diversion Dam gate operations, fish passage, construction of positive barrier fish screens on larger diversions, and improved habitat conditions.

Trends in adult fall-run Chinook salmon escapement on the San Joaquin River and tributaries has been relatively low since the 1950s, ranging from several hundred to approximately 100,000 adults (Figure 2A.5-3). Results of escapement estimates have shown a relationship between adult escapement in a cohort year and spring flows on the San Joaquin River 2.5 years earlier when the juvenile in the cohort were rearing and migrating downstream through the Sacramento–San Joaquin River Delta (Delta). Adult escapement appears to be cyclical and may be related to hydrology during the juvenile rearing and migration period, among other factors (San Joaquin River Group Authority 2010; California Department of Fish and Game 2008).

Population estimates for late fall–run Chinook salmon on the San Joaquin River system are not available, but it is thought that late fall–run Chinook salmon do not regularly spawn in the tributaries of the San Joaquin River (Moyle et al. 1995). Adult escapement estimates for late fall–run Chinook salmon returning to the Sacramento River from 1971 through 2009 have ranged from several hundred to over 40,000 adults. Adult escapement showed a general trend of declining abundance between 1971 and 1997 (Figure 2A.5-4). During the late 1990s and continuing through 2006, escapement has increased substantially but is characterized by high interannual variability. The 2008 and 2009 escapement estimates were lower than the previous 4 years, but were not characterized by the massive decline observed for fall-run Chinook salmon (Figure 2A.5-3). Many factors have been identified that may be contributing to the observed trends and patterns in late fall–run Chinook salmon escapement to the upper Sacramento River and its tributaries.

2A.5.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley fall- and late fall–run Chinook salmon ESU must pass through the Plan Area as adults migrating upstream and juveniles emigrating downstream. Adult Central Valley fall- and late fall–run Chinook salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway. Fall- and late fall–run Chinook salmon must migrate through the Delta toward the Pacific Ocean and use the Delta, Suisun Marsh, and the Yolo Bypass for rearing to varying degrees, depending on their life stage (fry versus juvenile), size, river flows, and time of year.

2A.5.3 Habitat Requirements and Special Considerations

Critical Habitat has not been designated for either fall- or late fall–run Chinook salmon because the ESU is not listed under the federal Endangered Species Act (ESA). However, Central Valley fall- and late fall–run Chinook salmon habitats are protected under the Magnuson-Stevens Fishery Conservation and Management Act as essential fish habitat (EFH). Those waters and substrate that support fall- and late fall–run Chinook salmon growth to maturity are included as EFH (Figure 2A.5-5 and Figure 2A.5-6).

Although no critical habitat has been designated, the primary constituent elements (PCEs) considered essential for the conservation of other ESA-listed Central Valley salmonids would likely also apply to fall- and late fall–run Chinook salmon. These PCEs include freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, estuarine areas, nearshore marine areas, and offshore marine areas.

2A.5.3.1 Spawning Habitat

Chinook salmon spawning sites include those stream reaches with instream flows, water quality, and substrate conditions suitable to support spawning, egg incubation, and larval development. Central Valley fall-run Chinook salmon currently spawn downstream of dams on every major tributary in the Sacramento and San Joaquin River systems (with the exception of the San Joaquin River downstream of Friant Dam, which is currently the subject of a settlement agreement and salmonid restoration program) in areas containing suitable environmental conditions for spawning and egg incubation.

Late fall–run Chinook salmon spawning is limited to the mainstem and tributaries of the Sacramento River. No Chinook salmon spawning habitat is known to occur in the Plan Area.

2A.5.3.2 Freshwater Rearing Habitat

Fall- and late fall–run Chinook salmon rear in streams and rivers with sufficient water flow and floodplain connectivity. They rear in these areas to form and maintain physical habitat conditions that support growth and mobility and provide suitable water quality (e.g., seasonal water temperatures) and forage species that support juvenile salmon growth and cover such as shade, submerged and overhanging large wood, logjams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors might also function as rearing habitat for juveniles, which feed and grow before and during their out-migration. Nonnatal, intermittent tributaries and seasonally inundated flood-control bypasses such as the Yolo Bypass also support juvenile rearing (Sommer et al. 2001). Rearing habitat value is strongly affected by habitat complexity, food supply, and predators. Some of these more complex and productive habitats with floodplains are still present in limited amounts in the Central Valley, for example, the lower Cosumnes River, Sacramento River reaches with setback levees (i.e., primarily located upstream of the City of Colusa). The channeled, leveed, and riprapped river reaches and sloughs common in the Sacramento and San Joaquin Rivers and throughout the Delta typically have low habitat diversity and complexity, have low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value because the juvenile life stage of salmonids is dependent on the function of this habitat for successful growth, survival, and recruitment to the adult population.

2A.5.3.3 Freshwater Migration Corridors

Freshwater migration corridors for fall- and late fall–run Chinook salmon, including river channels, channels through the Delta, and the Bay-Delta estuary, support mobility, survival, and food supply for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), have favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors are typically downstream of the spawning area and include the lower Sacramento and San Joaquin Rivers, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile salmon. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value.

Results of mark-recapture studies conducted using juvenile Chinook salmon released into both the Sacramento and San Joaquin Rivers have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001; Newman and Rice 2002; Hanson 2008). Mortality for juvenile salmon is typically greater on the San Joaquin River than for those fish emigrating from the Sacramento River. Results of survival studies have shown that closing the Delta Cross Channel gates and installing the Head of Old River Barrier to reduce the movement of juvenile salmon into the Delta contributes to improved survival of emigrating juvenile Chinook salmon. Observations at the State Water Project (SWP) and the Central Valley Project (CVP) fish salvage facilities have shown that very few of these marked salmon were entrained and salvaged at the export facilities. Although factors contributing to high juvenile mortality have not been quantified, results of anecdotal observations and acoustic tagging experiments suggest the exposure to adverse water quality conditions leading to mortality and vulnerability to predation mortality are two of the factors contributing to the high juvenile mortality observed in the rivers and Delta.

2A.5.3.4 Estuarine Areas

Estuarine migration and juvenile rearing habitats should be free of obstructions (i.e., dams and other barriers) and provide suitable water quality, water quantity (river and tidal flows), and salinity conditions to support juvenile and adult physiological transitions between fresh- and saltwater. Natural cover, such as submerged and overhanging large wood, aquatic vegetation, and side channels, provides juvenile and adult foraging. Estuarine areas contain a high conservation value because they support juvenile Chinook salmon growth, smolting, and the avoidance of predators, as well as provide a transition to the ocean environment.

2A.5.3.5 Ocean Habitats

Biologically productive coastal waters are an important habitat component for Central Valley fall- and late fall–run Chinook salmon. Juvenile fall-run and late fall–run Chinook salmon inhabit near-shore coastal marine waters for typically 2 to 4 years before adults return to Central Valley rivers to spawn. During their marine residence Chinook salmon forage on krill, squid, and other marine invertebrates, as well as a variety of fish such as northern anchovy and Pacific herring. These features are essential for conservation because without them juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown the variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting ocean-derived nutrient availability, phytoplankton and zooplankton production, and the availability of other forage species in near-shore surface waters (Wells et al. 2012). Ocean conditions at the end of the salmon's ocean residency period can be important, as indicated by the effect of the 1983 El Niño on the size and fecundity of Central Valley fall-run Chinook salmon (Wells et al. 2006). Although the effects of ocean conditions on Chinook salmon growth and survival have not been investigated extensively, recent observations since 2007 have shown a significant decline in the abundance of adult Chinook salmon and coho salmon returning to California rivers and streams (fall-run adult returns to the Sacramento and San Joaquin Rivers were the lowest on record [Pacific Fishery Management Council 2008]). This drop has been hypothesized to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008). The importance of changes in ocean conditions to growth, survival, and population abundance of Central Valley Chinook salmon is undergoing further investigation, although relatively rapid changes in ocean conditions would act on top of the long-term, steady degradation of the freshwater and estuarine environment (Lindley et al. 2009).

2A.5.4 Life History

The following life history information was summarized primarily from the *Final Restoration Plan for the Anadromous Fish Restoration Program* (U.S. Fish and Wildlife Service 2001a).

Chinook salmon exhibit two characteristic freshwater life history types (Healey 1991). Stream-type adult Chinook salmon enter fresh water months before spawning, and their offspring reside in fresh water 1 or more years following emergence. In contrast, ocean-type Chinook salmon spend significantly less time in fresh water, spawning soon after entering fresh water as adults and migrating to the ocean as juvenile fry or parr in their first year. Adequate stream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting the stream-type life history behaviors because of their residence in fresh water both as adults and juveniles over the warmer summer months.

Central Valley fall-run Chinook salmon exhibit an ocean-type life history. Adult fall-run Chinook salmon migrate through the Delta and into Central Valley rivers from June through December and spawn from September through December (Table 2A.5-1). Peak spawning activity usually occurs in October and November. The life history characteristics of late fall–run Chinook salmon are not well understood; however, they are thought to exhibit a stream-type life history. Adult late fall–run Chinook salmon migrate through the Delta and into the Sacramento River from October through April and may wait 1 to 3 months before spawning from December through April (Table 2A.5-2). Peak spawning activity occurs in February and March. Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998). The majority of Central Valley fall-run Chinook salmon spawn at age 3.

Information on the migration rates of Chinook salmon in fresh water is scant, and is mostly taken from the Columbia River basin where migration behavior information is used to assess the effects of dams on salmon travel times and passage (Matter et al. 2003). Adult Chinook salmon upstream migration rates ranged from 29 to 32 kilometers per day in the Snake River, a Columbia River tributary (Matter et al. 2003). Keefer et al. (2004) found migration rates of adult Chinook salmon in the Columbia River to range between approximately 10 kilometers per day to greater than 35 kilometers per day. Adult Chinook salmon with sonic tags have been tracked throughout the Delta and the lower Sacramento and San Joaquin Rivers (CALFED Bay-Delta Program 2001).

1 **Table 2A.5-1. Temporal Occurrence of Adult and Juvenile Central Valley Fall-Run Chinook Salmon in**
2 **the Sacramento River and Delta**

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]						Medium	High	High	High	High	High	Medium
Sacramento River Basin[2]							Low	Low	Low	High	High	High
San Joaquin River[2]								Low	Low	High	High	Low
Juvenile												
Sacramento River at Red Bluff[3]	High	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low	Medium
Delta (beach seine)[4]	High	High	High	High	Medium	Medium	Low	Low	Low		Low	Medium
Mossdale (trawl)[4]	Medium	High	High	High	High	Medium						
West Sacramento River (trawl)[4]	Medium	High	High	High	High	Low	Low	Low	Low		Low	Low
Chipps Island (trawl)[4]	Medium	Medium	Medium	High	High	High	Low	Low	Low	Low	Low	Low
Knights Landing (trap)[5]	High	High	High	High	High	Low	Low	Low	Low	Low	Low	Medium

Relative Abundance: [dark] = High; [medium] = Medium; [light] = Low

Note: Darker shades indicate months of greatest relative abundance
[1] State Water Project and Federal Water Project fish salvage data 1981–1988
[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991
[3] Martin et al. 2001
[4] U.S. Fish and Wildlife Service 2001b
[5] Snider and Titus 2000

Table 2A.5-2. Temporal Occurrence of Adult and Juvenile Central Valley Late fall–run Chinook Salmon in the Sacramento River and Delta

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]												
Sacramento River Basin[2]												
Juvenile												
Sacramento River at Red Bluff[3]												
West Sacramento River (trawl)[4]												
Delta (beach seine)[4]												
Chipps Island (trawl)[4]												
Knights Landing (trap)[5]												
Relative Abundance:	(dark) = High			(medium) = Medium				(light) = Low				

Note: Darker shades indicate months of greatest relative abundance

[1] Moyle 2002

[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991

[3] Martin et al. 2001

[4] U.S. Fish and Wildlife Service 2001b

[5] Snider and Titus 2000

These fish exhibited substantial upstream and downstream movement in a random fashion while migrating upstream several days at a time. Adult salmonids migrating upstream, particularly larger salmon such as Chinook (Hughes 2004), are assumed to make greater use of pool and mid-channel habitat than they do of channel margins (Stillwater Sciences 2004). Adult salmon are thought to exhibit crepuscular behavior during their upstream migrations, primarily migrating during twilight hours (Hallock et al. 1970).

Chinook salmon spawn in clean, loose gravel in swift, relatively shallow riffles, or along the margins of deeper river reaches where suitable water temperatures, depths, and velocities favor redd construction and oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds located at the tails or downstream ends of holding pools (U.S. Fish and Wildlife Service 1995). Egg incubation for Central Valley Chinook salmon begins with spawning in September and can extend into March (Vogel and Marine 1991). Egg incubation for late fall–run salmon occurs from December through June (Vogel and Marine 1991; Earley et al. 2010).

Fry emergence generally occurs at night. Upon emergence from the gravel, fry swim or are displaced downstream (Healey 1991). Fry seek streamside habitats containing beneficial aspects such as riparian vegetation and associated substrates that provide aquatic and terrestrial invertebrates, predator avoidance cover, and slower water velocities for resting (National Marine Fisheries Service 1996). These shallow water habitats have been described as more productive juvenile salmon rearing habitat than the deeper main river channels. Higher juvenile salmon growth rates (partially due to greater prey consumption rates) and favorable environmental temperatures have been associated with floodplains that have extensive shallow water habitats (Sommer et al. 2001).

Central Valley fall-run Chinook salmon fry (i.e., juveniles shorter than 2 inches long) generally emerge from December through March, with peak emergence occurring by the end of January. In general, fall-run Chinook salmon fry abundance in the Delta increases following high winter flows. Most fall-run Chinook salmon fry rear in fresh water from December through June, with emigration as smolts occurring primarily from January through June (Table 2A.5-1). Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A very small number (generally less than 5%) of fall-run juveniles spend over a year in fresh water and emigrate as yearling smolts the following November through April.

Central Valley late fall–run Chinook salmon fry generally emerge from April through June. Late fall–run fry rear in fresh water from April through the following April and emigrating as smolts from October through February (Snider and Titus 2000) . Juvenile fall-run Chinook salmon out-migration through the Delta is thought to be primarily a diurnal activity, whereas out-migration of juvenile late fall–run salmon through the Delta is thought to occur primarily at night (Wilder and Ingram 2006). There are a variety of possible explanations for the difference in diel activity between races, including fish size, water temperature, flow rate, and water clarity during downstream migration. Once downstream movement has commenced, individuals may continue this movement until reaching the estuary or they may reside in the stream for a few weeks to a few months (Healey 1991). Juvenile Chinook salmon migration rates vary considerably and likely depend on the physiological stage of the fish and hydrologic conditions. Kjelson et al. (1982) found Chinook salmon fry traveled downstream as fast as 30 kilometers per day in the Sacramento River. Sommer et al. (2001) found rates ranging from approximately 1 kilometer to greater than10 kilometers per day in the Yolo Bypass.

As juvenile Chinook salmon grow, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento by the U.S. Fish and Wildlife Service (USFWS) (1997) indicate that larger juveniles were captured in the main channel and smaller-sized fry along the channel margins. Where the river channel is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1980). Streamflow and/or turbidity increases in the upper Sacramento River basin are thought to stimulate juvenile emigration (Kjelson et al. 1982; Brandes and McLain 2001).

As Chinook salmon begin to smolt (i.e., make the physiological changes necessary for life in saltwater), they are found rearing further downstream where ambient salinity reaches 1.5 to 2.5 parts per thousand (Healey 1980; Levy and Northcote 1981). In the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and shallow vegetated zones (Meyer 1979; Healey 1980). Cladocerans, copepods, amphipods, and dipteran larvae, as well as small arachnids and ants, are common prey items (Kjelson et al. 1982; Sommer et al. 2001).

Juvenile Chinook salmon movement in the estuarine habitat is dictated by the interaction between tidally driven saltwater intrusions through the San Francisco Bay and freshwater outflow from the Sacramento and San Joaquin Rivers. Juvenile Chinook salmon follow rising tides into shallow water habitats from the deeper main channels, and return to the main channels when the tides recede (Levy and Northcote 1981; Healey 1991). Juvenile Chinook salmon were found to spend about

40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (i.e., fall-run Chinook salmon), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon smolts currently show little estuarine dependence and may benefit from expedited ocean entry. However, this may not be the case for emigrating fry that rear for a longer period in the Delta and estuary before emigrating to coastal marine waters. In addition, changes in habitat conditions in the Delta over the past century may have resulted in a reduction in extended juvenile salmon rearing when compared to periods during which habitat for juvenile fall-run and late fall–run salmon rearing was more suitable.

Central Valley Chinook salmon begin their ocean life in the coastal marine waters of the Gulf of the Farallones from where they distribute north and south along the continental shelf, primarily between Point Conception and Washington State (Healey 1991). Upon reaching the ocean, juvenile Chinook salmon feed on larval and juvenile fishes, plankton, and other marine invertebrates (Healey 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment, with growth rates dependent on water temperatures and food availability (Healey 1991). The first year of ocean life is considered a critical period of high mortality for Chinook salmon that largely determines survival to harvest or spawning (Beamish and Mahnken 2001; Quinn 2005).

Recovery of coded-wire tagged Chinook salmon from the Feather River Hatchery in the ocean recreational and commercial fisheries (Pacific States Marine Fisheries Commission Regional Mark Information System database) indicates that Central Valley fall-run Chinook salmon adults are broadly distributed along the Pacific Coast from northern Oregon to Monterey. Recovery of tagged late fall–run Chinook salmon from the Coleman Hatchery in the ocean recreational and commercial fisheries (Pacific States Marine Fisheries Commission Regional Mark Information System database) indicates that Central Valley late fall–run Chinook salmon adults are the most broadly distributed along the Pacific Coast of the Central Valley salmon, ranging from British Columbia to Monterey.

Like other ocean-type Chinook salmon, Central Valley fall- and late fall–run Chinook salmon remain near the coast throughout their ocean life (Healey 1983, 1991; Myers et al. 1984). Central Valley fall- and late fall–run Chinook salmon remain in the ocean for 2 to 5 years. Fall-run Chinook salmon mature in the ocean before returning to fresh water to spawn. Late fall–run Chinook salmon may return to fresh water as immature adults as indicated by a 1- to 3-month delay in spawning once reaching the spawning grounds.

2A.5.5 Threats and Stressors

The following have been identified as important threats and stressors to fall- and late fall–run Chinook salmon (without priority). Additionally, recent record low numbers of fall-run Chinook salmon adult returns to the Central Valley (Pacific Fishery Management Council 2008) suggest that ocean conditions may be an important stressor to the ESU (MacFarlane et al. 2008), although the mechanisms driving this potential effect are not well understood. Lindley et al. (2009) found that unusual ocean conditions in the spring of 2005 and 2006 led to poor growth and survival of juvenile salmon entering the ocean in those years, including Sacramento River fall Chinook salmon. From 2007 to 2009, the Central Valley also experienced drought conditions and low river and stream discharges, which are generally associated with lower survival of Chinook salmon. There is a possibility that with the recent cessation of the drought and a return to more typical patterns of upwelling and sea-surface temperatures, declining trends in abundance may reverse in the near future (National Marine Fisheries Service 2011).

2A.5.5.1 Reduced Staging and Spawning Habitat

Access to the upper extent of the historical upstream spawning habitat for fall- and late fall–run Chinook salmon (Figure 2A.5-1 and Figure 2A.5-2) has been eliminated or degraded by artificial structures (e.g., dams and weirs) associated with water storage and conveyance, flood control, and diversions and exports for municipal, industrial, agricultural, and hydropower purposes (Yoshiyama et al. 1998). Because spawning locations of fall- and late fall–run Chinook salmon are typically in the lower reaches of rivers, fall- and late fall–run Chinook salmon have been less affected by dam construction relative to other Central Valley salmonids. Spawning habitat for fall- and late fall–run Chinook salmon is still widely distributed in the Sacramento River basin, but more limited in the San Joaquin River basin.

Upstream diversions and dams have decreased downstream flows and altered the seasonal hydrologic patterns. These factors have been identified as contributing to delays in upstream migration by adults, contributing to increased mortality of out-migrating juveniles, and responsible for making some streams uninhabitable for fall- and late fall–run salmon (Yoshiyama et al. 1998; California Department of Water Resources 2005). Dams and reservoir impoundments and associated reductions in peak flows have blocked gravel recruitment and reduced flushing of sediments from existing gravel beds, reducing and degrading natal spawning grounds. Further, reduced flows can lower attraction cues for adult spawners, causing straying and delays in spawning (California Department of Water Resources 2005). Adult salmon migration delays can reduce fecundity and increase susceptibility to disease and harvest (McCullough 1999) Because fall-run Chinook salmon spawn shortly after entering fresh water, a delay in migration can have substantial impacts on prespawning mortality and spawning success relative to other races of Chinook salmon.

The Red Bluff Diversion Dam located on the Sacramento River has been identified as a barrier and impediment to adult upstream migration. Although the Red Bluff Diversion Dam is equipped with fish ladders, migration delays have been reported when the dam gates are closed. Mortality as a result of increased predation by Sacramento pikeminnow on juvenile salmon passing downstream through the fish ladder has also been identified as a factor affecting abundance of salmon produced on the Sacramento River (Hallock 1991). The dam gates were placed in a permanent open position in September 2011, and a new pump facility with a state-of-the-art fish screen was subsequently constructed. The project is expected to benefit both upstream and downstream migration and contribute to a reduction in juvenile predation mortality.

2A.5.5.2 Reduced Rearing and Outmigration Habitat

Natural migration corridors for juvenile fall- and late fall–run Chinook salmon consist of complex habitat types, including stream banks, floodplains, marshes, and shallow water areas used as rearing habitat during out-migration. Much of the Sacramento and San Joaquin River corridors and Delta have been leveed, channelized, and modified with riprap for flood protection, thereby reducing and degrading the value and availability of natural habitat for rearing and emigrating juvenile Chinook salmon (Brandes and McLain 2001). Juvenile out-migration delays associated with artificial passage impediments can reduce fitness and increase susceptibility to diversion screen impingement, entrainment, disease, and predation. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening of the hydrograph, reducing the extent and duration of seasonal floodplain inundation and other flow-dependent habitat used by migrating juvenile Chinook salmon (70 FR 52488; Sommer et al. 2001; California Department of Water Resources 2005). Recovery of floodplain habitat in the Central Valley has been found to contribute to increases in production in Chinook salmon (Sommer et al. 2001). Reductions in flow rates have resulted in increased water temperature and residence time, and reduced dissolved oxygen levels in localized areas of the Delta (e.g., Stockton Deep Water Ship Channel). Reduced dissolved oxygen levels in the San Joaquin River during summer and fall have been identified as a water quality barrier to salmon migration (Central Valley Regional Water Quality Control Board 2007).

Tidal and floodplain habitat areas provide important rearing habitat for foraging juvenile salmonids, including fall-run Chinook salmon. Studies have shown that these salmonids may spend 2 to 3 months rearing in these habitat areas, and losses resulting from land reclamation and levee construction are considered to be major stressors on juvenile salmonids (Williams 2009). Similarly, channel margins provide valuable rearing and connectivity habitat along migration corridors, particularly for smaller juvenile fry, such as fall-run Chinook salmon. However, these habitats are expected to provide less benefit to larger stream-type juvenile migrants, such as late fall–run Chinook salmon, which tend to spend less time rearing and foraging in the lower river reaches and the Delta.

2A.5.5.3 Predation by Nonnative Species

Predation on juvenile salmon by nonnative fish has been identified as an important threat to fall- and late fall–run Chinook salmon in areas with high densities of nonnative fish (e.g., small and large mouth bass, striped bass, and catfish) that prey on out-migrating juvenile salmon (Lindley and Mohr 2003). Nonnative aquatic vegetation, such as Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*), provide suitable habitat for nonnative predators (Nobriga et al. 2005; Brown and Michniuk 2007). Predation risk may also vary with increased temperatures. Metabolic rates of nonnative, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009; Miranda et al. 2010). Upstream gravel pits and flooded ponds attract nonnative predators because of their depth and lack of cover for juvenile salmon (California Department of Water Resources 2005). The low spatial complexity and reduced habitat diversity (e.g., lack of cover) of channelized waterways in the rivers and Delta reduce refugia from predators (Raleigh et al. 1984; Missildine et al. 2001; 70 FR 52488).

Predation by native species, such as the Sacramento pikeminnow in the Sacramento River at the Red Bluff Diversion Dam has also been identified as a potentially significant source of mortality on juvenile salmonids.

2A.5.5.4 Harvest

Fall-run Chinook salmon have been the most abundant species in the Central Valley for many years and have supported much of the California commercial and sport fishery (Lindley et al. 2004). However, a sharp decline in returning fall-run Chinook salmon in recent years, and the influence of large-scale hatchery production on the genetics of the species (Barnett-Johnson et al. 2007) have prompted concern for the fall-run stock.

Commercial or recreational harvest of fall- and late fall–run Chinook salmon populations in the ocean and inland fisheries has been a subject of management actions by the California Fish and Game Commission and the Pacific Fishery Management Council. Coastal marine waters offshore of

San Francisco Bay are a mixed stock fishery comprised of both wild and hatchery produced salmon. As a result of differences in survival rates for egg incubation, rearing, and emigration, juvenile salmon produced in streams and rivers have relatively low survival rates compared to Central Valley salmon hatcheries, which have relatively high survival rates. Therefore, naturally reproducing Chinook salmon populations are less able to withstand high harvest rates compared to hatchery-based stocks (Knudsen et al. 1999). The ocean fishery for fall- and late fall–run Chinook salmon is supplemented by hatchery enhancement programs (U.S. Fish and Wildlife Service 1999; Williams 2006). The Coleman National Fish Hatchery produces approximately 12 million fall-run and 1 million late fall–run Chinook salmon juveniles each year to mitigate for habitat loss from construction of Shasta and Keswick Dams (Williams 2006). Fall-run Chinook salmon are also produced at hatcheries on the Feather, American, Mokelumne, and Merced Rivers (Williams 2006). Harvest as a result of the commercial and recreational fisheries may ultimately be having detrimental effects on wild spawners in this mixed stock fishery, but few data are available. Commercial fishing for salmon is managed by the Pacific Fishery Management Council and is constrained by time and area to meet the Sacramento River winter-run ESA consultation standard and restrictions that require minimum size limits and use of circle hooks by anglers.

Beginning in 2007, Central Valley hatcheries have implemented a proportional marking program (tagging a set percentage of salmon produced in each hatchery) that is designed to provide improved information on the effects of harvest on various stocks of Chinook salmon. The program also provides information on ocean migration patterns, growth and survival for fish released at various life stages and locations, the contribution of hatcheries to the adult population, straying among hatcheries and watersheds, the relative contribution of in-river versus hatchery production, and other data that will assist managers in refining harvest regulations. Results of coded wire tag mark-recapture studies and data from the proportional marking program are continually being reviewed and analyzed each year, and used to modify harvest regulations and Central Valley salmon management.

2A.5.5.5 Reduced Genetic Diversity and Integrity

Artificial propagation programs (hatchery production) for fall- and late fall–run Chinook salmon in the Central Valley present multiple threats to wild (in-river spawning) Chinook salmon populations, including genetic introgression by hatchery origin fish that spawn naturally and interbreed with local wild populations (U.S. Fish and Wildlife Service 2001a; Bureau of Reclamation 2004; Goodman 2005). Central Valley hatcheries are recognized as a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (National Marine Fisheries Service 2009a). Interbreeding with hatchery fish contributes directly to reduced genetic diversity and introduces maladaptive genetic changes to the wild population (California Department of Fish and Game 1995; CALFED Bay-Delta Program 2004; Myers et al. 2004; Araki et al. 2007). In addition, releasing hatchery smolts downstream of hatcheries has resulted in an increase in straying rates, further reducing genetic diversity among populations (Williamson and May 2005). Central Valley hatcheries are currently undergoing a detailed review by NMFS and the California Department of Fish and Wildlife (CDFW) as part of a comprehensive hatchery master plan process. Various techniques and actions for reducing the effects of hatchery production on the genetic characteristics of Chinook salmon have been identified as part of the hatchery review. These include, but are not limited to, the following practices.

- Seasonally selecting brood stock for hatchery use in proportion to adult escapement to the river.

- Selecting brood stock from various age classes (including grilse) that represents the age structure of the wild population.
- Selecting brood stock by tagging and conducting genetic testing.
- Increasing the number of adults used as brood stock to increase genetic diversity.
- Reducing the interbasin transfer of eggs and fry.
- Imprinting juveniles to reduce straying among watersheds.

These and other hatchery management methods (e.g., reducing the use of antibiotics and implementing juvenile release strategies to reduce effects on wild rearing juveniles, and planning volitional releases) are expected to reduce the potential risk of hatchery production on the genetics and success of wild populations. However, artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are difficult to avoid (Bureau of Reclamation 2004).

The potential for inter-breeding between Central Valley spring- and fall-run salmon stocks is generally identified as a genetic concern (Yoshiyama et al. 1998). However, some studies indicate no evidence of natural hybridization among Chinook salmon runs despite the spatial and temporal overlap (Banks et al. 2000). Spring- and fall-run Chinook salmon were historically isolated in time and space during spawning; however, the construction of dams and reduction in flows haveeliminated access to historical spawning areas of spring-run salmon in the upper tributaries and streams, forcing spring-run salmon to spawn in lower elevation areas also used by fall-run salmon (Yoshiyama et al. 1998). Hybridization between spring- and fall-run salmon is a particular concern on the Feather River, where both runs occur, and is a potential concern for future restoration of salmon on the San Joaquin River downstream of Friant Dam. However, the genotypic proportions in the Butte Creek spring run cluster farther from the fall run versus the spring run from Deer and Mill Creeks. This challenges the hybridization hypothesis (Banks et al. 2000), which proposes that the cluster would be closer to the fall run. Deer and Mill Creeks, like many of the other Central Valley tributaries, have a reduced risk of hybridization because the runs can segregate geographically in the watersheds.

2A.5.5.6 Entrainment

The vulnerability of fall- and late fall–run Chinook salmon to entrainment and salvage at the SWP and CVP export facilities varies in response to multiple factors, including the seasonal and geographic distribution of juvenile salmon in the Delta, operation of Delta Cross Channel gates and Head of Old River Barrier, hydrodynamic conditions occurring in the central and southern regions of the Delta (e.g., Old and Middle Rivers), and export rates. The losses of fish to entrainment mortality has been identified as an impact on Chinook salmon populations (Kjelson and Brandes 1989). Kimmerer (2008) estimated that losses of Chinook salmon may have been up to 10% at high rates of south Delta export pumping but noted considerable uncertainty in the estimates because prescreen losses due to predation and other factors are difficult to quantify.

Juvenile fall-run Chinook salmon tend to be distributed in the central and southern Delta where they have an increased risk of entrainment/salvage between January and April (Table 2A.5-1). Juvenile late fall–run Chinook salmon tend to be distributed in the Delta primarily between December and January and again between April and May (Table 2A.5-2). The effect of changing hydrodynamics in Delta channels, such as reversed flows in Old and Middle Rivers resulting from SWP and CVP export operations, has the potential to increase attraction of emigrating juveniles into false migration pathways, delay emigration through the Delta, and directly or indirectly increase vulnerability to entrainment at unscreened diversions, risk of predation, and the duration of exposure to seasonally elevated water temperatures and other water quality conditions.

SWP and CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects vary in response to a variety of factors that include the tidal stage and magnitude of ebb and flood tides, the rate of SWP and CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from the upstream tributaries. Chinook salmon behaviorally respond to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. During the past several years additional investigations have been designed using radio or acoustically tagged juvenile Chinook salmon to monitor their migration behavior through the Delta channels and assess the effects of changes in hydraulic cues and SWP and CVP export operations on migration (Holbrook et al. 2009; Perry et al. 2010; San Joaquin River Group Authority 2010). These studies are ongoing.

Besides mortality, salmon fitness may be affected by entrainment at diversions and delays in out-migration of smolts caused by reduced or reverse flows. Delays in migration resulting from water operations related to SWP and CVP export facilities can make juvenile salmonids more susceptible to many of the threats and stressors, such as predation, entrainment, harvest, exposure to toxins, etc. The quantitative relationships among changes in Delta hydrodynamics, the behavioral and physiological response of juvenile salmon, and the increase or decrease in risks associated with other threats is unknown, but the subject of a number of current investigations and analyses.

In addition to SWP and CVP exports, more than 2,200 small water diversions exist throughout the Delta, in addition to unscreened diversions located on the tributary rivers (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978; Schneeberger and Jude 1981; Zeitoun et al. 1981; Weisberg et al. 1987). Many of the juvenile salmon migrate downstream through the Delta during the late winter or early spring when many of the agricultural irrigation diversions are not operating or are only operating at low levels. Juvenile salmon also migrate primarily in the upper part of the water column and, as a result, their vulnerability to an unscreened diversion located near the channel bottom is reduced. No quantitative estimates have been developed to assess the potential magnitude of entrainment losses for juvenile Chinook salmon migration through the rivers and Delta, or the effects of these losses on the overall population abundance of returning adult fall- and late fall–run Chinook salmon. Many of the larger water diversions located in the Central Valley and Delta (e.g., Glenn Colusa Irrigation District, Reclamation District 108 Wilkins Slough and Poundstone Pumping Plants, Sutter Mutual Water Company Tisdale Pumping Plant, Contra Costa Water District Old River and Alternative Intake Project, and others) have been equipped with positive barrier fish screens to reduce and avoid the loss of juvenile Chinook salmon and other fish species.

Power plants in the Plan Area have the ability to impinge juvenile Chinook salmon on the existing cooling water system intake screens. However, as older units are retired, the use of cooling water has declined. Newer units are equipped with a closed-cycle cooling system that virtually eliminates the risk of impingement of juvenile salmon.

2A.5.5.7 Exposure to Toxins

Toxic chemicals have the potential to be widespread throughout the Delta, or may occur on a more localized scale in response to episodic events (stormwater runoff, point source discharges, etc.). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to affect fish health and condition, and adversely affect salmon distribution and abundance. The concerns regarding exposure to toxic substances for Chinook salmon include waterborne chronic and acute exposure, as well as bioaccumulation and chronic dietary exposure. For example, selenium is a naturally occurring constituent in agricultural drainage water return flows from the San Joaquin River that is subsequently dispersed downstream into the Delta (Nichols et al. 1986). Exposure to selenium in the diet of juvenile Chinook salmon has been shown to result in toxic effects (Saiki 1986; Hamilton et al. 1986, 1990; Saiki and Lowe 1987; Hamilton and Buhl 1990). Selenium exposure has been associated with agricultural and natural drainage in the San Joaquin River basin and petroleum refining operations adjacent to San Pablo and San Francisco Bays. Other contaminants of concern for Chinook salmon include, but are not limited to, mercury, copper, oil and grease, pesticides, herbicides, and ammonia[1].

Ammonia released from the City of Stockton Wastewater Treatment Plant contributes to low dissolved oxygen in the adjacent Stockton Deep Water Ship Channel. In addition to the adverse effects of the lowered dissolved oxygen on salmonid physiology, ammonia is toxic to salmonids at low concentrations. The treatment train at the wastewater facility has been modified to remedy this source of ammonia (National Marine Fisheries Service 2012).

As a result of the extensive agricultural development in the Central Valley, exposure to pesticides and herbicides has been identified as a significant concern for salmon and other fish species in the Plan Area (Bennett et al. 2001). Mercury and other metals such as copper have also been identified as contaminants of concern for salmon and other fish as a result of toxicity and tissue bioaccumulation adversely affecting fish (U.S. Environmental Protection Agency 2006), as well as representing a human health concern (Gassel et al. 2008). These materials originate from a variety of sources including mining operations, municipal wastewater treatment, agricultural drainage in the tributary rivers and Delta, nonpoint runoff, natural runoff and drainage in the Central Valley, agricultural spraying, and a number of other sources.

The State Water Resources Control Board (State Water Board), Central Valley Regional Water Quality Control Board, U.S. EPA, U.S. Geological Survey (USGS), California Department of Water Resources (DWR), and others have ongoing monitoring programs designed to characterize water quality and identify potential toxicants and contaminant exposure to Chinook salmon and other aquatic resources in the Plan Area. Programs are in place to regulate point source discharges as part of the National Pollutant Discharge Elimination System (NPDES) as well as programs to establish and reduce total maximum daily loads (TMDL) of various constituents entering the Delta. Changes in regulations have also been made to help reduce chemical exposure and reduce the adverse impacts on aquatic resources and habitat conditions in the Plan Area. These monitoring and regulatory programs are ongoing.

Sublethal concentrations of toxins may interact with other stressors to cause adverse effects on salmonids, such as increasing the salmonids' vulnerability to mortality as a result of exposure to

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

seasonally elevated water temperatures, predation, or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to the infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Juvenile Chinook salmon have a relatively extended period of Delta and estuarine residence of several months (Quinn 2005), which increases exposure and susceptibility to toxic substances in these areas. Adult migrating Chinook salmon may be less affected by these toxins because they are not feeding, and thus not bioaccumulating toxic exposure, and they are moving rapidly through the system.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements and metals that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (Bureau of Reclamation 2004). EPA's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

2A.5.5.8 Increased Water Temperature

Water temperature is among the physical factors that affect the value of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive life stages, such as during incubation or rearing. The Central Valley is the southern limit of Chinook salmon geographic distribution. As a result, increased water temperatures are often recognized as a particularly important stressor to California populations. Water temperature criteria for various life stages of salmonids in the Central Valley have been developed by NMFS (2009a). The tolerance of fall-run and late fall–run Chinook salmon to water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004; Bureau of Reclamation 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, delayed passage, in vivo egg mortality of spawning adults, prespawning mortality, reduced spawning success, and increased mortality of salmon (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur because of reductions in flow as a result of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate, and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows further downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. As a result of the longitudinal gradient of seasonal water temperatures, the coldest water—and, therefore, the best areas for salmon spawning and rearing—are typically located immediately downstream of the dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily from actions upstream of the

Delta. As a result of the relatively wide channels that occur in the Delta, the effects of additional riparian vegetation on reducing water temperatures are minimal. The effects of climate change and global warming patterns, in combination with changes in precipitation and seasonal hydrology in the future have been identified as important factors that may adversely affect the health and long-term viability of Central Valley spring-run Chinook salmon (Crozier et al. 2008). The rate and magnitude of these potential environmental changes, and their effect on habitat value and availability for fall- and late fall–run Chinook salmon, however, are subject to a high degree of uncertainty.

2A.5.6 Relevant Conservation Efforts

Results of salvage monitoring and extensive experimentation over the past several decades have led to the identification of various management actions designed to reduce or avoid the potentially adverse effects of SWP and CVP export operations on salmon. Many of these actions have been implemented through State Water Board water quality permits (D-1485, D-1641), biological opinions issued on project export operations by NMFS, USFWS, and CDFW, as part of CALFED Bay-Delta Program programs such as the Environmental Water Account, and as part of Central Valley Project Improvement Act actions. As a result of these requirements, multiple conservation efforts exist to reduce entrainment of Chinook salmon by the SWP and CVP export facilities.

Several habitat problems that contributed to the decline of Central Valley salmonid species are being addressed and improved through restoration and conservation actions related to ESA Section 7 consultations on the SWP and CVP projects, including the reasonable and prudent alternatives addressing temperature, flow, and operations; the Central Valley Regional Water Quality Control Board decisions requiring compliance with Sacramento River water temperature objectives that resulted in installation of the Shasta Temperature Control Device in 1998; and EPA actions to control acid mine runoff from Iron Mountain Mine.

Biological opinions for SWP and CVP operations (e.g., National Marine Fisheries Service 2009b) and other federal projects involving irrigation and water diversion and fish passage have improved or minimized adverse effects on salmon in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act was enacted to give the protection of fish and wildlife equal priority with other Central Valley Project objectives. From this act arose several programs that have benefited listed salmonids. The Anadromous Fish Restoration Program is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the program include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The Anadromous Fish Screen Program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley salmon. These improvements have focused primarily on listed Chinook salmon and steelhead but have provided incidental benefits to fall- and late fall–run Chinook salmon. The improvements involve maintaining or increasing instream flows (Environmental Water Account) on the

Sacramento River and the San Joaquin River at critical times and lowering seasonal diversion rates during periods when protected fish species are vulnerable to export related losses to reduce salmonid entrainment at the SWP and CVP export facilities.

Two programs included under CALFED Bay-Delta Program, the Ecosystem Restoration Program and the Environmental Water Account, were created to improve conditions for fish, including fall- and late fall–run Chinook salmon, in the Central Valley. Restoration actions implemented by the program include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors and stressors affecting listed salmonids that incidentally benefit fall- and late fall–run Chinook salmon. Additional ongoing actions include efforts to enhance fishery monitoring and improvements to hatchery management to support salmonid production through hatchery releases.

A major Ecosystem Restoration Program action currently under way is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 48 miles (77 kilometers) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure continued hydropower operations. It is thought that this restoration effort is the largest cold water restoration project to date in North America.

To eliminate an impediment to migration of adult and juvenile fall- and late fall–run Chinook salmon and other species, operation of the Red Bluff Diversion Dam ceased in 2011 and dam gates were placed in a permanent open position. A new pumping facility includes a state-of-the-art fish screen.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Bay-Delta Program Ecosystem Restoration Program elements in the Delta (California Department of Fish and Game 2007). The DRERIP team has created a suite of ecosystem and species conceptual models, including fall- and late fall–run Chinook salmon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Program for implementation. DRERIP conceptual models were used in the analysis of proposed conservation measures.

The Vernalis Adaptive Management Program (VAMP) has implemented migration flow augmentation for the San Joaquin River basin to improve juvenile and adult migration for fall-run Chinook salmon (San Joaquin River Group Authority 2010). The VAMP program also includes seasonal reductions in SWP and CVP export rates and installation of the Head of Old River Barrier to further improve the survival of downstream migrating salmon. The program has been designed in the framework of adaptive management to improve the survival of juvenile salmon migrating from the river through the Delta, while also providing an experimental framework to quantitatively evaluate the contribution of each action to fall-run Chinook salmon survival. Preliminary results of the VAMP survival studies have shown evidence that juvenile Chinook salmon survival is positively correlated with San Joaquin River flows during the spring emigration period; however, no statistically significant relationship between juvenile salmon survival and SWP/CVP exports has been detected. The range of flows and SWP/CVP export rates that can be tested under the VAMP experimental design is relatively small (e.g., river flows from approximately 2,000 to 7,000 cubic feet per second [cfs] with SWP and CVP export rates ranging from 1,500 to 3,000 cfs). In addition, during the experimental period, installation of the Head of Old River Barrier has been precluded by federal court order to protect delta smelt. As a result of these and other factors, the level of additional protection that the VAMP has provided to naturally produced Chinook salmon during emigration downstream from the San Joaquin River and Delta, and the incremental contribution of the VAMP conditions to overall salmon survival and adult abundance, is uncertain. The VAMP experimental design and results of survival testing conducted to date is currently undergoing peer review and will also be the subject of a review conducted by the State Water Board. Based on results and recommendations from these technical reviews, the VAMP experimental design and testing program, as well as flow management for juvenile salmon migration on the San Joaquin River, is expected to be refined.

2A.5.7 Recovery Goals

Because fall- and late fall–run Chinook salmon are not listed for protection under either the federal or CESA, formal recovery goals will not be established. As part of other fishery management programs, such as the Central Valley Project Improvement Act and the State Water Board salmon doubling goal, goals and objectives have been established for Central Valley Chinook salmon.

2A.5.8 References Cited

2A.5.8.1 Literature Cited

Araki, H., B. Cooper, M.S. Blouin. 2007. Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild. *Science* 318:100–103.

Banks, M. A., V. K. Rashbrook, M. J. Calavetta, C. A. Dean, and D. Hedgecock. 2000. Analysis of Microsatellite DNA Resolves Genetic Structure and Diversity of Chinook Salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. *Canadian Journal of Fisheries and Aquatic Sciences* 57:915–927.

Barnett-Johnson, R., C. B. Grimes, C. F. Royer, C. J. Donohoe. 2007. Identifying the Contribution of Wild and Hatchery Chinook Salmon (*Oncorhynchus tshawytscha*) to the Ocean Fishery Using Otolith Microstructure as Natural Tags. *Canadian Journal of Fisheries and Aquatic Sciences* 64(12):1683–1692(10).

Beamish, R. J., C. Mahnken. 2001. A Critical Size and Period Hypothesis to Explain Natural Regulation of Salmon Abundance and Linage to Climate and Climate Change. *Progress in Oceanography* 49:423–437.

Bennett, J., J. Hofius, C. Johnson, T. Maurer. 2001. *Tissue Residues and Hazards of Water-Borne Pesticides for Federally Listed and Candidate Fishes of the Sacramento-San Joaquin River Delta, California: 1993–1995*. July. Sacramento, CA: U.S. Fish and Wildlife Service. Environmental Contaminants Division.

Brandes, P. L., J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. In: Brown, R.L. (ed.). *Contributions to the Biology of Central Valley Salmonids.* Volume 2. California Department of Fish and Game. *Fish Bulletin* 179:39–136.

Brown L. R., D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30:186–200.

Bureau of Reclamation. 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan, Biological Assessment.* Available: <http://www.usbr.gov/mp/cvo/ocap/OCAP_6_30_04.pdf>.

CALFED Bay-Delta Program. 2001. *Science in Action: Scrutinizing the Delta Cross Channel*. CALFED Science Program. June.

CALFED Bay-Delta Program. 2004. *Compatibility of Coleman National Fish Hatchery Operations and Restoration of Anadromous Salmonids in Battle Creek.* CALFED Technical Review Panel.

California Department of Fish and Game. 1965. *California Fish and Wildlife Plan.* Volumes 1-3. Inland Fisheries Division, Sacramento, CA.

California Department of Fish and Game. 1995. *Fish Species of Special Concern in California, Spring-Run Chinook Salmon. Habitat Conservation Planning Branch.* Available: <http://www.dfg.ca.gov/hcpb/species/ssc/sscfish/sprngrnchnok.htm>. Accessed: June 2007.

California Department of Fish and Game. 2007. *Delta Regional Ecosystem Restoration Implementation Plan.* Available<http://www.delta.dfg.ca.gov/erpdeltaplan>. Accessed: February 25, 2008.

California Department of Fish and Game. 2008. *San Joaquin River Salmon Population Model Version 1.5.* Presented at State Water Quality Resources Control Board September, 17, 2008 workshop.

California Department of Water Resources. 2005. *Fish Passage Improvement.* Bulletin 250. Available: <http://www.watershedrestoration.water.ca.gov/fishpassage/b250/content.html>.

Calkins, R. D., W. F. Durand, and W. H. Rich. 1940. *Report of the Board of Consultants on the Fish Problem of the Upper Sacramento River*. Stanford University. Portland, OR: Environmental and Technical Services Division, National Marine Fisheries Service.

Central Valley Regional Water Quality Control Board. 2007. *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region.* Fourth Edition, Revised October 2007 (with approved amendments). Available: <www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr.pdf>.

Clifford, M. A., K. J. Eder, I. Werner, R. P. Hendrick. 2005. Synergistic Effects of Esfenvalerate and Infectious Hematopoietic Necrosis Virus on Juvenile Chinook Salmon Mortality. *Environmental Toxicology and Chemistry* 24:1766–1772.

Crozier, L. G., P. W. Lawson, T. P. Quinn, A. P. Hendry, J. Battin, N .J. Mantua, W. Eldridge, R. G. Shaw. 2008. Potential Responses to Climate Change in Organisms with Complex Life Histories: Evolution and Plasticity in Pacific Salmon. *Evolutionary Applications*1:252–270.

Earley, J. T., D. J. Colby, and M. R. Brown. 2010. *Juvenile Salmonid Monitoring in Clear Creek, California, from October 2008 through September 2009.* Red Bluff, CA: U.S. Fish and Wildlife Service.

Gassel, M., S. A. Klasing, R. K. Btodberg, S. Roberts. 2008. *Mercury in Fish and Shellfish in the Sacramento River and Northern Delta.* Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. April.

Goodman, D. 2005. Selection Equilibrium for Hatchery and Wild Spawning Fitness in Integrated Breeding Programs. *Canadian Journal of Fisheries and Aquatic Sciences* 62:374–389.

Hallock, R. J. 1991. The Red Bluff Diversion Dam. In: A. Lufkin (ed.). *California's Salmon and Steelhead. The Struggle to Restore an Imperiled Resource.* Berkeley, CA: University of California Press. Pages 96–104.

Hallock, R. J., R. F. Elwell, D. H. Fry, Jr. 1970. *Migrations of Adult King Salmon* Oncorhynchus tshawytscha *in the San Joaquin Delta; as Demonstrated by the Use of Sonic Tags.* California Department of Fish and Game. Fish Bulletin 151.

Hamilton, S .J., K. J. Buhl. 1990. Acute Toxicity of Boron, Molybdenum, and Selenium to Fry of Chinook Salmon and Coho Salmon. *Archives of Environmental Contamination and Toxicology* 19(3):366–373.

Hamilton, S. J., A. N. Palmisano, G. A. Wedemeyer, and W. T. Yasutake. 1986. Impacts of Selenium on Early Life Stages and Smoltification of Fall Chinook Salmon. *Transactions of the Fifty First North American Wildlife and Natural Resources Conference.* Washington, DC: Wildlife Management Institute. Pages 343–356.

Hamilton, S. J., K. J. Buhl, N. L. Faerber, R. H. Wiedmeyer, F. A. Bullard. 1990. Toxicity of Organic Selenium in the Diet of Chinook Salmon. *Environmental Toxicology and Chemistry* 9:347–358.

Hanson, C. H. 2008. Declaration of Charles H. Hanson, Ph.D. in support of defendant-intervenor State Water Contractors' status report. United States District Court. Eastern District of California, Fresno Division. August 28.

Healey, M. C. 1980. Utilization of the Nanaimo River Estuary by Juvenile Chinook Salmon, *Oncorhynchus tshawytscha. U.S. Fisheries Bulletin* 77:653–668.

Healey, M. C. 1983. Coastwide Distribution and Ocean Migration Patterns of Stream- and Ocean-Type Chinook Salmon, *Oncorhynchus tshawytscha*. *Canadian Field-Naturalist* 97:427–433.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*). In: C. Groot, L. Margolis (eds.). *Pacific Salmon Life-Histories*. Vancouver, British Columbia: UBC Press. Pages 313–393.

Herren, J. R., S. S. Kawasaki. 2001. Inventory of Water Diversion in Four Geographic Areas in California's Central Valley. Contributions to the Biology of Central Valley Salmonids. *Fish Bulletin 179* (2):343–355.

Holbrook, C. M., R. W. Perry, N. S. Adams. 2009. *Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008.* Open-File Report 2009-1204. Available: < http://pubs.usgs.gov/of/2009/1204/>.

Hughes, N. F. 2004. The Wave-Drag Hypothesis: an Explanation for Sized-Based Lateral Segregation during the Upstream Migration of Salmonids. *Canadian Journal of Fisheries and Aquatic Sciences* 61:103–109.

Keefer, M. L., C. A. Perry, M. A. Jepson, L. C. Stuehrenberg. 2004. Upstream Migration Rates of Radio-Tagged Adult Chinook Salmon in Riverine Habitats of the Columbia River Basin. *Journal of Fish Biology* 65:1126–1141.

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *San Francisco Estuary & Watershed Science*. June 2008. Published by the California Bay-Delta Authority Science Program and the John Muir Institute of the Environment.

Kjelson, M. A. and P. Brandes. 1989. The Use of Smolt Survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. In: Levings, C., L. Holtby, and M. Henderson (eds.). Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publication of Fisheries and Aquatic Sciences* 105:100–115.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life History of Fall-Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin Estuary, California. In: V. S. Kennedy (ed.), *Estuarine Comparisons*. New York: Academic Press. Pages 393–411.

Knudsen, E. E., C. R. Steward, D. MacDonald, J. E. Williams, D. E. Reiser. 1999. *Sustainable Fisheries Management: Pacific Salmon.* CRC Press.

Levy, D. A., and T. G. Northcote. 1981. *The Distribution and Abundance of Juvenile Salmon in Marsh Habitats of the Fraser River Estuary*. Technical Report No. 25. Vancouver, B.C.: Westwater Research Centre, University of British Columbia.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L.W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, T. H. Williams. 2009. *What Caused the Sacramento River Fall Chinook Stock Collapse?* Prepublication report to the Pacific Fishery Management Council.

Lindley, S. T., M. S. Mohr. 2003. Modeling the Effect of Striped Bass on the Population Viability of Sacramento River Winter-Run Chinook Salmon. *Fishery Bulletin* 101:321–331.

Lindley, S. T., R. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. *Population Structure of Threatened and Endangered Chinook Salmon ESUs in California's Central Valley Basin.* NOAA TM NMFS SWFSC 360.

Loboschefsky, E., G. Benigno, T. Sommer, T. Ginn, A. Massoudieh, K. Rose, F. Loge. 2009. B*ioenergetic Modeling of Striped Bass Predation in California from 1969-2004.*

MacFarlane, B. R., S. Hayes, B. Wells. 2008. *Coho and Chinook Salmon Decline in California During the Spawning Seasons of 2007/08.* Paper distributed at BDCP Steering Committee meeting, February 8. Available: <http://www.resources.ca.gov/bdcp/docs/2.8.08_HO_Decline_of_salmon_in_California_in_2007.pdf>.

MacFarlane, B. R. and E. C. Norton. 2002. Physiological Ecology of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) at the Southern End of Their Distribution, the San Francisco Estuary and Gulf of the Farallones, California. *Fisheries Bulletin* 100:244–257.

Martin, C. D., P. D. Gaines, and R. R. Johnson. 2001. *Estimating the Abundance of Sacramento River Juvenile Winter Chinook Salmon with Comparisons to Adult Escapement*. Final Report, Report Series: Volume 5. July. Prepared by U.S. Fish and Wildlife Service, Red Bluff, CA. Prepared for U.S. Bureau of Reclamation, Red Bluff, CA.

Matter, A. L., B. P. Sandford. 2003. A Comparison of Migration Rates of Radio and PIT-Tagged Adult Snake River Chinook Salmon through the Columbia River Hydropower System. *North American Journal of Fisheries Management* 23:967–973.

McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Seattle, WA: U.S. Environmental Protection Agency, Region 10.

McEwan, D. R. 2001. Central Valley Steelhead. In: R. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids*. California Department of Fish and Game Fish Bulletin No 179.

Meyer, J. H. 1979. *A Review of the Literature on the Value of Estuarine and Shoreline Areas to Juvenile Salmonids in Puget Sound, Washington*. Olympia, WA: U.S. Fish and Wildlife Service. Fisheries Assistance Office,

Miranda J, R. Padilla, J. Morinaka, J. DuBois, M. Horn. 2010. *Release Site Predation Study.* California Department of Water Resources.

Missildine, B., R. Peters, R. Piaskowski, and R. Tabor. 2001. *Habitat Complexity, Salmonid Use, and Predation of Salmonids at the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington*. Miscellaneous report. Lacey, WA: U.S. Fish and Wildlife Service, Western Washington Office.

Moyle, P. B. 2002. *Inland Fishes of California*, Revised and Expanded. Berkeley, CA: University of California Press.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. *Fish Species of Special Concern in California*. Second edition. Davis, CA: Department of Wildlife and Fisheries Biology, University of California, Davis. Prepared for the California Department of Fish and Game, Rancho Cordova, CA.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, R. S. Waples. 1998. *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.* U.S. Department Commerce, NOAA Technical Memorandum NMFS-NWFSC-35.

Myers, K. W., D. E. Rogers, C. K. Harris, C. M. Knidsen, R. V. Walker, N. D. Davis. 1984. *Origins of Chinook Salmon in the Area of the Japanese Motherships and Landbased Driftnet Salmon Fisheries 1975-1981*. Submitted to annual meeting International North Pacific Fisheries Commission, Vancouver, British Columbia.November. Seattle, WA: Fisheries Research Institute, University of Washington.

Myers, R. A., S. A. Levin, R. Lande, F. C. James, W. W. Murdoch, R. T. Paine. 2004. Hatcheries and Endangered Salmon. *Science* 303:1980.

Myrick, C. A., J. J. Cech Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations.* Bay-Delta Modeling Forum Technical Publication 01-1. Available: <http://www.cwemf.org/Pubs/TempReview.pdf>.

Myrick, C. A., J. J. Cech, Jr. 2004. Temperature Effects on Juvenile Anadromous Salmonids in California's Central Valley: What Don't We Know? *Reviews in Fish Biology and Fisheries* 14:113 – 123.

National Marine Fisheries Service. 1996. *Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act*. Portland, OR and Long Beach, CA: Protected Resource Division.

National Marine Fisheries Service. 2009a. *Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead.* Sacramento Protected Resources Division. October.

National Marine Fisheries Service. 2009b. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project.* Southwest Region. June.

National Marine Fisheries Service. 2011. *Central Valley Recovery Domain. 5-Year Review: Summary and Evaluation of Central Valley Steelhead DPS.* Southwest Region.

National Marine Fisheries Service. 2012. *Biological Opinion: Formal Consultation for the California Department of Water Resources, 2012 Georgiana Slough Non-Physical Barrier Study.* Southwest Region. February 2012.

Newman, K. B., J. Rice. 2002. Modeling the Survival of Chinook Salmon Smolts Outmigrating through the Lower Sacramento River System. *Journal of the American Statistical Association* 97.

Nichols, F. H., J. E. Cloern, S. N. Luoma, D. H. Peterson. 1986. The Modification of an Estuary. *Science* 231:567–573. Available: <http://www.jstor.org/stable/1696456>.

Nobriga, M. L., F. Feyrer, R. D, Baxter, M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

Pacific Fishery Management Council. 2008. *Review of 2007 Ocean Salmon Fisheries.* February. Available: < http://www.pcouncil.org/salmon/salsafe07/salsafe07.pdf>.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, B. MacFarlane. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Quinn, T. P. 2005. *The Behavior and Ecology of Pacific Salmon and Trout.* Seattle, WA: University of Washington Press.

Raleigh R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. *Habitat Suitability Information: Rainbow Trout*. Washington, DC: U.S. Fish and Wildlife Service, FWS/OBS-82/10.60.

Reynolds, F. L., T. Mills, R. Benthin, and A. Low. 1993. *Restoring Central Valley Streams: A Plan for Action.* Sacramento, CA: California Department of Fish and Game, Inland Fisheries Division.

Saiki, M. K. 1986. A Field Example of Selenium Contamination in an Aquatic Food Chain. *Selenium in the Environment – Proceedings.* Fresno, CA: California Agricultural Technology Institute. Pages 67–76.

Saiki, M. K., T. P. Lowe. 1987. Selenium in Aquatic Organisms from Subsurface Agricultural Drainage Water, San Joaquin Valley, California. *Archives Environmental Contamination and Toxicology* 16:657–670.

San Joaquin River Group Authority. 2010. *On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.* 2009 Annual Technical Report.

Schneeberger, P. J., D. J. Jude. 1981. Use of Fish Larva Morphometry to Predict Exclusion Capabilities of Small-Mesh Screens at Cooling-Water Intakes. *Transactions of the American Fisheries Society* 110:246–252.

Snider, B. and R. G. Titus. 2000. *Timing, Composition, and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing, October 1996-September 1997.* California Department of Fish and Game, Habitat Conservation Division, Stream Evaluation Program Technical Report No. 00-04.

Sommer, T. R., M. L. Nobriga, W. C. Harrel, W. Batham, W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Stillwater Sciences. 2004. Appendix H: Conceptual Models of Focus Fish Species Response to Selected Habitat Variables. In: *Sacramento River Bank Protection final Standard Assessment Methodology.* July.

Tomljanovich, D. A., J. H. Heuer, C. W. Voigtlander, 1978. *Concept for Protecting Fish Larvae at Water Intakes.* 1978 Winter Meeting of American Nuclear Society, Washington, DC, USA. 30:105–107.

U.S. Environmental Protection Agency. 2006. *Abandoned Mine Lands Case Study: Iron Mountain Mine.* March.

U.S. Fish and Wildlife Service. 1995. *Working Paper: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California*. Volume 2. May 9. Prepared under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

U.S. Fish and Wildlife Service. 1997. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary*. 1994 Annual Progress Report. Stockton, CA.

U.S. Fish and Wildlife Service. 1999. *Q&A: The Battle Creek Restoration Program & Coleman National Fish Hatchery.* Available: <http://www.doi.gov/news/archives/coleman.html>. Accessed: June 12, 2007.

U.S. Fish and Wildlife Service. 2001a. *Final Restoration Plan for the Anadromous Fish Restoration Program A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California.* Available: < http://www.fws.gov/stockton/afrp/SWRCB/B.finalrestplan.pdf>.

U.S. Fish and Wildlife Service. 2001b. *Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary: 1997 and 1998*. Annual progress report Sacramento-San Joaquin Estuary.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. *Upper Sacramento River Fisheries and Riparian Habitat Management Plan.* A report prepared for the California Resources Agency by the Action Team. Sacramento.

Vogel, D. A. and K. R. Marine. 1991. *Guide to Upper Sacramento River Chinook Salmon Life History.* Prepared for the Bureau of Reclamation, Central Valley Project. July.

Waples, R. S., R. W. Zabel, M. D. Scheuerell, B. L. Sanderson. 2008. Evolutionary Responses by Native Species to Major Anthropogenic Changes to Their Ecosystems: Pacific Salmon in the Columbia River Hydropower System. *Molecular Ecology* 17:84–96.

Watanabe, M., R. M. Adams, J. Wu, J. Bolte, M. M. Cox, S. Johnson, W. J. Liss, W. G. Boggess, J. L. Ebersole. 2005. Toward Efficient Riparian Restoration: Integrating Economic, Physical, and Biological Models. *Journal of Environmental Management* 75(2): 93–104.

Weisberg, S. B., W. H. Burton, F. Jacobs, E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge-Wire Screens. *North American Journal of Fisheries Management* 7:386–393.

Wells, B. K., C. B. Grimes, J. C. Field, C .S. Reiss. 2006. Co-variation Between the Average Lengths of Mature Coho (*Oncorhynchus kisutch*) and Chinook Salmon (*O. tshawytscha*) and the Ocean Environment. *Fisheries Oceanography* 15:67–79.

Wells, B. K., J. A. Santora, J. C. Field, R. B. McFarland, B. B. Marinovic, W. J. Sydeman. 2012. Population Dynamics of Chinook Salmon *Oncorhybchus tshawytscha* Relative to Prey Availability in the Central California Coastal Region. *Marine Ecology Progress Series* 457:125–137.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern?* Seminar, University of California, Davis. November 8.

Wilder, R. M., J. F. Ingram. 2006. Temporal Patterns in Catch Rates of Juvenile Chinook Salmon and Trawl Net Efficiencies in the lower Sacramento River. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 19(1):18–28.

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* [online serial] 4(3): Article 2.

Williams, J. G. 2009. *Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan: Life-history Conceptual Model for Chinook Salmon and (*Oncorhynchus tshawytscha *and* O. mykiss*). Sacramento-San Joaquin Delta, Regional Ecosystem* Restoration Implementation Plan.

Williamson, K. S. B. May. 2005. Homogenization of Fall-Run Chinook Salmon Gene Pools in the Central Valley of California, USA. *North American Journal of Fisheries Management* 25:993–1009.

Yoshiyama, R. M., F. W. Fisher, P. B. Moyle. 1998. Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. *North American Journal of Fisheries Management* 18:487–521.

Zeitoun I. H., J. A. Gulvas, D. B. Roarabaugh, 1981. Effectiveness of Fine Mesh Cylindrical Wedge-Wire Screens in Reducing Entrainment of Lake Michigan Ichthyoplankton. *Canadian Journal of Fisheries and Aquatic Sciences* 38(1):120–125.

2A.5.8.2 Federal Register Notices Cited

64 FR 50394. 1999. Final Rule; Notice of Determination: Endangered and Threatened Species; Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California. *Federal Register* 64:50394.

69 FR 19975. 2004. Endangered and Threatened Species; Addition of Species to Species of Concern List. *Federal Register* 69:19975.

70 FR 52488. 2005. Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. *Federal Register* 70:52488.

76 FR 50447. 2011. Endangered and Threatened Species; 5-Year Reviews for 5 Evolutionarily Significant Units of Pacific Salmon and 1 Distinct Population Segment of Steelhead in California *Federal Register* 76:50447.

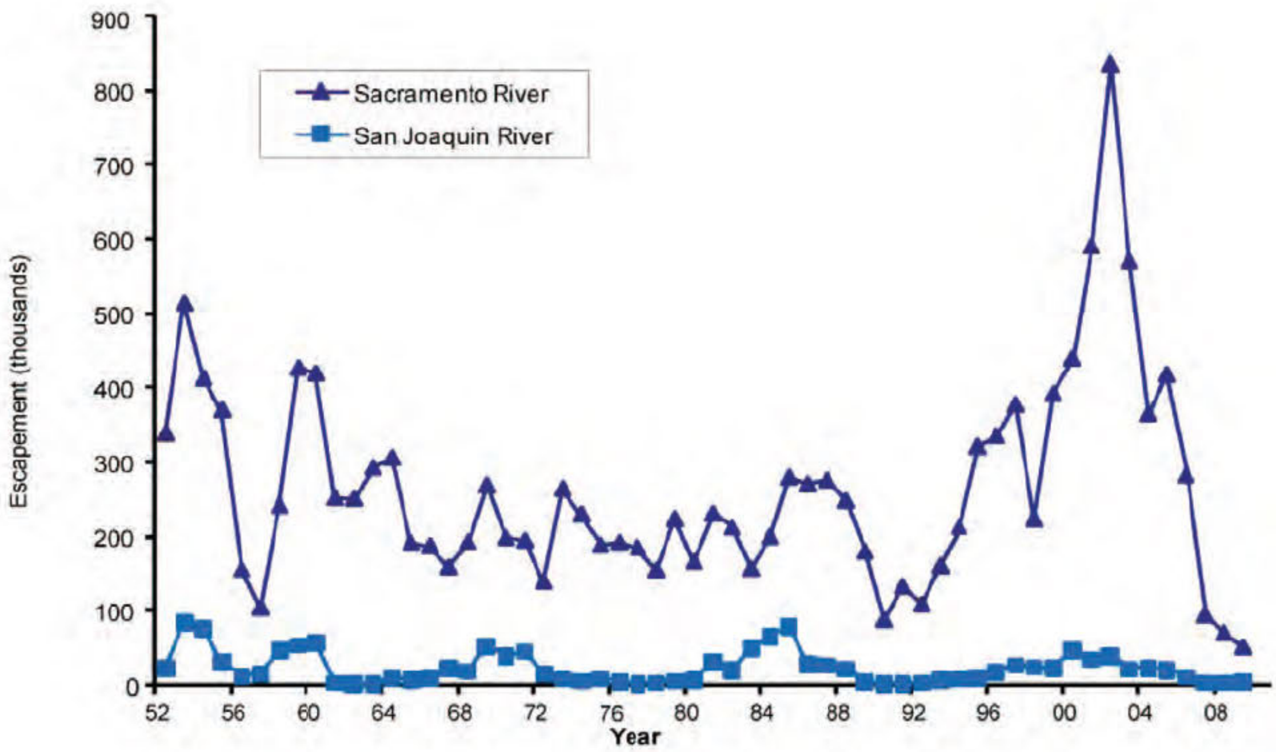
Source: DWR 2007

BDCP-HCP 00343.12 (8-8-12) tm

Figure 2A.5-1
Central Valley Fall-Run Chinook Salmon Inland Range

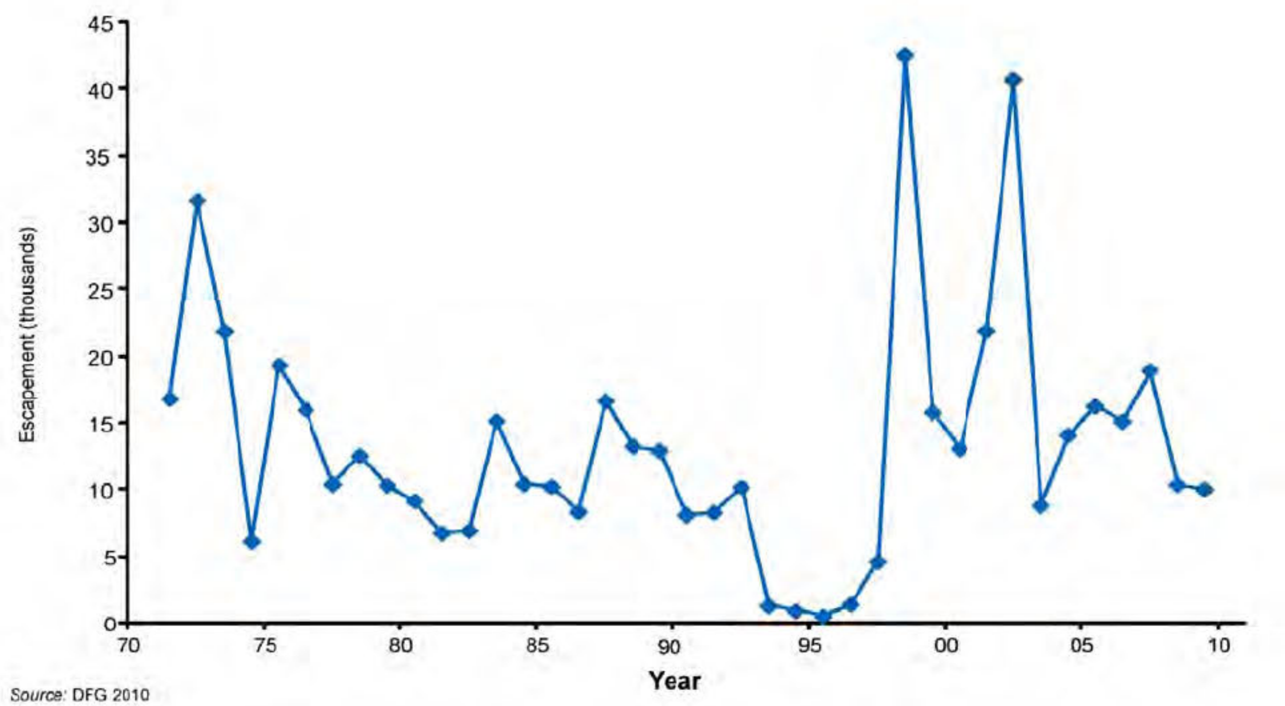
BDCP-HCP 00343.12 (8-8-12) tm

Figure 2A.5-2
Central Valley Late Fall-Run Chinook Salmon Inland Range



SOURCE: California Department of Fish and Game. 2010. Annual spawner escapement estimates for all rivers in the Central Valley. September. Available: <http://www.calfish.org/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/ItemId/123/Default.aspx>.

Figure 2A.5-3
Estimated Historical Spawner Escapement of Central Valley Fall-Run Chinook Salmon (1952–2009)



SOURCE: California Department of Fish and Game. 2010. Annual spawner escapement estimates for all rivers in the Central Valley. September. Available: <http://www.calfish.org/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/ItemId/123/Default.aspx>.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.5-4
Estimated Historical Spawner Escapement of Central Valley Late Fall-Run Chinook Salmon (1971–2009) in the Sacramento River

BDCP-HCP 00343.12 (8-8-12) tm

Figure 2A.5-5
Central Valley Fall-Run Chinook Salmon Inland Essential Fish Habitat

Source: Tierra Data Systems 1998

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.5-6
Central Valley Late Fall-Run Chinook Salmon Inland Essential Fish Habitat

Appendix 2A.6
Central Valley Steelhead (*Oncorhynchus mykiss*)

2A.6.1 Legal Status

The Central Valley steelhead evolutionarily significant unit (ESU) was listed as a threatened species under the federal Endangered Species Act (ESA) on March 19, 1998. This ESU includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin Rivers and their tributaries, including the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) (63 *Federal Register* [FR] 13347). Steelhead from San Francisco and San Pablo Bays and their tributaries were excluded from this listing but were included in the Central California Coast distinct population segment (DPS), which is also listed as threatened under the ESA. On June 14, 2004, the National Marine Fisheries Service (NMFS) proposed that all west coast steelhead be reclassified from ESUs to DPSs and proposed to retain Central Valley steelhead as threatened (69 FR 33102). On January 5, 2006, after reviewing the best available scientific and commercial information, NMFS issued its final decision to retain the status of Central Valley steelhead as a threatened DPS (71 FR 834). This decision included the Coleman National Fish Hatchery and Feather River Hatchery steelhead populations. These populations were previously included in the ESU but were not deemed essential for conservation and thus not part of the listed steelhead population.

On August 15, 2011, after conducting a 5-year review, NMFS issued its findings concerning the status of the Central Valley steelhead DPS (76 FR 50447). Based on new information, NMFS determined that the status of the DPS was worse than the previous review (Good et al. 2005), and the DPS faces an even greater extinction risk. This review found that the decline in natural production of steelhead had continued unabated since the 2005 status review, and the level of hatchery influence on the DPS corresponds to a moderate risk of extinction.

Central Valley steelhead are not listed under the California Endangered Species Act (CESA) but are designated as a California Species of Special Concern.

2A.6.2 Species Distribution and Status

Information on the status and geographic distribution of Central Valley steelhead is extremely limited (The Nature Conservancy et al. 2008). Adult steelhead typically migrate upstream in the Sacramento River between July and the following March, with the peak of the run positioned at the mouth of the Feather River around September (Hallock 1989). Migration duration in the American and Feather Rivers is similar, but the peak of the runs is in December (Hallock 1989). Unlike Chinook salmon, adult steelhead do not necessarily die after spawning and can return to the ocean. Juvenile steelhead cannot be differentiated from resident rainbow trout based on visual characteristics or genetics. In addition, steelhead frequently inhabit streams and rivers that are difficult to access and survey. Thus, information on the trends in steelhead abundance in the Central Valley has primarily been limited to observations at fish ladders and weirs (e.g., Red Bluff Diversion Dam when the gates were closed, Woodbridge Irrigation District dam, and fish ladders on the Mokelumne River) and returns to Central Valley fish hatcheries. Juvenile steelhead are collected incidentally in various fishery surveys (e.g., Mossdale and Chipps Island trawls). However, because of their relatively large size and good swimming performance, juvenile steelhead are able to avoid capture in most fishery surveys. Therefore, information on the distribution, abundance, habitat use, and behavior of steelhead in the Plan Area is very limited.

2A.6.2.1 Range and Status

Central Valley steelhead were widely distributed historically throughout the Sacramento and San Joaquin Rivers (Figure 2A.6-1) (Busby et al. 1996; McEwan 2001). Steelhead inhabited waterways from the upper Sacramento and Pit River systems (now inaccessible because of Shasta and Keswick Dams) south to the Kings River and possibly the Kern River systems, and in both east- and west-side Sacramento River tributaries (Yoshiyama et al. 1996). Lindley et al. (2006) estimated that there were historically at least 81 independent Central Valley steelhead populations distributed primarily throughout the eastern tributaries of the Sacramento and San Joaquin Rivers.

The geographic distribution of spawning and juvenile rearing habitat for Central Valley steelhead has been greatly reduced by the construction of dams (McEwan and Jackson 1996; McEwan 2001). Presently, impassable dams block access to 80% of historically available habitat and all spawning habitat for approximately 38% of historic populations (Lindley et al. 2006). Existing wild steelhead stocks in the Central Valley inhabit the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks, and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996).

Historical Central Valley steelhead run sizes are difficult to estimate given the paucity of data but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s, steelhead run size had declined to approximately 40,000 adults (McEwan 2001). Over the past 30 years, naturally spawned steelhead populations in the upper Sacramento River have declined substantially (Figure 2A.6-2). Until recently, Central Valley steelhead were thought to be extirpated from the San Joaquin River system. However, recent monitoring has detected small self-sustaining populations in the Stanislaus, Mokelumne, and Calaveras Rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001; Zimmerman et al. 2009; National Marine Fisheries Service 2011). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread throughout accessible streams and rivers in the Central Valley (Good et al. 2005). Some of these fish, however, may have been resident rainbow trout, which are the same species but have not found it advantageous to choose anadromy. Nonhatchery stocks of rainbow trout that have anadromous components within them are found in the Upper Sacramento River and its tributaries; Mill, Deer, and Butte Creeks; and the Feather, Yuba, Mokelumne, and Calaveras Rivers (McEwan 2001).

Along with the decline in accessible habitat, there has been a substantial decline in steelhead returning to the upper Sacramento River (Figure 2A.6-2). The reduction in numbers from an average of 6,574 fish from 1967 to 1991, to an average of 1,282 fish from 1992 to 2006, represents a significant drop in the upper Sacramento River populations. Although data are limited, similar population reductions are expected to have occurred throughout the Sacramento–San Joaquin system.

The most recent status review of the Central Valley steelhead DPS (National Marine Fisheries Service 2011) found that the status of the population appears to have worsened since the 2005 status review (Good et al. 2005), when it was considered to be in danger of extinction. Analysis of data from the Chipps Island monitoring program indicates that natural steelhead production has continued to decline and that hatchery origin fish represent an increasing fraction of the juvenile production in the Central Valley. In recent years, the proportion of hatchery produced juvenile steelhead in the catch has exceeded 90%, and in 2010 was 95% of the catch (National Marine Fisheries Service 2011).

2A.6.2.2 Distribution and Status in the Plan Area

The entire population of the Central Valley steelhead DPS must pass through the Plan Area as adults migrating upstream to spawning areas, with juveniles emigrating downstream to the ocean. Adult Central Valley steelhead migrating into the San Joaquin River and its tributaries use the central, southern, and eastern edge of the Delta, whereas adults entering the Sacramento River system to spawn use the northern, western, and central Delta as a migration pathway.

2A.6.3 Habitat Requirements and Special Considerations

Critical habitat for the Central Valley steelhead DPS was designated by NMFS on September 2, 2005 (70 FR 52488) with an effective date of January 2, 2006, and includes 2,308 miles of stream habitat in the Central Valley and an additional 254 square miles of estuarine habitat in the San Francisco-San Pablo-Suisun Bay complex (Figure 2A.6-3). Critical habitat for Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba Rivers; Deer, Mill, Battle, and Antelope Creeks in the Sacramento River basin; the San Joaquin River and its tributaries; and the Delta. Critical habitat includes stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent of critical habitat is defined by the bank-full elevation (defined as the level at which water begins to leave the channel and move into the floodplain. The bank-full elevation occurs at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (70 FR 52488).

Critical habitat for Central Valley steelhead is defined as specific areas that contain the primary constituent elements (PCEs) and physical habitat elements or biological features essential to the conservation of the species (U.S. Fish and Wildlife Service 2004). The following are the habitat types considered PCEs for Central Valley steelhead.

- Freshwater spawning—includes areas with substrate and water quantity and quality that support steelhead spawning, incubation, and larval development.
- Freshwater rearing—includes reaches with water quantity and floodplain connectivity to form and maintain physical habitat conditions to support juvenile steelhead growth and mobility; suitable water quality; availability of suitable prey and forage to support juvenile growth and development; and natural cover habitat.
- Freshwater migration corridors—include areas free of migratory obstructions, with water quantity and quality conditions that enhance migratory movements. They contain natural cover habitat that augments juvenile and adult mobility, survival, and food supply.

- Estuarine rearing—includes areas free of migratory obstructions, with water quality and quantity, and salinity conditions to support juvenile and adult physiological transitions between fresh and salt water. These areas include natural cover and side channels, suitable for juvenile and adult foraging.

While ocean habitat is not designated as critical habitat for Central Valley steelhead, biologically productive coastal waters are an important habitat component for the survival and success of Central Valley steelhead.

2A.6.3.1 Spawning Habitat

Freshwater spawning sites are those with water quantity and quality conditions and substrate supporting spawning, egg incubation, and larval development. Spawning habitat for Central Valley steelhead primarily occurs in mid to upper elevation reaches or immediately downstream of dams located throughout the Central Valley that contain suitable environmental conditions (e.g., seasonal water temperatures, substrate, dissolved oxygen) for spawning and egg incubation. Spawning habitat has a high conservation value because its function directly affects the spawning success and reproductive potential of steelhead.

2A.6.3.2 Freshwater Rearing Habitat

Freshwater steelhead rearing sites contain suitable instream flows, water quantity and quality (e.g., water temperatures), and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility, provide forage species, and include cover such as shade, submerged and overhanging large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Spawning areas and migratory corridors may also function as rearing habitat for juveniles, which feed and grow before and during their out-migration. Rearing habitat value is strongly affected by habitat complexity, food supply, and the presence of predators. Some of these more complex and productive habitats with floodplain connectivity are still present in the Central Valley (e.g., the lower Cosumnes River, Sacramento River reaches with set-back levees [i.e., primarily located upstream of the City of Colusa]). The channeled, leveed, and riprapped river reaches and sloughs common in the lower Sacramento and San Joaquin Rivers and throughout the Delta, however, typically have low habitat complexity and low abundance of food organisms, and offer little protection from predation by fish and birds. Freshwater rearing habitat has a high conservation value because juvenile steelhead are dependent on the function of this habitat for successful survival and recruitment to the adult population.

2A.6.3.3 Freshwater Migration Corridors

Optimal freshwater steelhead migration corridors (including river channels, channels through the Delta, and the Bay-Delta estuary) support mobility, survival, and food supply for juveniles and adults. Migration corridors should be free from obstructions (passage barriers and impediments to migration), provide favorable water quantity (instream flows) and quality conditions (seasonal water temperatures), and contain natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Migratory corridors are typically downstream of the spawning area and include the lower Sacramento and San Joaquin Rivers, the Delta, and the San Francisco Bay complex extending to coastal marine waters. These corridors allow the upstream passage of adults and the downstream emigration of juvenile steelhead. Migratory corridor conditions are strongly affected by the presence of passage barriers, which can include dams, unscreened or poorly screened diversions, and degraded water quality. For freshwater migration corridors to function properly, they must provide adequate passage, provide suitable migration cues, reduce false attraction, avoid areas where vulnerability to predation is increased, and avoid impediments and delays in both upstream and downstream migration. For this reason, freshwater migration corridors are considered to have a high conservation value.

2A.6.3.4 Ocean Habitats

Most juvenile steelhead rear in coastal marine waters for a period of approximately 1 to2 years before returning to the Central Valley rivers as adults to spawn (Burgner et al. 1992 as cited in McEwan and Jackson 1996). During their marine residence, steelhead forage on krill and other marine organisms. Offshore marine areas with water quality conditions and food, including squid, crustaceans, and fish (fish become a larger component in the steelhead diet later in life [Moyle 2002]) that support growth and maturation are important habitat elements. These features are essential for conservation because, without them, juveniles cannot forage and grow to adulthood.

Results of oceanographic studies have shown variation in ocean productivity off the West Coast within and among years. Changes in ocean currents and upwelling have been identified as significant factors affecting nutrient availability, and phytoplankton and zooplankton production in near-shore surface waters. Although the effects of ocean conditions on steelhead growth and survival have not been investigated, recent observations have shown a significant decline in the abundance of adult Chinook and coho salmon returning to California rivers and streams. This decline has been hypothesized to be the result of declines in ocean productivity and associated high mortality rates during the period when these fish were rearing in near-shore coastal waters (MacFarlane et al. 2008). The importance of changes in ocean conditions on growth, survival, and population abundance of Central Valley steelhead, although potentially similar to that of Chinook salmon, is largely unknown.

2A.6.4 Life History

Steelhead can be divided into two life history types based on their state of sexual maturity at the time of river entry and the duration of their spawning migration: stream-maturing and ocean-maturing. Stream-maturing steelhead enter fresh water in a sexually immature condition and require several months to mature prior to spawning, whereas ocean-maturing steelhead enter fresh water with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (i.e., summer [stream-maturing] and winter [ocean-maturing] steelhead). A variation of the two forms occurs in the Central Valley and primarily migrates into the system in the fall, then spawns during the winter and early spring, although this form is referred to as *winter run* (McEwan and Jackson 1996). There are, however, indications that summer steelhead were present in the Sacramento River system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program Steelhead Project Work Team 1999; McEwan 2001). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

There is high polymorphism among steelhead/rainbow trout populations with respect to a continuum from anadromy to permanent freshwater residency (Behnke 1992 as cited in McEwan 2001). Furthermore, there is plasticity in an individual from a specific life history form to assume a different life history strategy if conditions necessitate it (McEwan 2001). For example, if emigrating smolts show reduced survival, an individual may choose not to emigrate to the ocean (Satterthwaite et al. 2010). This polymorphic life history structure provides the flexibility for steelhead to remain persistent in highly variable conditions, particularly near the edges of their range (McEwan 2001).

Central Valley steelhead generally leave the ocean and migrate upstream from August through March (Busby et al. 1996; Hallock et al. 1957; National Marine Fisheries Service 2009a), and spawn from December through April (Newton and Stafford 2011; Bureau of Reclamation 2008). Peak immigration seems to have occurred historically in the fall from late September to late October, with some creeks such as Mill Creek showing a small run in mid-February (Hallock 1989). Peak spawning typically occurs from January through March in small streams and tributaries where cold, well-oxygenated water is available year-round (Table 2A.6-1) (Hallock et al. 1961; McEwan and Jackson 1996). Timing of upstream migration corresponds with higher flow events (e.g., freshets), associated lower water temperatures, and increased turbidity. The peak period of adult immigration appears to be during fall months with fewer immigrants in the winter (as reviewed in McEwan 2001). Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby et al. 1996). It is, however, rare for steelhead to spawn more than twice before dying; individuals that do spawn more than twice tend to be females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996).

Table 2A.6-1. Temporal Occurrence of Adult and Juvenile Central Valley Steelhead in the Central Valley

Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Adult												
Sacramento River [1,3]	Low	Low	Low	–	–	– / Low	Low	Low / Medium	Medium / High	High / Medium	Low	Low
Sacramento River at Red Bluff Diversion Dam[2,3]	Low	Low	Low	Low	Low	Low	Low	Low	Medium	High / Medium	Low	Low
Mill, Deer Creeks[4]	–	High / Medium	Medium / Low	Low	Low	Low	–	–	–	– / High	High / Medium	Medium
Sacramento River at Fremont Weir[5]	Low	Low	–	–	–	–	–	Medium	High	Medium	Low	Low
San Joaquin River[6]	Medium	Medium	Medium	–	–	–	Low	Low	Medium	Medium	Medium	High
Juvenile												
Sacramento River[1,2]	Low	Low	Medium	Medium	Medium	Medium	Low	Low	Low	Medium	Medium	Low
Sacramento River at Knights Landing[2,6]	Low	Low	High	Low	Low / –	–	–	–	–	–	–	– / Low
Sacramento River at Knights Landing[2,6]	Medium	Medium	High	High	Medium	–	–	–	–	–	Low	Low
Chipps Island (wild)[7]	Low	Low	High	High	Medium	Medium	Low	–	–	Low	Low	Low
Mossdale[6]	Low	Low	Low	High	High	Low	Low	–	–	Low	Low	Low
Woodbridge Dam[8]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	–	–	–	–	–
Stanislaus River at Caswell[9,11]	Low	Medium	High	Medium	Medium	Low	–	–	–	–	–	–
Sacramento River at Hood[10]	Low	High	High	High	High	–	–	–	–	–	Low	Low

Relative Abundance: [dark shading] = High [medium shading] = Medium [light shading] = Low

Note: Darker shades indicate months of greatest relative abundance

Sources:
[1] Hallock et al. 1961
[2] McEwan 2001
[3] Hallock 1989
[4] California Department of Fish and Game 1995
[5] Hallock et al. 1957
[6] Hallock 1989
[7] Nobriga and Cadrett 2003
[8] Jones & Stokes Associates Inc., 2002
[9] S.P. Cramer and Associates, Inc. 2000, 2001
[10] Schaffter 1980
[11] Cramer Fish Sciences 2012

After reaching a suitable spawning area, the female steelhead selects a site with good intergravel flow, digs a redd, and deposits eggs while an attendant male fertilizes them. Eggs in the redd are covered with gravel dislodged just upstream. The length of time it takes for eggs to hatch varies in response to water temperature. Optimal spawning temperatures range between from 4°C and 11°C (39°F to 52°F), with egg mortality beginning at about 13°C (55°F) (McEwan and Jackson 1996). Hatching of steelhead eggs in hatcheries takes about 30 days at 10.6°C (51°F). Fry generally emerge from the gravel 4 to 6 weeks after hatching, but factors such as redd depth, gravel size, siltation, and water temperature can speed or retard the time to emergence (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996). Newly emerged fry move to shallow, protected areas with lower water velocities associated with the stream margin, and soon establish feeding locations in the juvenile rearing habitat (Shapovalov and Taft 1954, as cited in McEwan and Jackson 1996).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by habitat complexity, primarily in the form of large and small woody debris and boulders. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991, as cited in McEwan and Jackson 1996).

About 70% of Central Valley steelhead spend 2 years within their natal streams before migrating out of the Sacramento-San Joaquin system as smolts, with small percentages (29%) and (1%) spending 1 or 3 years, respectively (Hallock et al. 1961). Juvenile steelhead emigrate primarily from natal streams in the spring in response to the first heavy runoff, and again in the fall (Hallock et al. 1961). Emigrating Central Valley steelhead use the lower reaches of the Sacramento and San Joaquin Rivers and the Delta as a migration corridor to the ocean. Juvenile Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects, and will take active bottom invertebrates (Moyle 2002).

Nobriga and Cadrett (2001) verified these temporal findings (spring migration) based on analysis of captures in U.S. Fish and Wildlife Service (USFWS) salmon monitoring conducted near Chipps Island. Diversity and richness of habitat and food sources in the estuary allow juveniles to attain a larger size before entry into the ocean, thereby increasing their chances for survival in the marine environment.

Central Valley steelhead typically spend from several months to 2 years in the Pacific Ocean before returning to fresh water to spawn. The age composition of the steelhead population in the Pacific Ocean is dominated by 1-year-old (61.9%) and 2-year-old (31.4%) fish (Burgner et al. 1992). Ocean migration and distribution of Central Valley steelhead stocks is unknown.

Steelhead experience most of their marine phase mortality soon after they enter the Pacific Ocean (Pearcy 1992). Ocean mortality is poorly understood, however, because few studies have been conducted to evaluate the importance of various factors, including predation mortality, changes in ocean currents, water temperatures, and coastal upwelling, on steelhead survival. Possible causes of ocean mortality include predation, competition, starvation, osmotic stress, unauthorized driftnet fisheries on the high seas, disease, advective losses, and other poor environmental conditions (Wooster 1983; Cooper and Johnson 1992; Pearcy 1992). Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992).

Ocean and climate conditions such as sea surface temperatures, air temperatures, strength of upwelling, El Niño events, salinity, ocean currents, wind speed, and primary and secondary productivity affect all facets of the physical, biological, and chemical processes in the marine environment. Some of the conditions associated with El Niño events include warmer water temperatures, weak upwelling, low primary productivity (which leads to decreased zooplankton biomass), decreased southward transport of subarctic water, and increased sea levels (Pearcy 1992). For juvenile steelhead, warmer water and weak upwelling are possibly the most important of the ocean conditions associated with El Niño. Because of the weakened upwelling during an El Niño year, juvenile California steelhead must migrate more actively offshore through possibly stressful warm waters with numerous inshore predators. Strong upwelling is probably beneficial because of the greater transport of smolts offshore, beyond major concentrations of inshore predators (Pearcy 1992). Investigations are currently under way to examine decadal oscillations in coastal marine environmental conditions and the associated biological changes that may affect the survival, growth, and recruitment of steelhead to the adult population.

2A.6.5 Threats and Stressors

The following conditions are important threats and stressors to Central Valley steelhead.

2A.6.5.1 Reduced Staging and Spawning Habitat

Adult steelhead historically migrated upstream into higher gradient reaches of rivers and tributaries where water temperatures were cooler, turbidity was lower, and gravel substrate size was suitable for spawning and egg incubation (McEwan 2001). Steelhead are known to migrate upstream into higher gradient and elevation reaches of the rivers and streams than fall-run Chinook salmon, which predominantly spawn at lower elevations in the valley floor. Most historical adult staging/holding and spawning habitat for Central Valley steelhead is no longer accessible to upstream migrating steelhead. Habitat has been eliminated or degraded by artificial structures (e.g., dams and weirs) associated with water storage and conveyance; diversions; flood control; and municipal, industrial, agricultural, and hydropower purposes (Figure 2A.6-1) (McEwan and Jackson 1996; McEwan 2001; Bureau of Reclamation 2004; Lindley et al. 2006; National Marine Fisheries Service 2007). These impediments and barriers to upstream passage limit the geographic distribution of steelhead to lower elevation habitats in the Central Valley.

Steelhead in the Central Valley migrate upstream into the mainstem Sacramento River and major tributaries (e.g., American and Feather Rivers; Clear and Battle Creeks), and are also known to occur in tributaries to the San Joaquin River (e.g., Mokelumne, Cosumnes, Stanislaus, Merced, Tuolumne Rivers), where they spawn and rear. Steelhead do not currently spawn in the mainstem San Joaquin River. The majority of current steelhead spawning habitat exists upstream of the Red Bluff Diversion Dam on the Sacramento River and its tributaries. Although the overall effect of operations of the dam on the Central Valley steelhead populations is not well understood, concerns have been expressed regarding the effect of gate operations on upstream and downstream migration by steelhead. Additional concerns include the potential for increased vulnerability of juvenile steelhead to predation by Sacramento pikeminnow, striped bass, and other predators that pass through the Red Bluff Diversion Dam gates or fish ladder.

Reduced flows from dams and upstream water diversions can lower attraction cues for adult spawners, causing straying and delays in spawning or the inability to spawn (California Department of Water Resources 2005). Adult steelhead migration delays can reduce fecundity and egg viability and increase susceptibility to disease and harvest.

2A.6.5.2 Reduced Rearing and Out-Migration Habitat

Juvenile steelhead prefer to utilize natural stream banks, floodplains, marshes, and shallow water habitats for rearing during out-migration. Modification of natural flow regimes from upstream reservoir operations has resulted in dampening of the hydrograph in most Central Valley rivers, reducing the extent and duration of inundation of floodplains and other flow-dependent habitat used by migrating juvenile steelhead (California Department of Water Resources 2005; 70 FR 52488). Changes in river hydrology that have affected floodplain inundation may have affected areas thought to provide significant growth benefits to rearing fish (Sommer et al. 2001). Reductions in flow rates have also resulted in increased water temperature and residence time, and reductions in dissolved oxygen levels in localized areas of the Delta (e.g., Stockton Deep Water Ship Channel), which affect the value of rearing and migration habitat. Reduced dissolved oxygen levels in the lower San Joaquin River during late summer and early fall have been identified as a barrier and/or impediment to migration for some salmonids (Regional Water Resources Control Board 2003), including Central Valley steelhead (Jassby and Van Nieuwenhuyse 2005). The data derived from the California Data Exchange Center files indicate that dissolved oxygen depressions occur during all migratory months, with significant events occurring from November through March when Central Valley steelhead adults and smolts would be utilizing this portion of the San Joaquin River as a migratory corridor (National Marine Fisheries Service 2012).

Much of the Delta has been leveed, channelized, and fortified with riprap for flood protection, reducing and degrading the quality and availability of natural habitat for use by steelhead during migration (McEwan 2001). Furthermore, impacts on the value, quantity, and availability of suitable habitat are likely to reduce fitness and increase susceptibility to entrainment, disease, exposure to contaminants, and predation.

2A.6.5.3 Predation by Nonnative Species

Native species such as the Sacramento pikeminnow are a potentially significant source of mortality in the Sacramento River at locations such as the Red Bluff Diversion Dam. However, predation by nonnative species is of particular concern. In general, the effect of nonnative predation on the Central Valley steelhead DPS is unknown but predation is most likely a threat in areas with high densities of nonnative fish (e.g., small and large mouth bass, striped bass, and catfish), which are thought to prey on out-migrating juvenile steelhead. Predation risk may covary with increased temperatures. Metabolic rates of nonnative, predatory fish increase with increasing water temperatures based on bioenergetic studies (Loboschefsky et al. 2009; Miranda et al. 2010). Upstream gravel pits and flooded ponds, such as those that occur on the San Joaquin River and its tributaries, attract nonnative predators because of their depth and lack of cover for juvenile steelhead (California Department of Water Resources 2005). Nonnative aquatic vegetation, such as Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*), provide suitable habitat for nonnative predators (Brown and Michniuk 2007). The low spatial complexity of channelized waterways (e.g., riprap-lined levees that provide virtually no cover protection from predators) and general low habitat diversity elsewhere in the Delta reduces refuge cover and protection of steelhead from predators (Raleigh et al. 1984; Missildine et al. 2001; 70 FR 52488).

2A.6.5.4 Harvest

Steelhead have been, and continue to be, an important recreational fishery in inland rivers throughout the Central Valley. Although there are no commercial fisheries for steelhead, inland steelhead fisheries include tribal and recreational fisheries. In the Central Valley, recreational fishing for steelhead of hatchery origin is popular, but harvest is restricted to only visibly marked fish of hatchery origin (adipose fin clipped). Unmarked steelhead (adipose fin intact) must be released, reducing the take of naturally spawned wild fish. The level of illegal harvest of Chinook salmon and steelhead in the Delta and bays is unknown.The effects of recreational fishing and this unknown level of illegal harvest on the abundance and population dynamics of wild Central Valley steelhead have not been quantified.

2A.6.5.5 Reduced Genetic Diversity and Integrity

Artificial propagation programs for steelhead in Central Valley hatcheries present multiple threats to the wild steelhead population, including mortality of natural steelhead in fisheries targeting hatchery origin steelhead, competition for prey and habitat, predation by hatchery origin fish on younger natural fish, disease transmission, and impediments to fish passage imposed by hatchery facilities. It is now recognized that Central Valley hatcheries are a significant and persistent threat to wild Chinook salmon and steelhead populations and fisheries (National Marine Fisheries Service 2009b). One major concern with hatchery operations is the genetic introgression by hatchery origin fish that spawn naturally and interbreed with local natural populations (U.S. Fish and Wildlife Service 2001; Bureau of Reclamation 2004; Goodman 2005). Such introgression introduces maladaptive genetic changes to the wild steelhead stocks (McEwan and Jackson 1996; Myers et al. 2004). Hatchery operations have been found to decrease Chinook salmon fitness (Araki et al. 2007). Taking eggs and sperm from a large pool of individuals is one method for ameliorating genetic introgression, but artificial selection for traits that assure individual success in a hatchery setting (e.g., rapid growth and tolerance to crowding) are unavoidable (Bureau of Reclamation 2004).

The increase in Central Valley hatchery production has reversed the composition of the steelhead population, from 88% naturally produced fish in the 1950s (McEwan 2001) to an estimated 23% to 37% naturally produced fish by 2000 (Nobriga and Cadrett 2003), and less than 10% currently (National Marine Fisheries Service 2011). The increase production of in hatchery steelhead has reduced the viability of the wild steelhead populations (National Marine Fisheries Service 2012).

2A.6.5.6 Entrainment

Juvenile steelhead migrating downstream through the Delta are vulnerable to entrainment and salvage at the State Water Project (SWP) and Central Valley Project (CVP) export facilities, primarily between March and May (Table 2A.6-1). Multiple factors can influence the vulnerability of juvenile steelhead to entrainment by SWP/CVP export facilities, including the geographic distribution of steelhead in the Delta and hydrodynamic factors such as reverse flows in the Old and Middle Rivers, which are a function of export operations relative to San Joaquin River inflows, and southward flows of Sacramento River water towards pumps through an open Delta Cross Channel and Georgiana Slough. SWC/CVP exports have been shown to affect the tidal hydrodynamics (e.g., water current velocities and direction). The magnitude of these hydrodynamic effects varies in response to a variety of factors including tidal stage and magnitude of ebb and flood tides, the rate of SWP/CVP exports, operation of the Clifton Court Forebay radial gate opening, and inflow from upstream tributaries. Steelhead respond behaviorally to hydraulic cues (e.g., water currents) during both upstream adult and downstream juvenile migration through the Delta. Changes in these hydraulic cues as a result of SWP/CVP export operations when steelhead are migrating through Delta channels may contribute to attraction to false migration pathways, delays in migration, or increased movement of migrating steelhead toward the export facilities where there is an increased risk of entrainment and/or predation at the salvage facilities. The California Department of Water Resources and Bureau of Reclamation (1999) found significant relationships between total monthly exports in January through May and monthly steelhead salvage at SWP/CVP facilities, suggesting the risk of steelhead entrainment is related, in part, to export rates. During the past several years, additional investigations have used radio- or acoustically tagged juvenile and adult (post spawning adults) steelhead to monitor their migration behavior through the Delta channels and to assess the effects of changes in hydraulic cues and SWP/CVP export operations on migration (Holbrook et al.

2009; Perry et al. 2010; San Joaquin River Group Authority 2010). These studies are ongoing. Studies have also been conducted to assess the potential losses of juvenile steelhead to predation by adult striped bass during passage through Clifton Court Forebay (Clark et al. 2009). Results of these studies have estimated that prescreen losses of juvenile steelhead in Clifton Court Forebay are greater than 80%.

In addition to SWP/CVP export facilities, there are more than 2,200 small water diversions in the Delta, of which the majority are unscreened (Herren and Kawasaki 2001). The risk of entrainment is a function of the size of juvenile fish and the slot opening of the screen mesh (Tomljanovich et al. 1978; Schneeberger and Jude 1981; Zeitoun et al. 1981; Weisberg et al. 1987). Although entrainment/salvage of steelhead at the SWP/CVP export facilities is well documented, it is unclear how many juvenile steelhead are entrained at other unscreened Delta diversions. Because steelhead are moderately large (greater than 200-millimeter fork length) and relatively strong swimmers when out-migrating, the effects on steelhead of small in-Delta agricultural water diversions are thought to be lower than those on other Central Valley salmonids. In addition, many of the juvenile steelhead migrate downstream through the Delta during the late winter or early spring before many of the agricultural irrigation diversions are operating. Power plants in the Plan Area have the ability to impinge juvenile steelhead on the existing intake screens. However, use of cooling water is currently low with the retirement of older units. Furthermore, newer units are equipped with a closed-cycle cooling system that virtually eliminates the risk of impingement of juvenile steelhead.

2A.6.5.7 Exposure to Toxins

Toxic chemicals are widespread throughout the Delta and may occur on a more localized scale in response to episodic events (e.g., stormwater runoff, point source discharges, etc.). These toxic substances include mercury, selenium, copper, pyrethroids, and endocrine disruptors with the potential to affect fish health and condition, and negatively affect steelhead distribution and abundance directly or indirectly. Some loads of toxics, such as selenium, are much higher in the San Joaquin River than the Sacramento River because they are naturally occurring in the alluvial soils and have been leached by irrigation water and concentrated by evapotranspiration (Nichols et al. 1986). This may indicate that the potential effects of chronic exposure could be greater for steelhead of San Joaquin River origin. Additionally, agricultural return flows that may contain toxic chemicals are widely distributed throughout the Sacramento and San Joaquin Rivers and the Delta, although dilution flows from the rivers may reduce chemical concentrations to sublethal levels. Sublethal concentrations of toxic substances may interact with other stressors on salmonids, such as increasing their vulnerability to predation or disease (Werner 2007). For example, Clifford et al. (2005) found in a laboratory setting that juvenile fall-run Chinook salmon exposed to sublethal levels of a common pyrethroid, esfenvalerate, were more susceptible to infectious hematopoietic necrosis virus than those not exposed to esfenvalerate. Although not tested on steelhead, a similar response is likely; however, juvenile steelhead generally migrate through the Delta in a comparatively shorter time than Chinook salmon. The short duration may decrease juvenile steelhead exposure and susceptibility to toxic substances in the Delta. Adult migrating steelhead may be less affected by toxins in the Delta because they are not feeding, and thus not bioaccumulating toxic exposure, and they are moving rapidly through the system.

Iron Mountain Mine, located adjacent to the upper Sacramento River, has been a source of trace elements that are known to adversely affect aquatic organisms (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Storage limitations and limited availability of dilution flows have caused downstream copper and zinc levels to exceed salmonid tolerances and resulted in documented fish kills in the 1960s and 1970s (Bureau of Reclamation 2004). The U.S. Environmental Protection Agency's Iron Mountain Mine remediation program has removed toxic metals in acidic mine drainage from the Spring Creek watershed with a state-of-the-art lime neutralization plant. Contaminant loading into the Sacramento River from Iron Mountain Mine has shown measurable reductions since the early 1990s.

Ammonia[1] released from the City of Stockton Wastewater Treatment Plant contributes to the low dissolved oxygen in the adjacent Deep Water Ship Channel. In addition to the adverse effects of the lowered dissolved oxygen on salmonid physiology, ammonia is toxic to salmonids at low concentrations. Actions have been implemented to remedy this source of ammonia, by modifying the treatment train at the wastewater facility (National Marine Fisheries Service 2012).

2A.6.5.8 Increased Water Temperature

Water temperature is among the physical factors that affect the value of habitat for salmonid adult holding, spawning and egg incubation, juvenile rearing, and migration. Adverse sublethal and lethal effects can result from exposure to elevated water temperatures at sensitive life stages, such as during incubation or rearing. Water temperature criteria for various life stages of salmonids in the Central Valley have been developed by the NMFS (2009a). The tolerance of steelhead water temperatures depends on life stage, acclimation history, food availability, duration of exposure, health of the individual, and other factors such as predator avoidance (Myrick and Cech 2004; Bureau of Reclamation 2004). Higher water temperatures can lead to physiological stress, reduced growth rate, reduced spawning success, and increased mortality of steelhead (Myrick and Cech 2001). Temperature can also indirectly influence disease incidence and predation (Waples et al. 2008). Exposure to seasonally elevated water temperatures may occur from reductions in flow because of upstream reservoir operations, reductions in riparian vegetation, channel shading, local climate, and solar radiation. The installation of the Shasta Temperature Control Device in 1998, in combination with reservoir management to maintain the cold water pool, has reduced many of the temperature issues on the Sacramento River. During dry years, however, the release of cold water from Shasta Dam is still limited. As the river flows farther downstream, particularly during the warm spring, summer, and early fall months, water temperatures continue to increase until they reach thermal equilibrium with atmospheric conditions. Because of the longitudinal gradient of seasonal water temperatures, the coldest water and, therefore, the best areas for steelhead spawning and rearing are typically located immediately downstream of the dam.

Increased temperature can also arise from a reduction in shade over rivers by tree removal (Watanabe et al. 2005). Because river water is typically in thermal equilibrium with atmospheric conditions by the time it enters the Delta, this issue is caused primarily by actions upstream of the Delta. Because the Delta channels are relatively wide, additional riparian vegetation will not significantly reduce water temperatures.

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

2A.6.6 Relevant Conservation Efforts

Because steelhead biology is similar to that of Chinook salmon, few conservation actions are specific to steelhead. Efforts by the California Department of Fish and Wildlife (CDFW) to restore Central Valley steelhead are described in *Steelhead Restoration and Management Plan for California* (McEwan and Jackson 1996). Measures to protect steelhead throughout the state of California have been in place since 1998, and a wide range of measures have been implemented, including 100% marking of all hatchery steelhead, zero bag limits for unmarked steelhead, gear restrictions, closures, and size limits designed to protect rearing juveniles and smolts. The Central Valley Steelhead Project Work Team, an interagency technical working group led by CDFW, drafted a proposal to develop a comprehensive steelhead monitoring plan that was selected by the CALFED Bay-Delta Program (CALFED) Ecosystem Restoration Program Implementing Agency Managers for directed action funding. Long-term funding for implementation of the monitoring plan still needs to be secured.

Biological opinions for SWP/CVP operations (e.g., National Marine Fisheries Service 2009a) and other federal projects involving irrigation and water diversion and fish passage, for example, have improved or minimized adverse effects on steelhead in the Central Valley. In 1992, an amendment to the authority of the CVP through the Central Valley Project Improvement Act was enacted to give protection of fish and wildlife equal priority with other Central Valley Project objectives. Several programs under this act have benefited listed salmonids. The USFWS's Anadromous Fish Restoration Program is engaged in monitoring, education, and restoration projects designed to contribute toward doubling the natural populations of select anadromous fish species residing in the Central Valley. Restoration projects funded through the program include fish passage, fish screening, riparian easement and land acquisition, development of watershed planning groups, instream and riparian habitat improvement, and gravel replenishment. The program combines federal funding with state and private funds to prioritize and construct fish screens on major water diversions mainly in the upper Sacramento River. The goal of the Water Acquisition Program is to acquire water supplies to meet the habitat restoration and enhancement goals of the Central Valley Project Improvement Act, and to improve the ability of the U.S. Department of the Interior to meet regulatory water quality requirements. Water has been used to improve fish habitat for Central Valley steelhead by maintaining or increasing instream flows on Butte and Mill Creeks and the San Joaquin River at critical times. Additionally, salmonid entrainment at the SWP/CVP export facilities is decreased by reducing seasonal diversion rates during periods when protected fish species are vulnerable to export related losses.

Two programs included under CALFED, the Ecosystem Restoration Program and the Environmental Water Account, were created to improve conditions for fish, including steelhead, in the Central Valley. Restoration actions implemented by the Ecosystem Restoration Program include the installation of fish screens, modification of barriers to improve fish passage, habitat acquisition, and instream habitat restoration. The majority of these actions address key factors affecting listed salmonids, and emphasis has been placed on tributary drainages with high potential for Central Valley steelhead and spring-run Chinook salmon production. Additional ongoing actions include efforts to enhance fishery monitoring and directly support salmonid production through hatchery releases. The Environmental Water Account has been under scrutiny recently as to its success in meeting its original goal.

A major CALFED Ecosystem Restoration Program action currently under way is the Battle Creek Salmon and Steelhead Restoration Project. The project will restore 77 kilometers (48 miles) of habitat in Battle Creek to support steelhead and Chinook salmon spawning and juvenile rearing at a cost of over $90 million. The project includes removal of five small hydropower diversion dams, construction of new fish screens and ladders on another three dams, and construction of several hydropower facility modifications to ensure the continued hydropower operations. It is thought that this restoration effort is the largest cold-water restoration project to date in North America.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements in the Delta (California Department of Fish and Game 2007). The DRERIP team has created a suite of ecosystem and species conceptual models, including steelhead, that document existing scientific knowledge of Delta ecosystems. The team has used these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models were used in the analysis of proposed conservation measures.

Oroville Dam Federal Energy Regulatory Commission relicensing efforts on the Feather River have considered instream flows and temperature management for steelhead spawning and juvenile rearing downstream of the dam.

Multiple fish passage projects have been recently implemented for steelhead and other salmonids in the Sacramento and San Joaquin Watersheds. Multiple large diversions on the Sacramento River (e.g., Glenn-Colusa Irrigation District, Reclamation District 108, Reclamation District 1004, Sutter Mutual, and Wilkins Slough) have been equipped with positive barrier fish screens to reduce entrainment of steelhead and other salmonids. The Woodbridge Irrigation District Dam on the Mokelumne River was designed to improve upstream and downstream passage of steelhead and other salmonids by installing fish screens and fish ladders at the dam.

Mitigation under the Delta Fish Agreement has increased the number of wardens enforcing harvest regulations for steelhead and other fish in the Delta and upstream tributaries by creating the Delta Bay Enhanced Enforcement Program. Initiated in 1994, the program currently consists of nine wardens and a supervisor.

Many smaller tributaries to the Sacramento and San Joaquin Rivers have local watershed conservancies with master plans to contribute to conservation and recovery of steelhead and other salmonids.

2A.6.7 Recovery Goals

The draft recovery plan for Central Valley salmonids, including steelhead, was released on October 19, 2009 (National Marine Fisheries Service 2009b). Although not final, the overarching goal in the public draft is the removal of, among other listed salmonids, the Central Valley steelhead DPS from the federal List of Endangered and Threatened Wildlife (National Marine Fisheries Service 2009b). Several objectives and related criteria represent the components of the recovery goal, including the establishment of at least two viable populations in each historical diversity group, as well as other measurable biological criteria.

2A.6.8 References Cited

2A.6.8.1 Literature Cited

Araki, H., B. Cooper, and M.S. Blouin. 2007. Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild. *Science* 318:100–103.

Behnke, R. J. 1992. Native Trout of Western North America. *American Fisheries Society Monograph* 6:275.

Brown, L. R. and D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30:186–200.

Bureau of Reclamation. 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan, Biological Assessment.* Mid-Pacific Region. Available: <http://www.usbr.gov/mp/cvo/ocap/OCAP_6_30_04.pdf>.

Bureau of Reclamation. 2008. *Biological Assessment of the Continued Long-Term Operations of the Central Valley Project and the State Water Project*. Available: <http://www.usbr.gov/mp/cvo/ocap_page.html>.

Burgner, R. L., J. T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and Origins of Steelhead Trout (*Oncorhynchus mykiss*) in Offshore Waters of the North Pacific Ocean. *International North Pacific Fisheries Commission Bulletin* 51.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. *Status Review of West Coast steelhead from Washington, Idaho, Oregon and California.* U.S. Department of Commerce. NOAA Technical Memo. NMFS-NWFSC-27.

California Department of Fish and Game. 1995. *Fish Species of Special Concern in California, Spring-run Chinook Salmon.* Habitat Conservation Planning Branch. Available: <http://www.dfg.ca.gov/hcpb/species/ssc/sscfish/sprngrnchnok.htm>. Accessed: June 21, 2007.

California Department of Fish and Game. 2007. *Delta Regional Ecosystem Restoration Implementation Plan.* Available: <http://www.delta.dfg.ca.gov/erpdeltaplan>. Accessed: February 25, 2008.

California Department of Water Resources and Bureau of Reclamation. 1999. *Biological Assessment: Effects of the Central Valley Project and State Water Project operations from October 1998 through March 2000 on Steelhead and Spring-Run Chinook Salmon.*

California Department of Water Resources. 2005. Bulletin 250. *Fish Passage Improvement.* Available <http://www.watershedrestoration.water.ca.gov/fishpassage/b250/content.html>.

Clark, K. W., M. D. Bowen, R. B. Mayfield, K. P. Zehfuss, J. D. Taplin, and C. H. Hanson. 2009. *Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay*. Fishery Improvements Section, Bay-Delta Office, California Department of Water Resources: Sacramento, CA. March. Available: <http://baydeltaoffice.water.ca.gov/ndelta/fishery/documents/2009_clark_et_al_quantification_of_steelhead_pre-screen_loss.pdf>.

Clifford, M. A., K. J. Eder, I. Werner, and R. P. Hendrick. 2005. Synergistic Effects of Esfenvalerate and Infectious Hematopoietic Necrosis Virus on Juvenile Chinook Salmon Mortality. *Environmental Toxicology and Chemistry* 24:1766–1772.

Cooper, R. and T. H. Johnson. 1992. *Trends in Steelhead Abundance in Washington and along the Pacific Coast of North America.* Fisheries Management Division, Report 92-20. Olympia, WA: Washington Department of Wildlife.

Cramer Fish Sciences. 2012. *Juvenile Salmonid Out-Migration Monitoring at Caswell Memorial State Park in the Lower Stanislaus River, California. 2010-2011* Biannual Report. Prepared for U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program. Grant No. 813326G008.

Cramer, S. P. and Associates, Inc. 2000. *Stanislaus River Data Report.* Oakdale, California.

Cramer, S. P. and Associates, Inc. 2001. *Stanislaus River Data Report.* Oakdale, California.

Good, T. P., R. S. Waples, and P. Adams (eds.). 2005. *Updated Status of Federally Listed ESU Of West Coast Salmon And Steelhead.* U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-66.

Goodman, D. 2005. Selection Equilibrium for Hatchery and Wild Spawning Fitness in Integrated Breeding Programs. *Canadian Journal of Fisheries and Aquatic Sciences* 62:374–389.

Hallock, R. J. 1989. *Upper Sacramento River Steelhead,* Onchorhychus mykiss, *1952–1988.* Report to the U.S. Fish and Wildlife Service, September 15.

Hallock, R. J., D. H. Fry, and D. A. LaFaunce. 1957. The Use of Wire Fyke Traps to Estimate the Runs of Adult Salmon and Steelhead in the Sacramento River. *California Fish and Game* 43(4):271–298.

Hallock, R. J., W. F. Van Woert, and L. Shapovalov. 1961. An Evaluation of Stocking Hatchery Reared Steelhead Rainbow (*Salmo gairdnerii gairdnerii*) in the Sacramento River System. *California Department of Fish and Game Bulletin* No. 114.

Herren, J .R. and S. S. Kawasaki. 2001. Inventory of Water Diversion in Four Geographic Areas in California's Central Valley. Contributions to the Biology of Central Valley Salmonids. *Fish Bulletin 179* (2):343–355.

Holbrook, C. M., R. W. Perry, N. S. Adams. 2009. *Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008.* Open-File Report 2009-1204. Available: <http://pubs.usgs.gov/of/2009/1204/>.

Interagency Ecological Program Steelhead Project Work Team. 1999. Monitoring, Assessment, and Research on Central Valley Steelhead: Status of Knowledge, Review Existing Programs, and Assessment Needs. In: *Comprehensive Monitoring, Assessment, and Research Program Plan*, Technical Appendix VII-11.

Jassby, A. D. and E. E. Van Nieuwenhuyse. 2005. Low DO in an Estuarine Channel (San Joaquin River, California): Mechanisms and Models Based on Long-Term Time Series. *San Francisco Estuary and Watershed Science* [online serial] 3(2): Article 2.

Jones & Stokes Associates, Inc. 2002. *Foundation Runs Report for Restoration Action Gaming Trials.* Prepared for Friant Water Users Authority and Natural Resource Defense Council.

Lindley, S. T., R. Schick, A. Agrawal, M. Goslin, T. E. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical Population Structure of Central Valley Steelhead and Its Alteration by Dams. *San Francisco Estuary and Watershed Science* 4(2):Article 3. Available: <http://escholarship.org/uc/item/1ss794fc>.

Loboschefsky, E., G. Benigno, T. Sommer, T. Ginn, A. Massoudieh, K. Rose, and F. Loge. 2009. *Bioenergetic Modeling of Striped Bass Predation in California from 1969-2004.* Unpublished manuscript.

MacFarlane, B. R., S. Hayes, and B. Wells. 2008. *Coho and Chinook Salmon Decline in California During the Spawning Seasons of 2007/08.* Paper distributed at BDCP Steering Committee meeting, February 8. Available: <http://www.resources.ca.gov/bdcp/docs/2.8.08_HO_Decline_of_salmon_in_California_in_2007.pdf>.

McEwan, D. R. 2001. Central Valley Steelhead. In R. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids.* California Department of Fish and Game. Fish Bulletin No. 179.

McEwan, D. R. and T. Jackson. 1996. *Steelhead Restoration and Management Plan for California.* California Department of Fish and Game. February.

Meehan W. R. and T. C. Bjornn. 1991. Salmonid Distribution And Life Histories. In: W. R. Meehan(ed.). *Influence of Forest And Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication* 19:47–82.

Miranda J, R. Padilla, J. Morinaka, J. DuBois, and M. Horn. 2010. *Release Site Predation Study.* California Department of Water Resources.

Missildine, B., R. Peters, R. Piaskowski, and R. Tabor. 2001. *Habitat Complexity, Salmonid Use, and Predation of Salmonids at the Bioengineered Revetment at the Maplewood Golf Course on the Cedar River, Washington.* Miscellaneous report. Lacey, WA: U.S. Fish and Wildlife Service, Western Washington Office.

Moyle, P. B. 2002. *Inland Fishes of California*, Revised and Expanded. Berkeley, CA: University of California Press.

Myers, R. A., S. A. Levin, R. Lande, F. C. James, W. W. Murdock, and R. T. Paine. 2004. Hatcheries and Endangered Salmon. *Science* 303:1980.

Myrick C. A. and J. J. Cech, Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations.* Bay-Delta Modeling Forum Technical Publication 01-1. Available: <http://www.cwemf.org/Pubs/TempReview.pdf>.

Myrick C. A. and J. J. Cech, Jr. 2004. Temperature Effects on Juvenile Anadromous Salmonids in California's Central Valley: What Don't We Know? *Reviews in Fish Biology and Fisheries* 14: 113–123.

National Marine Fisheries Service. 2007. *2007 Federal Recovery Outline for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead.* Available: <http://swr.nmfs.noaa.gov/recovery/Concurrence-2007_Recovery_Outline_for_ESU.pdf>. Accessed: May 2007.

National Marine Fisheries Service. 2009. *Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. June 4. Long Beach, CA. Available: <http://www.swr.noaa.gov/ocap/NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the _CVP_and_SWP.pdf>.

National Marine Fisheries Service. 2009b. *Public Draft Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead.* Sacramento Protected Resources Division. October.

National Marine Fisheries Service. 2011. *Central Valley Recovery Domain, 5-Year Review: Summary and Evaluation of Central Valley Spring-Run Chinook Salmon ESU.* Southwest Region, Long Beach CA.

National Marine Fisheries Service. 2012. *Biological Opinion: Formal Consultation for the California Department of Water Resources, 2012 Georgiana Slough Non-Physical Barrier Study.* Southwest Region. February.

Newton, J. M. and L. A. Stafford. 2011. *Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from March through November 2009*. Red Bluff, CA: U.S. Fish and Wildlife Service.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The Modification of an Estuary. *Science* 231:567–573.

Nobriga, M., and P. Cadrett. 2001. Differences Among Hatchery and Wild Steelhead: Evidence from Delta Fish Monitoring Programs. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 14(3):30–38.

Pearcy, W. G. 1992. *Ocean Ecology of North Pacific Salmonids.* Seattle, WA: University of Washington Press.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Raleigh R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. *Habitat Suitability Information: Rainbow Trout*. Washington, DC: U.S. Fish and Wildlife Service, FWS/OBS-82/10.60.

Regional Water Resources Control Board. 2003. *Total Maximum Daily Load for Low Dissolved Oxygen in the San Joaquin River.* Available: <http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/san_joaquin_oxygen/low_do_report_6-2003/do_tmdl_rpt.pdf>. Accessed: June 2003.

San Joaquin River Group Authority. 2010. *On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan.* 2009 Annual Technical Report.

Satterthwaite, W. H., M. P. Beakes, E. M. Collins, D. R. Swank, J. E. Merz, R. G. Titus, S. M. Sogard, and M. Mangel. 2010. State-Dependent Life History Models in a Changing (and regulated) Environment: Steelhead in the California Central Valley. *Evolutionary Applications* 3:221–243

Schaffter, R. 1980. *Fish Occurrence, Size, and Distribution in the Sacramento River Near Hood, California during 1973 and 1974.* California Department of Fish and Game.

Schneeberger, P. J. and D. J. Jude. 1981. Use of Fish Larva Morphometry to Predict Exclusion Capabilities of Small-Mesh Screens at Cooling-Water Intakes. *Transactions of the American Fisheries Society* 110:246–252.

Shapovalov, L. and A. C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) with Special Reference ro Waddell Creek, California, and Recommendations Regarding rheir Management. California Department of Fish and Game *Fish Bulletin* 98.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

The Nature Conservancy, Stillwater Sciences, and ESSA Technologies. 2008. *Sacramento River Ecological Flows Study: Final Report.* Prepared for CALFED ERP. Sacramento, CA.

Tomljanovich, D. A., J. H. Heuer, and C. W. Voigtlander. 1978. *Concept for Protecting Fish Larvae at Water Intakes.* 1978 Winter meeting of American Nuclear Society, Washington, DC, USA 30: 105–107.

U.S. Fish and Wildlife Service. 2001. *Biological Assessment of Artificial Propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: Program Description and Incidental Take of Chinook Salmon and Steelhead Trout*. Red Bluff, CA. Available: <http://www.fws.gov/redbluff/he_reports.aspx>.

U.S. Fish and Wildlife Service. 2004. *Endangered Species Glossary.* Available: <http://www.fws.gov/nc-es/piplch/glossary.pdf>. Accessed: March 5, 2008.

Upper Sacramento River Fisheries and Riparian Habitat Advisory Council. 1989. *Upper Sacramento River Fisheries and Riparian Habitat Management Plan.* A report prepared for the California Resources Agency by the Action Team. Sacramento, CA.

Waples, R. S., R. W. Zabel, M. D. Scheuerell, and B. L. Sanderson. 2008. Evolutionary Responses by Native Species to Major Anthropogenic Changes to Their Ecosystems: Pacific Salmon in the Columbia River Hydropower System. *Molecular Ecology* 17:84–96.

Watanabe, M., R. M. Adams, J. Wu, J. Bolte, M. M. Cox, S. Johnson, W. J. Liss, W. G. Boggess, and J. L. Ebersole. 2005. Toward Efficient Riparian Restoration: Integrating Economic, Physical, and Biological Models. *Journal of Environmental Management* 75(2):93–104.

Weisberg, S. B., W. H. Burton, F. Jacobs, and E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge-Wire Screens. *North American Journal of Fisheries Management* 7:386–393.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern?* Seminar, University of California, Davis, November 8.

Wooster, W. S. 1983. *From Year to Year: Interannual Variability of the Environment and Fisheries of the Gulf of Alaska and the Eastern Bering Sea*. Seattle, WA: University of Washington Press.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B Moyle. 1996. Historical and Present Distribution of Chinook salmon in the Central Valley Drainage of California. In: *Sierra Nevada Ecosystem Project, Final Report to Congress, volume III, Assessments, Commissioned Reports, and Background Information.* University of California, Davis, Centers for Water and Wildland Resources.

Zeitoun I. H., J. A. Gulvas, and D. B. Roarabaugh. 1981. Effectiveness of Fine Mesh Cylindrical Wedge-Wire Screens in Reducing Entrainment of Lake Michigan Ichthyoplankton. *Canadian Journal of Fisheries and Aquatic Sciences* 38(1):120–125.

Zimmerman, C. E., G. W. Edwards, and K. Perry. 2008. *Maternal Origin and Migratory History of* Oncorhynchus mykiss *Captured in Rivers of the Central Valley, California.* Final Report prepared for the California Department of Fish and Game. Contract P0385300.

2A.6.8.2 Federal Register Notices Cited

63 FR 13347. 1998. Final Rule; Notice of Determination: Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. *Federal Register* 63:13347.

69 FR 33102. 2004. Proposed Rule: Threatened and Endangered Species; Proposed listing determinations for 27 West Coast Salmonid ESUs, and Proposed Amendments to 4(d) Protective Regulations for Threatened ESUs. *Federal Register* 69:33102.

70 FR 52488. 2005. Final Rule: Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. *Federal Register* 70:52488.

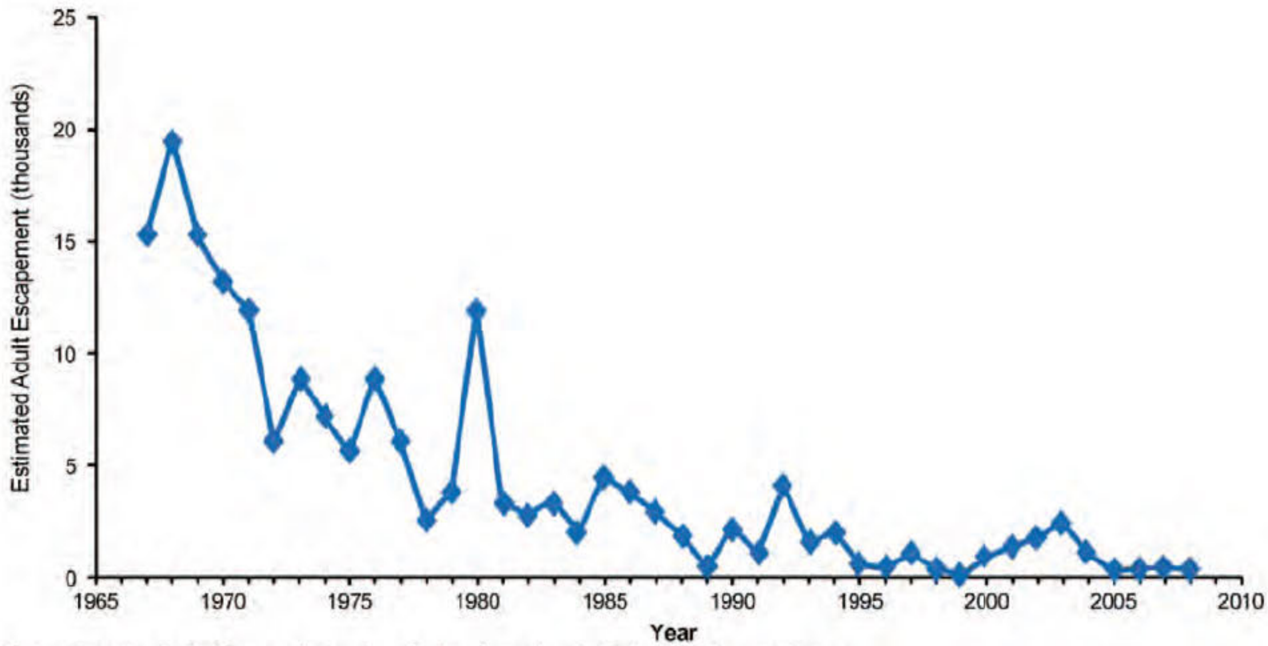
71 FR 834. 2006. Final Rule: Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. *Federal Register* 71:834.

76 FR 50447. 2011. Endangered and Threatened Species; 5-Year Reviews for 5 Evolutionarily Significant Units of Pacific Salmon and 1 Distinct Population Segment of Steelhead in California. *Federal Register* 76:50477.

Source: 63 FR 13347, March 19, 1998; Lindley et al. 2006

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.6-1
Central Valley Steelhead Inland Range



Note: Trapping in 2008 was discontinued after June due to high water temperatures.

SOURCE: Data from 1967 to 1991: Mills, T.J. and F. Fisher. 1994. Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991. August 1994. California Department of Fish and Game. Sacramento, CA. Data from 1992 to 2008, California Department of Fish and Game, Red Bluff. Unpublished data.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.6-2
Estimated Historical Spawner Escapement of Wild Central Valley Steelhead in the Upper Sacramento River Upstream of the Red Bluff Diversion Dam (1967–2008)

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.6-3
Central Valley Steelhead Critical Inland Habitat

Appendix 2A.7
Sacramento Splittail (*Pogonichthys macrolepidotus*)

2A.7.1 General

The Sacramento splittail, a cyprinid fish, is endemic to the San Francisco Estuary and watershed (Moyle 2002). Splittail regularly inhabit the Sacramento River upstream to the Red Bluff Diversion Dam at River Mile 243 and the San Joaquin River into Salt Slough (River Mile 135) (Moyle 2002) and Mud Slough at River Mile 125 (plus an additional 10.5 miles into Mud Slough). Splittail also inhabit the Napa and Petaluma River drainages (upper documented range: River Miles 18 and 17, respectively) and marshes. Splittail inhabiting these drainages have been found to be genetically distinct from splittail inhabiting the Sacramento and San Joaquin Rivers (Baerwald et al. 2007). Splittail from the Petaluma River exhibited a higher degree of differentiation from the Sacramento–San Joaquin population than did Napa River splittail, suggesting high salinities in San Pablo Bay and Carquinez Strait isolated these populations to differing degrees from the larger Sacramento–San Joaquin population. Spawning occurs in the Petaluma and Napa Rivers, but spawning locations within these rivers remain unknown (Moyle et al. 2004; Feyrer et al. 2005). No populations of splittail exist outside of the Central Valley rivers and the San Francisco/Sacramento–San Joaquin River Delta (Bay-Delta) estuary.

2A.7.2 Legal Status

The Sacramento splittail was listed as threatened under the federal Endangered Species Act (ESA) on February 8, 1999 (64 *Federal Register* [FR] 5963). This ruling was challenged by two lawsuits (*San Luis & Delta-Mendota Water Authority v. Anne Badgley et al.* and *State Water Contractors et al. v. Michael Spear et al.*). On June 23, 2000, the Federal Eastern District Court of California found the ruling to be unlawful and on September 22 of the same year remanded the determination back to the U.S Fish and Wildlife Service (USFWS) for re-evaluation of their original listing decision. Upon further evaluation, splittail was removed from the ESA on September 22, 2003 (68 FR 55139). On August 13, 2009, the Center for Biological Diversity (2009) challenged the 2003 decision to remove splittail from the ESA. However, on October 7, 2010, USFWS found that listing of splittail was not warranted (75 FR 62070).

The splittail is designated as a species of special concern by the California Department of Fish and Wildlife (CDFW).

2A.7.3 Distribution and Abundance

The splittail range includes the Sacramento River up to the Red Bluff Diversion Dam and the San Joaquin River to River Mile 135 (Figure 2A.7-1). Selected observations in the lower portions of Sacramento River and tributaries include the American River to River Mile 12, in the Feather River to River Mile 58 and from just below the Thermalito Afterbay outlet (Oppenheim pers. comm.; Seesholtz pers. comm.), and in Butte Creek/Sutter Bypass to vicinity of Colusa State Park.

Long-term beach seine sampling data for age 0 splittail (less than or equal to 50-millimeter fork length) in the Sacramento River spanning 32 years (1976 to 2008) indicates that the farthest location upstream where juvenile splittail have been collected was 144 to 184 miles upstream of the confluence of the Sacramento and San Joaquin Rivers. The consistency in the upstream range of juvenile splittail found in these long-term studies supports a finding that there was no decrease in distribution during this period (Feyrer et al. 2005).

The following rivers are within the splittail range:

- Cosumnes River—just above the confluence with the Mokelumne River (Crain et al. 2004).
- Mokelumne River—observed above Woodbridge Diversion Dam to River Mile 60.
- Stanislaus River—no confirmed sightings, but, based on observations from other tributaries, splittail probably inhabit low-gradient portions of the lower river.
- Tuolumne River—River Mile 17 (Legion Park, Modesto) (Ford pers. comm.), and several annually at River Mile 5 from 1999 to 2002 (Heyne pers. comm.).
- Merced River—River Mile 13, several annually from 1999 to 2001 (1 mile upstream of Hagaman Park) (Horvath pers. comm.; Heyne pers. comm.).

Near Mud and Salt Sloughs, splittail can access historical valley floodplains and apparently use them for spawning in wet years (e.g., 1995 and 1998) (Baxter 1999; Moyle et al. 2004). Splittail occasionally extend their range farther southward into central and southern San Francisco Bays using freshwater and low-salinity habitats created during high-outflow years (Moyle et al. 2004). After high-outflow years in the early 1980s and mid-1990s, splittail were captured in the estuary of Coyote Creek, South San Francisco Bay (Stevenson pers. comm.). In a study by researchers at the University of California, Davis, that started in August of 2010 and samples monthly, no splittail have been caught in Coyote Creek (Hobbs pers. comm.).

The abundance of juvenile splittail (young-of-the-year) is highly variable from one year to the next and positively correlated with hydrologic conditions within the rivers and Delta during the late-winter and spring spawning period and the magnitude and duration of floodplain inundation (Sommer et al. 1997). Because splittail are a long-lived species (5 to 7 years) (Moyle 2002; Grimaldo pers. comm.), the abundance of juveniles in a given year may not be a good predictor of adult splittail abundance. Results of CDFW fall midwater trawl surveys indicate a marked decline in overall splittail abundance and consistently low population levels since 2002 (Figure 2A.7-2). In addition, Bay study indices were extremely low (Figures 2A.7-2[B] and [C]).

No population-level estimates currently exist for Sacramento splittail. However, because much of the overall distribution of splittail occurs in the Plan Area, population status and trends in the Plan Area are expected to be very similar to overall population status and trends.

2A.7.4 Life Stages

Kratville (2008) describes five life stages of Sacramento splittail. Moyle (2002) also described five life stages, although rather than two adult stages (spawning and postspawning), Moyle described two juvenile life stages (young-of-year and yearling). Table 2A.7-1 compares the Sacramento splittail life stages of Kratville and Moyle.

Table 2A.7-1. Sacramento Splittail Life Stages

Kratville 2008	Moyle 2002	BDCP
Eggs	Egg/embryo	Egg/embryo
Larvae	Larvae	Larvae
Juvenile	Juvenile (young-of-year)	Juvenile (young-of-year)
Adult/spawning	Juvenile (yearling)	Juvenile (yearling)
Adult/postspawning	Adult	Adult/nonspawning
		Adult/spawning

2A.7.5 Life History

2A.7.5.1 Phenology

Mature splittail begin a gradual upstream migration towards spawning areas sometime between late November and late January, with larger splittail migrating earlier (Caywood 1974; Moyle et al. 2004). The relationship between migrations and river flows is poorly understood, but it is likely that splittail have a positive behavioral response to increases in flows and turbidity. Feeding in flooded riparian areas in the weeks just prior to spawning may be important for later spawning success and for postspawning survival. Not all splittail make significant movements prior to spawning, as indicated by evidence of spawning in Suisun Marsh (Meng and Matern 2001) and the Petaluma River.

The upstream movement of splittail is closely linked with flow events from February to April that inundate floodplains and riparian areas (Garman and Baxter 1999; Harrell and Sommer 2003). Seasonal inundation of shallow floodplains provides both spawning and foraging habitat for splittail (Caywood 1974; Daniels and Moyle 1983; Baxter et al. 1996; Sommer et al. 1997). Evidence of splittail spawning on floodplains has been found on both the San Joaquin and Sacramento Rivers. In the San Joaquin River drainage, spawning has apparently taken place in wet years in the region where the San Joaquin River is joined by the Tuolumne and Merced Rivers (Ford pers. comm.). In the Plan Area, splittail spawn on inundated floodplains in the Yolo and Sutter Bypasses, which are extensively flooded in wet years, and along the Cosumnes River area from February to July (Sommer et al. 1997, 2001, 2002; Crain et al. 2004; Moyle et al. 2004). When floodplain inundation does not occur in the Yolo or Sutter Bypasses, adult splittail migrate farther upstream to suitable habitat along channel margins or flood terraces; spawning in such locations occurs in all water year types (Feyrer et al. 2005). Although spawning is typically greatest in wet years, CDFW surveys demonstrate spawning takes place every year along the river edges and backwaters created by small increases in flow. In the eastern Delta, the floodplain along the lower Cosumnes River appears to be important as spawning habitat. Ripe splittail have been observed in areas flooded by levee breaches, turbid water, and flooded terrestrial vegetation.

Limited collections of ripe adults and early stage larvae indicate splittail spawn in shallow water (less than 2 meters [6.6 feet] deep) over flooded vegetated habitat with a detectable water flow in association with cool temperatures (less than 15°C [59°F]) (Moyle et al. 2004). Turbidity is typically high under these conditions, but decreases rapidly as flows diminish. On floodplains, complex topography slows water velocities, creating eddies and increasing hydraulic residence time.

Increased hydraulic residence time promotes phytoplankton and zooplankton production on seasonally inundated floodplains.

With rising water temperatures during the spring, young juveniles (about 25 to 40 millimeters) begin their migration downstream through the Delta. Such migrations often occur in late April, May, or even June of high-flow years (Moyle et al. 2004; Crain et al. 2004). In low-flow years, juvenile splittail are most abundant in the northern and western regions of the Delta; in high-flow years, their distribution is more even throughout the Delta (Sommer et al. 1997).

When juveniles reach a length of approximately 29 millimeters fork length, they move into deeper habitats (Sommer et al. 2002). On the Cosumnes River, juveniles have been observed leaving the floodplain at a size of 25 to 40 millimeters total length, when they disperse rapidly downstream. Although some larval and juvenile splittail are swept off floodplains and downstream by flood currents (Baxter et al. 1996), many larvae and juveniles remain in riparian or annual vegetation along shallow edges on floodplains as long as water temperatures remain cool (Sommer et al. 2002; Moyle et al. 2004). Most late-stage juveniles and nonreproductive adults inhabit moderately shallow (less than 4 meters [13 feet]) brackish and freshwater tidal sloughs and shoals, such as those found in Suisun Bay and Suisun Marsh and the margins of the lower Sacramento River (Moyle et al. 2004; Feyrer et al. 2005). Figure 2A.7-3 indicates the geographic distribution of splittail over the past 34 years throughout the Delta region and Figure 2A.7-4 indicates seasonal variation in the abundance of postlarval and juvenile splittail throughout their range.

Splittail spend little time in habitats surrounding floodplains, and are only present for about two weeks in adjacent sloughs after leaving the Cosumnes floodplain. Migration through river corridors is also fairly quick, with splittail from the Cosumnes floodplain reaching the mouth of Mokelumne River in about two weeks after leaving the area. There is some evidence that a small fraction of splittail young-of-year that are spawned in the Sacramento River and Butte Creek remain upstream their first year (Baxter 1999).

Channel margins and backwater habitats can be critical to the survival of young-of-year splittail, as well as the population as a whole (Moyle et al. 2004; Feyrer et al. 2005). Such habitats provide refugia from predatory fishes and feeding sites as fish grow in upstream regions before and during downstream migration. Many backwater habitats are associated with the complex topography of remnant riparian habitats and are created ephemerally in response to increases in river stage (water surface elevation); others are synthetic creations such as cut channels, boat ramps, or agricultural pump intakes. This contrasts with major floodplain inundation typically associated with large splittail year classes (Meng and Moyle 1995; Baxter et al. 1996; Sommer et al. 1997), which may require an 8- to 10 meter [26- to 33-foot] increase in river stage (typically associated with flood flow events).

Two early life history strategies occur in juvenile splittail produced in the Sacramento River system. The dominant strategy is characterized by juveniles migrating downstream in late spring and early summer to the Delta, Suisun Bay, and Suisun Marsh; a less well-studied strategy is to remain upstream through the summer into the next fall or spring and migrate downstream as a subadult (Baxter 1999; Moyle et al. 2004). This latter strategy occurs in Butte Creek and the mainstem Sacramento River. As water recedes further, juveniles remaining in upstream riverine habitats and congregate in large eddies for feeding.

2A.7.6 Life Cycle

Splittail spawning occurs between late February and early July (Wang 1986). Females lay between 5,000 and 150,000 eggs, but fecundity is size-dependent and highly variable, probably related to food availability and selenium content in bivalves (Feyrer and Baxter 1998; Moyle et al. 2004). Egg incubation lasts for 3 to 7 days depending on water temperature (Moyle 2002). Newly hatched larvae are typically 6.5 to 8 millimeters [0.26 to 0.32 inches] fork length (Wang 1986). Larvae remain in shallow weedy areas near spawning areas for 10 to 14 days (Meng and Moyle 1995). In the case of floodplains, larvae are found in shallow water associated with flooded terrestrial vegetation (Crain et al. 2004).

Splittail grow to a typical length of 110 to 120 millimeters [4.3 to 4.7 inches] during their first year, 140 to 160 millimeters [5.5 to 6.3 inches] during their second year, 200 to 215 millimeters [7.9 to 8.5 inches] during their third year, and grow 25 to 35 millimeters/year during remaining years, reaching up to 400 millimeters [15.75 inches], but fish over 300 millimeters [11.8 inches] are rare, as growth has decreased since the introduction of the overbite clam (*Potamocorbula amurensis*) (Moyle et al. 2004). Maturity is typically reached at the end of their second year (Daniels and Moyle 1983).

2A.7.6.1 Diet

The diet of splittail larvae up to 15 millimeters in length is dominated by zooplankton, primarily cladocerans with some copepods, rotifers, and chironomids present in small amounts; chironomids become important after splittail reach 15 millimeters long (Kurth and Nobriga 2001; Moyle 2002). In the 1980s, the diet for splittail age 1 and above included the native mysid shrimp, *Neomysis*, amphipods, and harpacticoid copepods, with detritus accounting for more than half the diet (Feyrer et al. 2003). After the invasion of *Potamocorbula* in the 1980s and the crash of *Neomysis*, clams, especially *Potamocorbula*, became an important component of the diet (Feyrer et al. 2003).

2A.7.6.2 Temperature and Salinity Requirements

Juvenile and subadult splittail commonly inhabit regions of the estuary characterized by salinities of 10 to 18 parts per thousand (ppt) (Meng and Moyle 1995; Sommer et al. 1997). Relatively warm temperatures and an abundance of food allow young splittail to grow and develop rapidly on floodplains so that they are physically prepared to leave floodplains when water levels recede. Increased water temperatures and reduced water levels may cue floodplain emigration of juvenile splittail. Many of these ecosystem benefits are dependent upon the frequency, duration, and timing of the floodplain inundation.

Salinity tolerance increases with size (and age) such that adult splittail can survive salinities up to 29 ppt for brief periods of time (Young and Cech 1996). Splittail inhabit a broad range of temperatures, 5 to 24°C (41 to 75.2°F) depending upon season, and acclimated fish can tolerate 29 to 33°C (84.2 to 91.4°F) for short periods (Young and Cech 1996).

Complementing their temperature and salinity tolerances, splittail of all sizes can tolerate low dissolved oxygen levels (less than 1 milligram of oxygen per liter^{-1}) (Moyle et al. 2004), making them well suited to slow-moving sections of sloughs and rivers. In Suisun Marsh during summer, splittail commonly inhabit areas with salinities of 6 to 10 ppt and temperatures of 15 to 23°C (59 to 73.4°F) (Meng and Moyle 1995). Juveniles are most abundant in shallow (less than 2 meters), turbid water with a current. Napa and Petaluma River stocks may possess a higher salinity tolerance than the Central Valley stock (Baerwald et al. 2007).

2A.7.7 Threats and Stressors

A number of threats and stressors exist for splittail. Stressor rankings and the certainty associated with these rankings for splittail are provided in Chapter 5 of the BDCP. The discussion below outlines some of the main threats and stressors to splittail.

2A.7.7.1 Water Exports

Splittail are salvaged year-round in the State Water Project (SWP) and Central Valley Project (CVP) fish salvage facilities, with the greatest occurrence during May to July. The majority of splittail observed in fish salvage monitoring are early juveniles. Splittail mortality during the SWP/CVP fish salvage process has not been quantified, but it is thought to be high. Mortality to young splittail may occur because of overcrowding within transport tanks and predation at release locations within the Delta. Furthermore, adults that are salvaged are returned to an area downstream of the export facilities, which is expected to increase the energy expenditure needed to reach their upstream spawning sites and could reduce their ability to spawn successfully (Moyle et al. 2004). Young-of-year splittail have critical swimming velocities that are similar to water velocities occurring at the SWP/CVP diversions and are entrained at these facilities (Young and Cech 1996).

The highest levels of splittail salvage occur during years with high outflows that persist into the March and April spawning period (Sommer et al. 1997). For example, splittail salvage increased substantially in both 2005 and 2006, but was even higher in 2011, corresponding to high levels of juvenile production, reaching a record high of over 7.5 million fish at the CVP Tracy Fish Collection Facility (Aasen 2012). However, because salvage rates are high when splittail abundance is high, the net effect of entrainment at the export facilities on the overall population of splittail may not be great, and there is no evidence that juvenile entrainment mortality has a significant population-level effect (Sommer et al. 1997). Nevertheless, prolonged drought and subsequent reduction in adult splittail abundance could eventually cause a proportionally large effect on the population, particularly if the geographic distribution of the splittail population were to occur near the export facilities (Sommer et al. 1997).

In addition to SWP/CVP export facilities, there are over 2,200 small water diversions within the Plan Area, the majority of which are unscreened (Herren and Kawasaki 2001). Results of surveys at unscreened diversions (Nobriga et al. 2004) have shown that a variety of fish species (e.g., threadfin shad, silversides, striped bass), primarily larval and juvenile life stages, are vulnerable to entrainment. Based on results of this and similar studies conducted on unscreened diversions, it has been hypothesized that early juvenile splittail would be vulnerable to entrainment from these smaller diversions. However, water velocities at these relatively small agricultural pumps and siphons are low enough that larger fish are able to avoid entrainment. The potential magnitude of the entrainment risk, risk variations across seasons and areas, and the cumulative effect of entrainment losses on the population dynamics of splittail cannot be determined. No comprehensive, quantitative estimates have been developed for the level of potential entrainment mortality that may occur because of diversions from the rivers and Delta.

Power plants within the Plan Area have the ability to entrain large numbers of fish. However, with the retirement of older units, use of cooling water is currently low. Furthermore, recent State Water Resources Control Board regulations require that units at these plants be equipped with a closed cycle cooling system by 2017.

2A.7.7.2 Habitat-Changing Structures

In the Sacramento River, levees constrain river meander from River Mile 194 at Chico Landing downstream to Collinsville (River Mile 0) and restrict the riparian zone accessible via the river channel. Levee configuration differs through three reaches downstream of Chico Landing and has important implications in terms of splittail spawning and rearing habitat (Feyrer et al. 2005).

- The river reach from Chico Landing to Colusa (River Mile 144) is characterized by setback levees enclosing remnant floodplain (flood terraces) and a narrowly meandering river channel.
- The reach from Colusa to Verona (River Mile 80) is tightly leveed and contains fewer and much narrower flood terraces, many of which are actively eroding and targeted for riprap.
- The reach from Verona to Collinsville (River Mile 0) is also tightly leveed and contains extensive, narrow flood terraces between Verona and Sacramento, but is almost completely riprapped from Sacramento to Collinsville.

2A.7.7.3 Habitat Loss

Maintaining and increasing seasonally inundated floodplain habitat suitable for splittail spawning and juvenile rearing throughout the species range has been identified as a factor that will help maintain successful reproduction and increase juvenile abundance and genetic diversity during prolonged drought events and avoid a genetic "bottleneck."

2A.7.7.3.1 Reduced Juvenile/Adult Rearing Habitat

Reclamation of Delta islands and wetlands during the 19th and early 20th centuries removed or degraded large areas of high-value juvenile/adult rearing habitat. This habitat consisted of shallow, low-velocity areas throughout the Delta, and particularly in the western Delta and Suisun Marsh (Moyle et al. 2004). In the 1960s and 1970s, the U.S. Army Corps of Engineers increased downstream water conveyance and reinforced levees by clearing and riprapping levees along the lower Sacramento River. These actions further reduced or eliminated suitable rearing habitat for splittail from the City of Sacramento downstream by removing large areas of shallow channel margins. Current efforts are underway to improve flood protection for communities along much of the lower Sacramento River and several other valley rivers. Actions being proposed and conducted include removal of trees and riparian vegetation and armoring with riprap. The current policy is for removal of all large trees and brush from levees to improve detection of weak points and potential levee failures.

2A.7.7.3.2 Reduced Spawning/Larval Rearing Habitat

Reclamation and levee construction along the majority of Delta waterways and upstream riverine habitats has degraded or eliminated large areas of seasonally inundated floodplains that once served as spawning and larval rearing habitat for splittail. Although some spawning occurs on shallow margins of the main channels every year, floodplains are highly productive and, when inundated, are used by splittail for spawning and larval rearing more heavily than channel margins.

Changes in river stage resulting from upstream diversions and reservoir storage have not been well studied, but during low- and moderate-runoff years, water management may affect splittails' access to floodplains and their ability to emigrate successfully after spawning and early rearing (Moyle et al. 2004). Reservoir operations are designed to reduce peak flows during winter and spring months that historically would have resulted in seasonal inundation of floodplains.

2A.7.7.4 Food Resources

There are multiple mechanisms that may cause reductions in food supplies for juvenile and adult splittail, including competition with nonnative species and reductions in productivity as a result of heavy grazing by introduced clams. The introduced *Potamocorbula* is a highly efficient filter feeder that has reduced phytoplankton in the Delta and Suisun Bay, with subsequent effects on zooplankton consumers (Kimmerer and Orsi 1996). The invasion of the estuary by *Potamocorbula* reduced the availability of the native mysid, *Neomysis*, to splittail (Feyrer et al. 2003). However, the effect of *Potamocorbula* on food availability to splittail is mixed because splittail now consume the clams as well as the nonnative mysid shrimp, *Acanthomysis* (Feyrer et al. 2003).

In addition to the effect of introduced claims, reductions in productivity within the estuary have been attributed to changes in hydrology associated with in-Delta water diversions, upstream reservoir operations, reduced hydraulic residence time in the Delta, and ammonia[1] from wastewater treatment plants.

- The SWP/CVP export facilities and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export nutrients, organic material, phytoplankton, and zooplankton from the Delta that would otherwise support the base of the food web (Jassby et al. 2002; Resources Agency 2007).
- Upstream reservoir operations have reduced seasonal variability in Delta and river hydrology, resulting in fewer and shorter high-flow events and, therefore, reduced frequency and duration of floodplain inundation (Sommer et al. 1997, 2002; Meng and Matern 2001; Feyrer et al. 2005, 2006). Floodplains are an important source of food for splittail (Sommer et al. 2001; Schemel et al. 2004; Lehman et al. 2008).
- Reductions in hydraulic residence time in the central Delta have resulted, in part, from the need to maintain good water quality in the Delta for agricultural uses and SWP/CVP exports (Resources Agency 2007). Water of a higher quality is conveyed from the Sacramento River southward through the Delta via the Delta Cross Channel, creating a hydraulic barrier against salt water that may otherwise enter the Delta from the west. As a result, water movement has increased and hydraulic residence time has declined in the central Delta. Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002; Kimmerer 2002a, 2002b; Resources Agency 2007). Increased hydraulic residence time allows more opportunity for phytoplankton and zooplankton production.

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

- High concentrations of ammonium from municipal wastewater treatment plants may inhibit diatom production, reducing the food available for the prey of splittail prey and other fish species (Wilkerson et al. 2006; Dugdale et al. 2007; Glibert 2010; Cloern et al. 2011; Glibert et al. 2011).

2A.7.7.5 Exposure to Toxins

Although there is strong support from laboratory studies that toxics can be lethal to splittail (Teh et al. 2002, 2004a, 2004b, 2005), there is little information about the chronic or acute toxicity of contaminants within the Delta (Greenfield et al. 2008). The longevity of splittail relative to most other covered fish species (5 to 7 years) (Moyle 2002) enables their tissue to bioaccumulate toxicants to higher concentrations than those other species. This makes splittail particularly vulnerable to heavy metals such as mercury, and other fat-soluble chemicals. Perhaps the greatest concern among the impacts of contaminants on splittail relates to selenium. Tissues of splittail collected in Suisun Bay had sufficiently high selenium concentrations to cause physiological impacts, in particular, reproductive abnormalities (Stewart et al. 2004). Adult splittail feed on the *Potamocorbula,* which bioaccumulates and transfers selenium in high concentrations (Luoma and Presser 2000). With the decline of the mysid shrimp, *Neomysis*, in the estuary, juvenile and adult splittail have increased foraging on benthic macroinvertebrates such as clams (Feyrer et al. 2003). Teh et al. (2004b) found that young splittail that were fed a diet high in selenium grew significantly slower and had higher liver and muscle selenium concentrations after nine months of testing.

Kuivila and Moon (2004) documented dissolved pesticides in the Sacramento–San Joaquin Delta during April to June (1998 to 2000) when young, growing splittail were migrating into the Delta and estuary. The use of pyrethroid pesticides has increased substantially in the Central Valley since the early 1990s (Oros and Werner 2005). Though relatively nontoxic to mammals, these chemicals are highly toxic to aquatic organisms, including fishes. Also, pesticide use on row crops (including rice) commonly grown in the Yolo and Sutter Bypasses and their proclivity to adhere to sediment particles suspended in water and deposited on the bottom provide a dietary pathway to splittail ingestion along with detritus during feeding (Werner 2007). Exposure to pesticides and other chemical contaminants may occur while splittail forage on inundated floodplains or in the estuary after the pesticides have entered Delta channels through agricultural drainage and have been transported to and settled in the Delta.

2A.7.7.6 Predation

Major nonnative predatory fish introduced into the Bay-Delta estuary, such as striped bass and largemouth bass, have resided in the Delta for over a century (Dill and Cordone 1997), and splittail have persisted. However, reduced turbidity in the Delta and increased habitat for nonnative predatory species provided by Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*) have enhanced both largemouth bass abundance and their ability to visually forage, thus increasing predation risk to splittail (Toft et al. 2003; Brown and Michniuk 2007).

2A.7.7.7 Harvest

The legal fishery for splittail is thought to be substantial, despite poor documentation (Moyle et al. 2004). Subadult and adult splittail are harvested by recreational anglers for consumption, as well as for use as bait by striped bass anglers. There is no evidence that splittail are affected at a population level by the fishery, but there is insufficient evidence to conclude this with confidence. CDFW now regulates the take of splittail to two fish per day, which may only be taken by angling (California Code of Regulations 14(2):4,5.70).

2A.7.8 Relevant Conservation Efforts

The Ecosystem Restoration Program (CALFED Bay-Delta Program 2000) includes specific objectives for splittail as follows.

> Species recovery objectives will be achieved when 2 of the following 3 criteria are met in at least 4 of every 5 years for a 15 year period: 1) the fall midwater trawl survey numbers must be 19 or greater for 7 of 15 years. 2) Suisun Marsh catch per trawl must be 3.8 or greater and the catch of young-of-year must exceed 3.1 per trawl for 3 of 15 years, and 3) Bay Study otter trawls must be 18 or greater AND catch of young-of-year must exceed 14 for 3 out of 15 years.

The CALFED Bay-Delta Program (CALFED) Ecosystem Restoration Program has funded the Yolo Bypass Watershed Restoration Strategy. The purpose is to develop a local implementation strategy for a broad landscape level of restoration and rehabilitation for the Yolo Bypass, which should have direct benefits to splittail. The program has also funded a feasibility study for flood protection and ecosystem restoration at Hamilton City.

A new integrated monitoring and outreach program to evaluate fish contamination issues has recently been funded by the Ecosystem Restoration Program. This project will monitor mercury levels in sport fish and biosentinel indicators for three years throughout the watershed. The monitoring will evaluate spatio-temporal variability and gather information needed for management decisions.

Several conservation activities are planned to improve shallow subtidal habitat in the Delta that should provide benefit to splittail. The CALFED Ecosystem Restoration Program Suisun Marsh Land Acquisition and Tidal Marsh Restoration project will restore 500 acres within the Suisun Marsh to tidal wetland. The Suisun Marsh/North San Francisco Bay Ecological Zone Biological Restoration and Monitoring project will restore, maintain, and monitor the biology of at least three major eastern San Pablo Bay and southern Suisun Bay areas within a single CALFED-defined ecological zone (Suisun Bay/North San Francisco Bay), and compare and improve these restoration efforts through an integrated monitoring program. Restoration of three commercial salt ponds along the Napa River will provide habitat benefits for splittail and other aquatic species.

Connectivity to and restoration of floodplain habitat were achieved along the Cosumnes River through breaching of levees on the Cosumnes River Preserve during the 1990s (Booth et al. 2006). The Cosumnes River Preserve is managed by a coalition of state, federal, and nonprofit organizations, such as The Nature Conservancy California. The Cosumnes River floodplain is now thought to be used for spawning by splittail (Crain et al. 2004; Moyle et al. 2004).

Construction is ongoing for the Reclamation District 108 Poundstone Intake Consolidation and Positive Barrier Fish Screen Project in Colusa County, which will construct an 81-foot-long, positive barrier fish screen at the entrance to a new water diversion site on the Sacramento River (River Mile 110.5) in Colusa County. The new diversion will consolidate and allow removal of three existing unscreened diversions. Other projects (e.g., Reclamation District 1004 intake screens, Reclamation District 108 Wilkins Slough Positive Barrier Fish Screen) have been constructed on the Sacramento River to reduce entrainment of splittail and other fish.

The Sacramento River Conservation Area Forum, the California Department of Water Resources (DWR), USFWS, CDFW, the California Department of Parks and Recreation, the Wildlife Conservation Board, nonprofit organizations such as the Nature Conservancy and the Sacramento River Partners, and many other stakeholders conduct conservation and restoration activities in the middle and upper reaches of the Sacramento River.

On December 10, 2009, the California Fish and Game Commission adopted CDFW's proposal to establish fishing regulations on splittail in an effort to reduce the potential effects of harvest on the splittail population. Effective March 1, 2010, there is a year-round two-fish daily bag and possession limit.

2A.7.9 Recovery Goals

Although splittail is not listed, it is included in the *Sacramento–San Joaquin Delta Native Fishes Recovery Plan* (U.S. Fish and Wildlife Service 1996), which also includes the delta smelt, longfin smelt, green sturgeon, Sacramento perch, and three races of Chinook salmon. USFWS has the responsibility to review and update the recovery plan for these species. To accomplish this task, USFWS has formed a new Delta Native Fishes Recovery Team to assist in the preparation of this updated plan.

2A.7.10 References Cited

2A.7.10.1 Literature Cited

Aasen, G. A. 2012. *2006 Fish Salvage at the Tracy Fish Collection Facility.* California Department of Fish and Game. Stockton, CA. Available: <ftp://ftp.delta.dfg.ca.gov/salvage/Annual%20Salvage%20Reports/2011%20Water%20Year%20TFCF%20Annual%20Salvage%20Report.pdf>.

Baerwald, M., V. Bien, F. Feyrer, and B. May. 2007. Microsatellite Analysis Reveals Two Genetically Distinct Splittail (*Pogonichthys macrolepidotus*) Populations in the San Francisco Estuary. *Conservation Genetics.* 8:159–167.

Baxter, R. D. 1999. Status of Splittail in California. *California Fish and Game*. 85(1):28–30.

Baxter, R., W. Harrell, and L. Grimaldo. 1996. 1995 Splittail Spawning Investigations. *Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter* 9(4):27–31.

Booth, E., J. Mount, and J. Viers. 2006. Hydrologic Variability of the Cosumnes River Floodplain. *San Francisco Estuary and Watershed Science* [online serial] 4(2), Article 2.

Brown, L. R. and D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980–1983 and 2001–2003. *Estuaries and Coasts* 30(1):186–200.

CALFED Bay-Delta Program. 2000. *Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

Caywood, M. L. 1974. *Contributions to the Life History of the Splittail,* Pogonichthys macrolepidotus *(Ayers).* MS thesis. California State University, Sacramento.

Center for Biological Diversity. 2009. *Complaint for Declaratory and Injunctive Relief.* Case filed in the United State District Court for the Northern District of California. Available: <http://www.biologicaldiversity.org/species/fish/Sacramento_splittail/pdfs/Sacramento_Splittail_complaint.pdf>.

Cloern, J. E., A. D. Jassby, J. Carstensen, W. A. Bennett, W. J. Kimmerer, R. Mac Nally, D. H. Schoellhamer, and M. Winder. 2011. Perils of Correlating CUSUM-Transformed Variables to Infer Ecological Relationships (Breton et al. 2006; Glibert 2010). *Limnology and Oceanography* 57:665–668.

Crain, P. K., K. Whitener and P. B. Moyle. 2004. Use of a Restored Central California Floodplain by Larvae of Native and Alien Fishes. In: F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi (eds.). *Early Life History of Fishes in the San Francisco Estuary and Watershed.* American Fisheries Society, Santa Cruz, California. Pages 125–140.

Daniels, R. A. and P. B. Moyle. 1983. Life History of Splittail (Cyprinidae: Pogonichthys macrolepidotus) in the Sacramento-San Joaquin Estuary. *Fishery Bulletin* 81(3):647–657.

Dill, W. A. and A. J. Cordone. 1997. *History and status of introduced fishes in California, 1871-1996, Volume 178*. California Department of Fish and Game.

Dugdale, R. C., F. P. Wilkerson, V. E. Hogue, and A. Marchi. 2007. The Role of Ammonium and Nitrate in Spring Bloom Development in San Francisco Bay. *Estuarine, Coastal Shelf Science* 73:17–29.

Feyrer, F. and R. Baxter. 1998. Splittail Fecundity and Egg Size. *California Fish and Game* 84:119–116

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary Shifts in a Stressed Fish Assemblage: Consequences of a Bivalve Invasion in the San Francisco Estuary. *Environmental Biology of Fishes* 67(3):277–288.

Feyrer, F., T. Sommer, and R. D. Baxter. 2005. Spatial-Temporal Distribution and Habitat Associations of Age-0 Splittail in the Lower San Francisco Watershed. *Copeia* 2005(1):159–168.

Feyrer, F., T. Sommer, and W. Harrell. 2006. Managing Floodplain Inundation for Native Fish: Production Dynamics of Age-0 Splittail (Pogonichthys macrolepidotus) in California's Yolo Bypass. *Hydrobiologia* 573:213–226.

Garman, G. and R. Baxter. 1999. Splittail Investigations. *Interagency Ecological Program Newsletter* 12(4):7.

Glibert, P. 2010. Long-Term Changes in Nutrient Loading and Stoichiometry and Their Relationships With Changes in The Foodweb and Dominant Pelagic Fish Species in the San Francisco Estuary, California. *Reviews in Fisheries Science* 18:211–232.

Glibert, P. M., D. Fullerton, J. M. Burkholder, J. C. Cornwell, and T. M. Kana. 2011. Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems. *Reviews in Fisheries Science* 19(4):358–417.

Greenfield, B. K., S. J. Teh, J. R. M. Ross, J. Hunt, J. H. Zhang, J. A. Davis, G. Ichikawa, D. Crane, S. S. O. Hung, D. F. Deng, F. Teh, and P. G. Green. 2008. Contaminant Concentrations and Histopathological Effects in Sacramento Splittail (*Pogonichthys macrolepidotus*). *Archives of Environmental Contamination and Toxicology* 55(2):270–281.

Harrell W. C. and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. In: P. M. Faber (ed.), *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration. 2001 Riparian Habitat and Floodplains Conference Proceedings* Sacramento, CA: Riparian Habitat Joint Venture. Pages 88–93.

Herren, J. R. and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. In R.L. Brown (ed.). Contributions to the Biology of Central Valley Salmonids. Volume 2. *California Fish and Game. Fish Bulletin* 179:343–355

Jassby, A. D., J. E. Cloern, and B. E. Cole. 2002. Annual Primary Production: Patterns and Mechanisms of Change in a Nutrient-Rich Tidal Ecosystem. *Limnology and Oceanography* 47:698–712.

Kimmerer, W. J. 2002a. Effects of Freshwater Flow on Abundance of Estuarine Organisms: Physical Effects of Trophic Linkages. *Marine Ecology Progress Series* 243:39–55.

Kimmerer, W. J. 2002b. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. *Estuaries* 25(6B): 1275–1290.

Kimmerer, W. J. and J. J. Orsi. 1996. Changes in the Zooplankton of the San Francisco Bay Estuary since the Introduction of the Clam *Potamocorbula amurensis.* In: J. T. Hollibaugh (ed.). *San Francisco Bay: The Ecosystem.* San Francisco, CA: Pacific Division, American Association for the Advancement of Science. Pages 403–424.

Kratville, D. 2008. *Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, Semi-final Species Life History Conceptual Model: Sacramento Splittail (*Pogonichthys macrolepidotus*)*. Sacramento, CA: California Department of Fish and Game.

Kuivila, K. M. and G. E. Moon. 2004. Potential Exposure of Larval and Juvenile Delta Smelt to Dissolved Pesticides in the Sacramento-San Joaquin Delta, California. In: F. Feyrer, L. R. Brown, R. L. Brown, J. J. Orsi (eds.). *Early Life History of Fishes of the San Francisco Estuary and Watershed, Symposium 39.* American Fisheries Society, Bethesda, Maryland. Pages 229–242.

Kurth, R. and M. Nobriga. 2001. Food Habits of Larval Splittail. *Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter* 14(3):40–42.

Lehman, P. W., T. Sommer, and L. Rivard. 2008. The Influence of Floodplain Habitat on the Quantity and Quality of Riverine Phytoplankton Carbon Produced during the Flood Season in San Francisco Estuary. *Aquatic Ecology* 42:363–378.

Luoma, S. N. and T. S. Presser. 2000. *Forecasting Selenium Discharges to the San Francisco Bay Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension*. U.S. Geological Survey. Open-file report 00-416.

Meng L. and S. A. Matern. 2001. Native and Introduced Larval Fishes of Suisun Marsh, California: The Effects of Freshwater Flow. *Transactions of the American Fisheries Society* 130:750–765.

Meng, L. and P. B. Moyle. 1995. Status of Splittail in the Sacramento-San Joaquin Estuary. *Transactions of the American Fisheries Society* 124:538–549.

Moyle, P. B. 2002. *Inland Fishes of California.* Revised and Expanded. Berkeley, CA: University of California Press.

Moyle, P. B., R. D. Baxter, T. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and Population Dynamics of Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: A Review. *San Francisco Estuary and Watershed Science* [online serial] 2(2), Article 3.

Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison Among Open-Water Fishes. *American Fisheries Society Symposiu.* 39:281–285.

Oros, D. and R. I. Werner. 2005. *Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley*. White Paper for the Interagency Ecological Program. SFEI Contribution 415. Oakland, CA: San Francisco Estuary Institute.

Resources Agency. 2007. *Pelagic Fish Action Plan*. Available: <http://www.water.ca.gov/deltainit/030507pod.pdf>.

Schemel, L. E., T. R. Sommer, A. B. Müeller-Solger, and W. C. Harrell. 2004. Hydrologic Variability, Water Chemistry, and Phytoplankton Biomass in a Large Floodplain of the Sacramento River, CA. *Hydrobiologia* 513:129–139.

Sommer, T. R., L. Conrad, G. O'Leary, F. Feyrer, and W. C. Harrell. 2002. Spawning and Rearing of Splittail in a Model Floodplain Wetland. *Transactions of the American Fisheries Society* 131(5): 966–974.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Bathman, and W. J. Kimmerer. 2001. Floodplain Rearing of juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58(2):325–333.

Sommer, T. R., R. Baxter, and B. Herbold. 1997. Resilience of Splittail in the Sacramento-San Joaquin Estuary. *Transactions of the American Fisheries Society* 126:961–976.

Stewart, A. R., S. N. Luoma, C. E. Schlekat, M. A. Doblin, and K. A. Hieb. 2004. Food Web Pathway Determines How Selenium Affects Aquatic Ecosystems: A San Francisco Bay Case Study. *Environmental Science & Technology* 38(17):4519–4526.

Teh, S. J., Z. Deng, D. Deng, F. Teh, S. S. O. Hung, T. Fan, J. Liu, and R. M. Higashi. 2004b. Chronic Effects of Dietary Selenium on Juvenile Sacramento Splittail (*Pogonichthys macrolepidotus*). *Environmental Science & Technology* 38(22):6085–6093.

Teh, S. J., X. Deng, F. Teh, and S. Hung. 2002. Selenium-Induced Teratogenicity in Sacramento Splittail (*Pogonichthys macrolepidotus*). *Marine Environmental Research* 54:605–608.

Teh, S. J., D. Deng, I. Werner, F. Teh, and S. Hung. 2005. Sublethal Toxicity of Orchard Stormwater Runoff in Sacramento Splittail (Pogonichthys macrolepidotus) Larvae. *Marine Environmental Research* 59:203–216.

Teh, S. J., G. H. Zhang, T. Kimball, and F. Teh. 2004a. Lethal and Sublethal Effects of Esfenvalerate and Diazinon on Splittail Larvae. *American Fisheries Society Symposium* 39:243–253.

Toft J. D., C. A. Simenstad, J. R. Cordell, and L. F. Grimaldo. 2003. The Effects of Introduced Water Hyacinth on Habitat Structure, Invertebrate Assemblages, and Fish Diets. *Estuaries* 26(3):746–758.

U.S. Fish and Wildlife Service. 1996. *Sacramento-San Joaquin Delta Native Fishes Recovery Plan*. Portland, OR.

Wang, J. C. S. 1986. *Fishes of the Sacramento–San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories.* IEP Technical Report. 9.

Werner, I. 2007. *Pyrethroids in the Water Column – Is There Reason For Concern*? Seminar, University of California, Davis, November 8.

Wilkerson, F. P., R. C. Dugdale, V. E. Hogue and A. Marchi. 2006. Phytoplankton Blooms and Nitrogen Productivity in San Francisco Estuary. *Estuaries and Coasts* 29:401–416.

Young, P. S. and J. J. Cech Jr. 1996. Environmental Tolerances and Requirements of Splittail. *Transactions of the American Fisheries Society* 125:664–678.

2A.7.10.2 Federal Register Notices Cited

64 FR 5963. 1999. Endangered and Threatened Species; Determination of Threatened Status for the Sacramento Splittail. *Federal Register* 64: 5963.

68 FR 55139. 2003. Endangered and Threatened Species; Notice of Remanded Determination of Status for the Sacramento Splittail (*Pogonichthys macrolepidotus*). *Federal Register* 68: 55139.

75 FR 62070. 2010.Endangered and Threatened Wildlife and Plants; 12–Month Finding on a Petition to List the Sacramento Splittail as Endangered or Threatened. *Federal Register*75:62070.

2A.7.10.3 Personal Communications

Ford, Tim. Biologist, Turlock and Modesto Irrigation Districts. February 16, 1994—Fax and phone call to Randall Baxter, California Department of Fish and Game, documenting splittail catches in the Tuolumne and lower San Joaquin Rivers 1986–1992.

Grimaldo, L. California Department of Water Resources. 8–10 years of data using fin rays, unpublished data.

Heyne, Tim. Biologist, California Department of Fish and Game. October 3, 2003—Email to Randall Baxter, California Department of Fish and Game, documenting splittail counts from the Tuolumne (River Mile 5) and Merced (River Mile 13) rotary screw traps 1999–2003.

Hobbs, Jim. August 30, 2011—Personal communication.

Horvath, Mike. Fish and Wildlife Technician, California Department of Fish and Game. April 16, 1999—Email to Randall Baxter, California Department of Fish and Game, describing the catch in a screw trap of a gravid female splittail the previous day.

Oppenheim, Bruce. Biologist, National Marine Fisheries Service. September 15, 2003—Email report to Randall Baxter, California Department of Fish and Game, of a fresh angler-killed adult splittail thrown up on a river bank just below the Thermalito outlet.

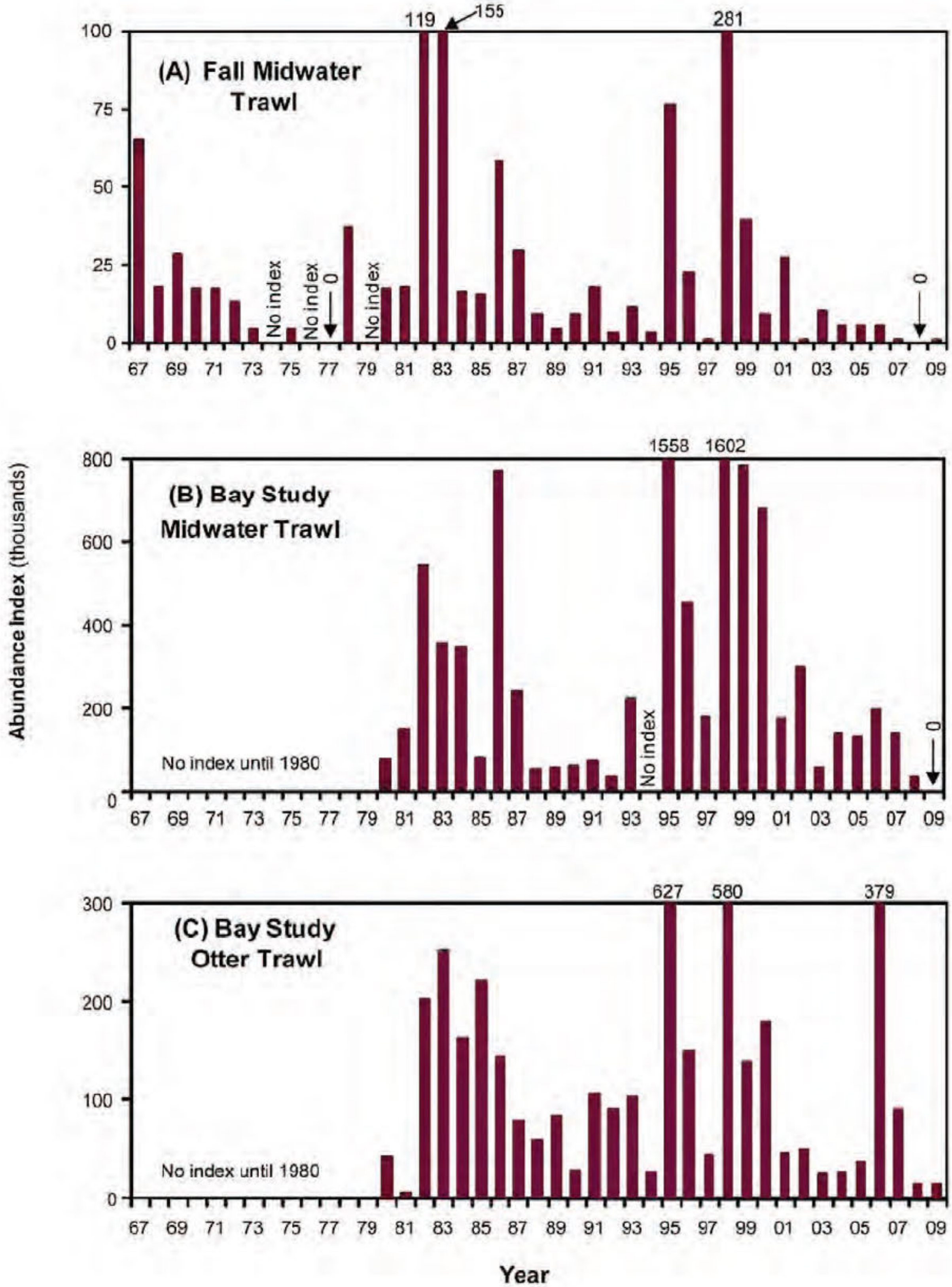
Seesholtz, Alicia. Environmental Scientist, California Department of Water Resources. September 20, 2007—Phone conversation with Rick Wilder about fish use of the Feather River.

Stevenson, Marty. Biologist/Consultant, Kinetic Laboratory for South Bay Dischargers. May 16, 1997—Email to Randall Baxter, California Department of Fish and Game, describing juvenile splittail collected in Coyote Creek and adjacent, Guadalupe Slough in 1983 and 1984.

Source: Kratville 2008

BDCP-HCP 00343.12 (12-4-12) tm

Figure 2A.7-1
Sacramento Splittail Inland Range



SOURCE: California Department of Fish and Game unpublished data, Interagency Ecological Program unpublished data.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.7-2
Annual Abundance Indices of Sacramento Splittail from 1967 to 2009

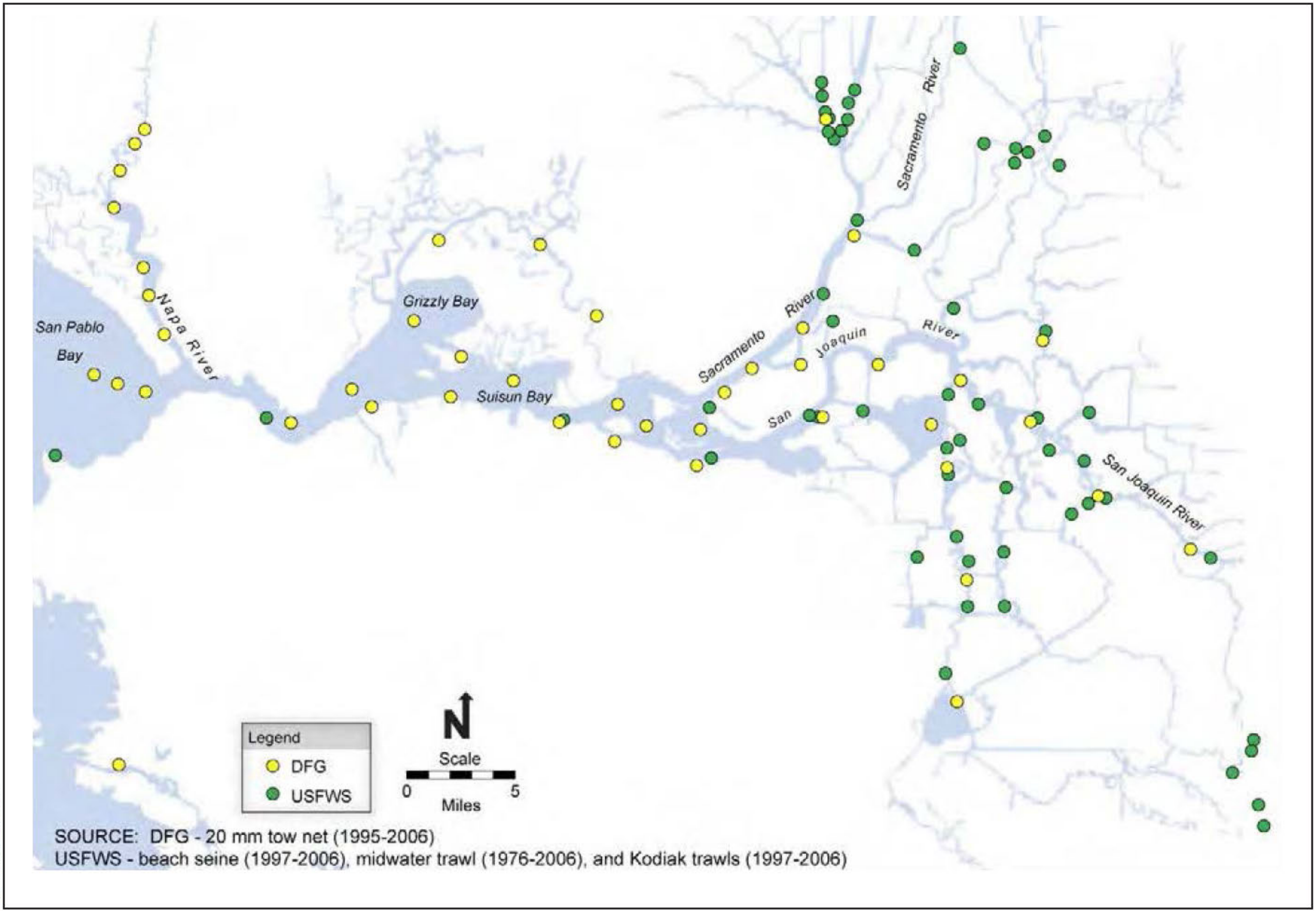
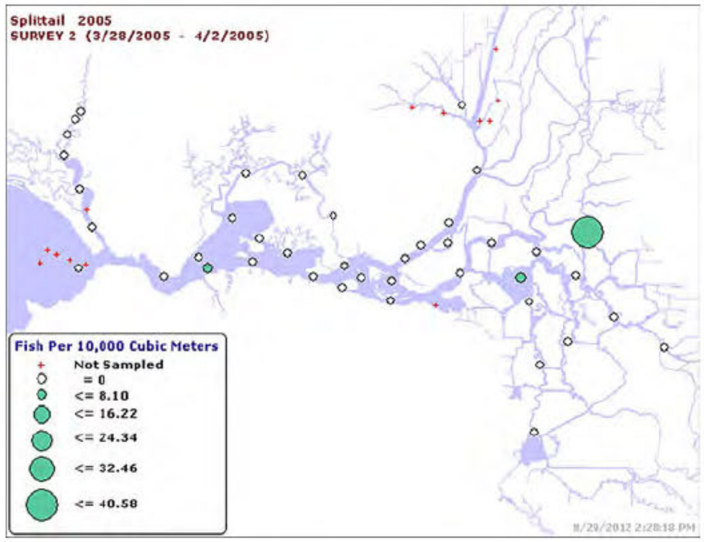
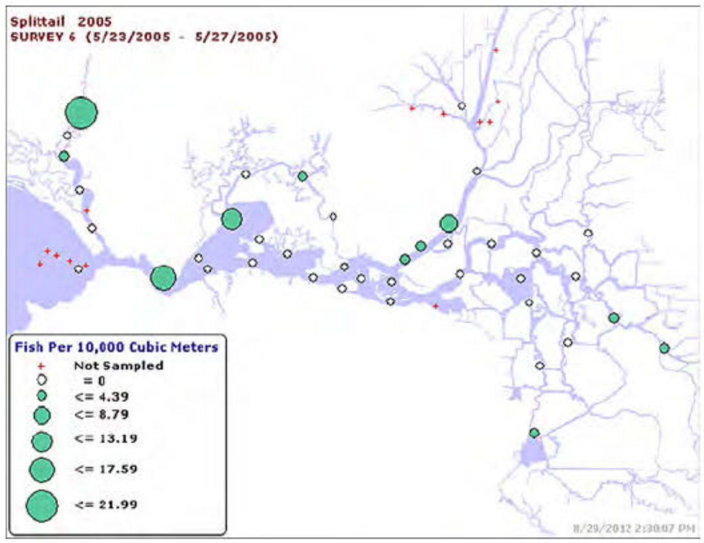


Figure 2A.7-3
Historical Sampling Locations Where Splittail Have Been Captured Since 1976

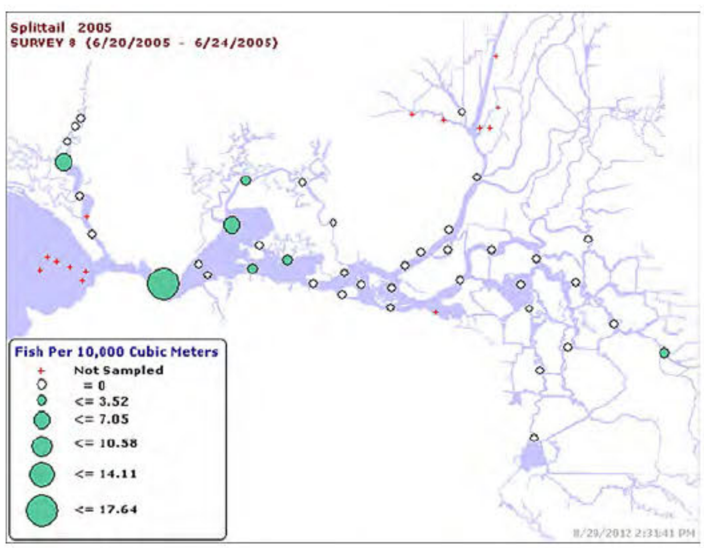
March-April



May



June



SOURCE: California Department of Fish and Game. 2003. 20 mm Juvenile Splittail Survey. Available: <http://ww/delta.dfg.ca.gove/data/20mm/description.asp>. This annual survey monitors post-larval and juvenile splittail distribution and relative abundance every two weeks during spring and early summer throughout their historical spring range using a 1600 µm egg and larval net.

BDCP-HCP 00343.12 (8-29-12) tm

Figure 2A.7-4
Example of Distribution of Juvenile Splittail in Spring-Summer of a Representative Above-Normal Water Year

Appendix 2A.8
Green Sturgeon (*Acipenser medirostris*)

2A.8.1 Legal Status

The North American green sturgeon is composed of two distinct population segments (DPSs): the Northern DPS, which includes all populations in the Eel River and northward; and the Southern DPS, which includes all populations south of the Eel River. The Northern DPS green sturgeon currently spawns in the Klamath River in California and the Rogue River in Oregon, and is listed as a Species of Concern (69 *Federal Register* [FR] 19975). Only the Southern DPS is found in the Plan Area.

The primary threat to the southern DPS is the reduction in habitat and spawning area due to dams (such as Keswick, Shasta, and Oroville). Spawning is limited to one population in the Sacramento River, making green sturgeon highly vulnerable to catastrophic events. Continuing threats include migration barriers, insufficient flow, increased water temperatures, juvenile entrainment in water export facilities, nonnative forage species, competitors, predators, poaching, pesticides and heavy metals, and local harvest (Biological Review Team 2005).

After a status review was completed in 2002 (Adams et al. 2002), the National Marine Fisheries Service (NMFS) determined that the Southern DPS did not warrant listing as threatened or endangered but should be identified as a Species of Concern. This determination was challenged on April 7, 2003. NMFS updated its status review on February 22, 2005, and determined that the Southern DPS should be listed as threatened under the federal Endangered Species Act (ESA) (Biological Review Team 2005). NMFS published a final rule on April 7, 2006 that listed the Southern DPS as threatened (71 FR 17757); the rule took effect on June 6, 2006. Included in the listing are the spawning population in the Sacramento River and fish living in the Sacramento River, the Sacramento–San Joaquin River Delta (Delta), and the San Francisco Estuary.

In September 2008, NMFS proposed critical habitat for the Southern DPS (73 FR 52084). NMFS made a final critical habitat designation for the Southern DPS on October 9, 2009 (74 FR 52300). Designated areas in California include the Sacramento River, lower Feather River, and lower Yuba River; the Delta; and Suisun, San Pablo, and San Francisco Bays (National Marine Fisheries Service 2012).

On May 21, 2009, NMFS proposed an ESA Section 4(d) rule to apply ESA take prohibitions to the Southern DPS. NMFS published the final 4(d) rule and protective regulations July 2, 2010 (75 FR 30714). In California, green sturgeon is a Class 1 Species of Special Concern (qualifying as threatened under the California Endangered Species Act [CESA]) (California Department of Fish and Game 2003).

2A.8.2 Species Distribution and Abundance

2A.8.2.1 Range

Green sturgeon ranges from Ensenada, Mexico to the Bering Sea, Alaska (Colway and Stevenson 2007; Moyle 2002). Green sturgeon spawn in two California basins: the Sacramento and Klamath Rivers (Figure 2A.8-1). These reproducing populations are genetically distinct and occupy the Southern and Northern DPS, respectively (Adams et al. 2002; Israel et al. 2004). Adult populations in the less-altered Klamath and Rogue Rivers are fairly constant, with a few hundred spawning adults typically harvested annually by tribal fisheries. In the Sacramento River, the green sturgeon population is believed to have declined over the last two decades, with less than 50 spawning green sturgeon sighted annually in the best spawning habitat (Corwin pers. comm.). In the Umpqua, Feather, Yuba, and Eel Rivers, green sturgeon sightings are extremely limited and spawning has not been recently recorded. In the San Joaquin and South Fork Trinity Rivers, the green sturgeon population appears extirpated (Figure 2A.8-1).

Green sturgeon have been recorded in the Feather River as larvae caught in screw traps (Beamesderfer et al. 2004). Spawning has recently been recorded with eggs from three different sturgeon females (Van Eenenaam 2011). In spring 2011, many sturgeon adults were spotted while DIDSON surveys were being conducted (Seesholtz 2011). No juvenile green sturgeon have been documented in the San Joaquin River. Moyle (2002) suggested that reproduction may have taken place in the San Joaquin River because adults have been captured at Santa Clara Shoal and Brannan Island. However, given the conditions that exist in the San Joaquin River today, they are probably extirpated (Israel and Klimley 2008).

Green sturgeon are anadromous and pass through the San Francisco Bay to the ocean at about 1 to 3 years of age. In the ocean they primarily move northward and commingle with other sturgeon populations, spending much of their lives in the ocean or in Oregon and Washington estuaries (California Department of Fish and Game 2002; Kelly et al. 2007). Subadult and adult green sturgeon are thought to potentially migrate thousands of miles along the coasts of northern California and the Pacific Northwest. Relatively large concentrations of sturgeon occur in the Columbia River estuary, Willapa Bay, and Grays Harbor, with smaller aggregations in the San Francisco estuary (Emmett et al. 1991; Moyle et al. 1992; Israel 2006).

Musick et al. (2000) noted that the abundance of North American green sturgeon populations has declined by 88% throughout much of its range. The California Department of Fish and Wildlife (CDFW) (California Department of Fish and Game 2002) estimated that green sturgeon abundance in the Bay-Delta estuary (generally defined as the San Francisco Bay and the Sacramento River-San Joaquin River Delta) ranged from 175 to more than 8,000 adults between 1954 and 2001 with an annual average of 1,509 adults. Fish monitoring efforts at Red Bluff Diversion Dam and the Glenn-Colusa Irrigation District pumping facility on the upper Sacramento River have recorded between zero and 2,068 juvenile North American green sturgeon per year (Adams et al. 2002). Using CDFW angler report card reports, the number of green sturgeon caught from 2006 to 2011 ranged from 311 to 389 (Gleason et al. 2007; DuBois et al. 2009, 2010, 2011, 2012). Because these fish were primarily captured in San Pablo Bay, where both northern and Southern DPSs exist, the proportion of fish captured in sampling from the Southern DPS is unknown.

Green sturgeon are long-lived (up to 60 to 70 years) and late maturing (sexual maturity is reached at approximately 15 years of age) (Van Eenennaam et al. 2006). They have a low fecundity rate

(59,000 to 242,000 eggs per female) due to a larger egg size and smaller adult size relative to white sturgeon (180,000 to 590,000 eggs per female). They may spawn every 3 to 5 years (California Fish Tracking Consortium 2009; National Marine Fisheries Service 2010). These characteristics make green sturgeon particularly susceptible to habitat degradation and overharvest (Musick 1999). With only one population in the Central Valley, a lack of spatial and geographic diversity make the viability of the Southern DPS vulnerable to changes in the environment and catastrophic events. As a result of low abundance, the population has limited genetic diversity, which decreases the ability of individuals in the green sturgeon population to withstand environmental variation.

2A.8.2.2 Distribution in the Plan Area

The Delta serves as a migratory corridor, feeding area, and juvenile rearing habitat for North American green sturgeon in the Southern DPS. Adults migrate upstream primarily through the western edge of the Delta into the lower Sacramento River between March and June (Adams et al. 2002). The only confirmed spawning site for Southern DPS green sturgeon is a short stretch of the upper mainstem Sacramento River below Keswick Dam (National Marine Fisheries Service 2010). Larvae and post-larvae are present in the lower Sacramento and North Delta between May and October, primarily in June and July (California Department of Fish and Game 2002). Juvenile green sturgeon have been captured in the Delta during all months of the year (Borthwick et al. 1999; California Department of Fish and Game 2002). Adult green sturgeon have been documented in the Yolo Bypass, but these individuals usually end up stranded against the Freemont Weir (Marshall pers. comm.) and rear in Suisun Bay and Suisun Marsh.

2A.8.3 Habitat Requirements and Special Considerations

As anadromous fish, North American green sturgeon rely on riverine, estuarine, and marine habitats during their long life. On October 9, 2009, NMFS (74 FR 52300) designated critical habitat for the green sturgeon Southern DPS. Critical habitat in marine waters includes areas within the 60-fathom isobath from Monterey Bay to the U.S.-Canada border. Coastal bays and estuaries designated as critical habitat include San Francisco Estuary and Humboldt Bay in California; Coos, Winchester, Yaquina, and Nehalem Bays in Oregon; Willapa Bay and Grays Harbor in Washington; and the lower Columbia River Estuary from the mouth to River Kilometer 74. In fresh water, critical habitat includes the mainstem Sacramento River downstream of Keswick Dam (including the Yolo and Sutter Bypasses), the Feather River below Fish Barrier Dam, the Yuba River below Daguerre Point Dam, and the Delta (Figure 2A.8-2). The essential physical and biological habitat features identified for the Southern DPS include prey resources (benthic invertebrates and small fish), water quality, water flow (particularly in freshwater rivers), water depth, substrate type/size (i.e., appropriate spawning substrates in freshwater rivers), sediment quality, and migratory corridors.

Freshwater habitat of green sturgeon of the Southern DPS varies in function, depending on location in the Sacramento River watershed. Spawning areas currently are limited to accessible reaches of the Sacramento River upstream of Hamilton City and downstream of Keswick Dam (Figure 2A.8-1) (California Department of Fish and Game 2002). Preferred spawning habitats are thought to contain large cobble in deep and cool pools with turbulent water (California Department of Fish and Game 2002; Moyle 2002; Adams et al. 2002). Sufficient flows are needed to oxygenate and limit disease and fungal infection of recently laid eggs (Deng et al. 2002; Parsley et al. 2002). In the Sacramento River, spawning appears to be triggered by large increases in water flow during spawning (Brown and Michniuk 2007). However, in the Rogue River, Erickson et al. (2002) found that green sturgeon were most often found at depths greater than 5 meters (16 feet) with low or no currents during summer and fall months.

In addition, acoustic tagging studies by Erickson et al. (2002) indicate that adult green sturgeon hold for as long as six months in deep (greater than 5 meters [16 feet]), low-gradient reaches or off-channel sloughs or coves of the river during summer months when water temperatures were between 15 and 23°C (59 and 73.5°F). When ambient temperatures in the river dropped in fall and early winter (less than 10°C [50°F]) and flows increased, fish moved downstream and into the ocean. Water temperatures in spawning and egg incubation areas are critical; temperatures greater than 19°C (66.2°F) are lethal to green sturgeon embryos (Cech et al. 2000; Mayfield and Cech 2004; Van Eenennaam et al. 2005; Allen et al. 2006).

Habitats for migration are downstream of spawning areas and include the mainstem Sacramento River, Delta, and San Francisco Bay Estuary. These corridors allow the upstream passage of adults and the downstream emigration of juveniles (71 FR 17757). Migratory habitat conditions are strongly affected by the presence of barriers and impediments to migration (e.g., dams), unscreened or poorly screened diversions, and degraded water quality. Heublein et al. (2009) found two different patterns of spawning migration and out-migration for green sturgeon in the Sacramento River. Results of this study found six individuals potentially spawned, over-summered, and moved out of the river with the first fall flow event; this is the pattern that is thought to be the common behavior of green sturgeon. Alternatively, nine individuals promptly moved out of the Sacramento River before September 1 without any known flow or temperature cue. While some green sturgeon appeared to be impeded on their upstream movement by closure of the Red Bluff Diversion Dam in mid-May, at least five individuals passed under the dam gates during their downstream migration. Both spawning areas and migratory corridors comprise rearing habitat for juvenile green sturgeon, which feed and grow up to 3 years in fresh water. Stomach contents from adult and juvenile green sturgeon captured in the Delta point to the importance of habitat that supports shrimp, mollusks, amphipods, and small fish (Radtke 1966; Houston 1988; Moyle et al. 1992). Rearing habitat condition and function may be affected by variation in annual and seasonal flow and water temperatures (71 FR 17757).

Nearshore marine habitats must provide adequate food resources, suitable water quality, and natural cover for juvenile green sturgeon to successfully forage and grow to adulthood. Offshore marine habitats are also important for supporting growth and maturation of sub-adult green sturgeon.

2A.8.4 Life History

There is relatively little known about the North American green sturgeon, particularly for those that spawn in the Sacramento River (The Nature Conservancy et al. 2008). Adult North American green sturgeon are believed to spawn every 3 to 5 years, but can spawn as frequently as every 2 years (National Marine Fisheries Service 2005) and reach sexual maturity at an age of 15 to 20 years, with males maturing earlier than females. Adult green sturgeon begin their upstream spawning migrations into the San Francisco Bay in March, reach Knights Landing during April, and spawn between March and July (Heublein et al. 2006). Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, CDFW (California Department of Fish and Game 2002) concluded that green sturgeon spawn in late spring and early summer upstream of Hamilton City, and possibly to Keswick Dam. Peak spawning is believed to occur between April and June. Adult female green sturgeon produce between 59,000 and 242,000 eggs, depending on body size, with a mean egg diameter of 4.3 millimeters (0.17 inch) (Moyle et al. 1992; Van Eenennaam et al. 2006). Life stages are summarized in Table 2A.8-1.

Table 2A.8-1. Green Sturgeon Life Stages in Delta

River	Life Stage	Start Month	End Month	Reference
Upper Sacramento	Migrant	January	December	National Marine Fisheries Service 2009
	Adult Migration	February	June	Bureau of Reclamation 2008
	Adult river holding	March	December	Israel and Klimley 2008
	Adult summer emigration	March	August	
	Eggs	March	July	National Marine Fisheries Service 2009
		March	June	Bureau of Reclamation 2008
		April	Jul July	Israel and Klimley 2008
	Larvae, post-larvae	May	October	National Marine Fisheries Service 2009
		May	October	Bureau of Reclamation 2008
		May	October	Israel and Klimley 2008
Bay-Delta	Adult Bay-Delta holding	July	December	
South Delta	Older juvenile >10 months	January	December	National Marine Fisheries Service 2009
Delta	Older juvenile >10 months	January	December	National Marine Fisheries Service 2009
		April	October	National Marine Fisheries Service 2009
Suisun Bay	Older juvenile >10 months	January	December	National Marine Fisheries Service 2009
Feather	Migrant	February	April	Seesholtz 2011; Healey and Vincik 2011
	Prespawn		April	Seesholtz 2011
	Spawner	February	June	Seesholtz 2011; Moyle 2002
	Larvae, post-larvae			
	Post-spawn migration	September	November	Seesholtz 2011; Healey and Vincik 2011
Trinity River	Migrants	June	August	Bensen et al. 2007

Newly hatched green sturgeon are approximately 12.5 to 14.5 millimeters (0.5 to 0.57 inch) long. Green sturgeon are strongly oriented to the river bottom and exhibit nocturnal activity patterns (Cech et al. 2000). After six days, the larvae exhibit nocturnal swim-up activity (Deng et al. 2002). After about 10 days they begin nocturnal downstream migrational movements (Kynard et al. 2005). Juvenile green sturgeon continue to exhibit nocturnal behavior beyond the metamorphosis from larval to juvenile stages. After approximately 10 days, larvae begin feeding and growing rapidly, and young green sturgeon appear to rear for the first 1 to 2 months in the upper Sacramento River between Keswick Dam and Hamilton City (California Department of Fish and Game 2002). Length measurements estimate juveniles to be 2 weeks old (24 to 34 millimeters [0.95 to 1.34 inch] fork length) when they are captured at the Red Bluff Diversion Dam (California Department of Fish and Game 2002; U.S. Fish and Wildlife Service 2002), and three weeks old when captured further downstream at the Glenn-Colusa facility (Van Eenennaam et al. 2001). Growth is rapid as juveniles reach up to 30 centimeters (11.8 inches) the first year and over 60 centimeters (24 inches) in the first 2 to 3 years (Nakamoto et al. 1995).

Juveniles spend 1 to 4 years in freshwater and estuarine habitats before they enter the ocean (Nakamoto et al. 1995). According to Heublein (2006), all adults leave the Sacramento River prior to September. Lindley (2006) found frequent large-scale migrations of green sturgeon along the Pacific Coast. Kelly et al. (2007) reported that green sturgeon enter the San Francisco Estuary during the spring and remain until fall. Juvenile and adult green sturgeon enter coastal marine waters after making significant long-distance migrations with distinct directionality thought to be related to resource availability.

Little is known about juvenile and adult green sturgeon feeding and diet in the ocean. On entering the highly productive ocean environment, green sturgeon grow at a rate of approximately 7 centimeters (2.76 inches) per year until they reach maturity. Male green sturgeon mature at an earlier age and are smaller than females (Van Eenennaam et al. 2006). Green sturgeon spend 3 to 13 years in the ocean before returning to fresh water to spawn

2A.8.5 Threats and Stressors

A number of threats and stressors exist for green sturgeon. Stressor rankings and the certainty associated with these rankings for green sturgeon are provided in Chapter 5 of the BDCP. The discussion below outlines some of the main threats and stressors to green sturgeon. Delta outflow is recognized as important to green sturgeon and is discussed in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*.

2A.8.5.1 Reduced Spawning Habitat

Access to historical spawning habitat has been reduced by construction of migration barriers, such as major dams, that block or impede access to the spawning habitat. Major dams include Keswick Dam on the Sacramento River and Oroville Dam on the Feather River (Lindley et al. 2004; National Marine Fisheries Service 2005). The Feather River is likely to have supported significant spawning habitat for the green sturgeon population in the Central Valley before dam construction (Figure 2A.8-1) (California Department of Fish and Game 2002). Green sturgeon adults have been observed periodically in the lower Feather River (U.S. Fish and Wildlife Service 1995; Beamesderfer et al. 2004). Results of habitat modeling by Mora (2006) suggested there is potential habitat on the Feather River upstream of Oroville Dam that would have been suitable for sturgeon spawning and rearing prior to construction of the dam. This modeling also suggested sufficient conditions are present in the San Joaquin River to Friant Dam, and in the tributaries such as Stanislaus, Tuolumne, and Merced Rivers upstream to their respective dams, although it is unknown whether green sturgeon ever inhabited the San Joaquin River or its tributaries (Beamesderfer et al. 2004).

2A.8.5.2 Migration Barriers

NMFS reports several potential migration barriers, including structures such as the Red Bluff Diversion Dam, Sacramento Deep Water Ship Channel locks, Sutter Bypass, and Delta Cross Channel gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River (71 FR 17757). In the Central Valley, approximately 4.6% of the total river kilometers have spawning habitat characteristics similar to where Northern DPS green sturgeon spawn, with only 12% of this habitat currently occupied by sturgeon (Neuman et al. 2007). Of the 88% that is unoccupied (approx. 4,000 kilometers [2,485 miles]), 44.2% is currently inaccessible due to dams (Neuman et al. 2007).

The Red Bluff Diversion Dam has been identified as a major barrier and impediment to sturgeon migration on the Sacramento River (U.S. Fish and Wildlife Service 1995). Adult sturgeon can migrate past the dam when gates are raised between mid-September and mid-May to allow passage for winter-run Chinook salmon. However, tagging studies by Heublein (2006) found that when the gates were closed, a substantial portion of tagged adult green sturgeon failed to use fish ladders at the dam and were, therefore, unable to access upstream spawning habitats. Recent changes to water operations at the Red Bluff Diversion Dam, including placing dam gates in a permanent open position and construction of a new pumping facility with a state-of-the-art fish screen, are expected to eliminate passage issues at the dam for green sturgeon and other migratory fish species.

Sacramento River water passes through a set of locks at the end of the Sacramento River Deep Water Ship Channel at the connection with the Sacramento River. However, the locks prevent the fish that sense water coming from the Sacramento River from migrating from the Deep Water Ship Channel back to the Sacramento River (California Department of Water Resources 2005).

The Fremont Weir is located at the upstream end of the Yolo Bypass, a 40-mile (64-kilometer) long basin that functions as a flood control project on the Sacramento River. Green sturgeon are attracted by high floodwater flows into the Yolo Bypass basin and then concentrate behind Fremont Weir, which they cannot effectively pass (California Department of Water Resources 2005). Green sturgeon that concentrate behind the weir are subject to heavy illegal fishing pressure or become stranded behind the flashboards when high flood flows recede (Marshall pers. comm.). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003:88–93). Methods to reduce stranding and increase passage have been investigated by the California Department of Water Resources (DWR) and CDFW (California Department of Water Resources 2007; Navicky pers. comm.).

It is thought that adult and juvenile green sturgeon use the same migratory routes as Chinook salmon. Delta Cross Channel gate closures occur during the winter and early spring sturgeon migration period (February through May) as required by State Water Resources Control Board (State Water Board) water right Decision 1641 (D-1641). Upstream migrating adult Chinook salmon are known to use the Delta Cross Channel as a migratory pathway when the gates are open (Hallock et al. 1970). When the gates are open, Sacramento River water flows into the central Delta and the Mokelumne and San Joaquin Rivers, providing migration cues. It is possible that attraction to water passing from the Sacramento River into the interior Delta causes delays and straying of green sturgeon, as it does to Chinook salmon (CALFED Bay-Delta Program 2001; McLaughlin and McLain 2004). The Delta Cross Channel completely blocks juvenile and adult sturgeon migration to and from the interior Delta when the gates are closed.

2A.8.5.3 Exposure to Toxins

Exposure of green sturgeon to toxins has been identified as a factor that can lower reproductive success, decrease early life stage survival, and cause abnormal development, even at low concentrations (U.S. Fish and Wildlife Service 1995; Environmental Protection Information Center et al. 2001; Klimley 2002). Water discharges containing metals from Iron Mountain Mine, located adjacent to the Sacramento River, have been identified as a factor affecting survival of sturgeon downstream of Keswick Dam. In addition, storage limitations and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances. Treatment processes and improved drainage management in recent years have reduced the toxicity of runoff from Iron Mountain Mine to acceptable levels. Although the impact of trace elements on green sturgeon reproduction is not completely understood, negative impacts similar to those of salmonids are suspected (U.S. Fish and Wildlife Service 1995; Environmental Protection Information Center et al. 2001; Klimley 2002).

Green sturgeon consume overbite clams (*Potamocorbula amurensis*) and Asian clams (*Corbicula fluminea*), which are known to bioaccumulate selenium rapidly and lose selenium slowly (Linville et al. 2002; Doroshov 2006). Selenium is transferred to the egg yolk where it can cause mortality of larvae. Although chronic and acute exposure to toxics has been identified as a factor adversely affecting various life stages of green sturgeon, the severity, frequency, geographic locations, and population level consequences of exposure to toxics have not been quantified (Linville et al. 2002; Doroshov 2006). However, Linville (2006) observed larvae to have increased skeletal deformities and mortality associated with maternal effects of selenium exposure, while smaller quantities (about 20 milligrams per kilogram [mg/kg]) decreased feeding efficiency and larger quantities (greater than 20 mg/kg) reduced growth rates after four weeks (Lee et al. 2008a).

Methylmercury is another toxic substance that could potentially affect sturgeon development and survival. Between 2002 and 2006, sediment concentrations of methylmercury were highest in the Central Bay, while shallower parts of San Pablo Bay and Suisun Bay also contained levels greater than 0.2 parts per billion (ppb) (San Francisco Estuary Institute 2007). The amount of methylmercury resulting in the death of juvenile green sturgeon ranges between 20 to 40 mg/kg, with greater consumption increasing mortality significantly (Lee et al. 2008b).

2A.8.5.4 Harvest

As a long-lived, late maturing fish with relatively low fecundity and periodic spawning, the green sturgeon is particularly susceptible to threats from overfishing (Musick 1999). Total captures of green sturgeon in the Columbia River Estuary in commercial fisheries between 1985 and 2003 ranged from 46 fish per year to 6,000 (Adams et al. 2007). However, a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as high as 80% in the Columbia River) may be from the Southern DPS (California Department of Fish and Game 2002; Israel 2006). Long-term data indicate that harvest for green sturgeon occurs primarily in the Columbia River (51%), coastal trawl fisheries (28%), the Oregon fishery (8%), and the California tribal fishery (8%). Harvest of green sturgeon dropped substantially from over 6,000 from 1985 to 1989 to 512 in 2003 (Adams et al. 2007). Much of the reduction results from progressively more restrictive regulation in the Columbia River. Coastal trawl fisheries have declined to low levels, thereby lowering the by-catch of green sturgeon. In 2003, Klamath and Columbia River tribal fisheries accounted for 65% of total catch (Adams et al. 2007).Green sturgeon are also vulnerable to recreational sport fishing in the Bay-Delta estuary and Sacramento River, as well as other estuaries located in Oregon and Washington. Green sturgeon are primarily captured incidentally in California by sport fishermen targeting the more desirable white sturgeon, particularly in San Pablo and Suisun Bays (Emmett et al. 1991).

To protect spawning Southern DPS green sturgeon, new federal and state regulations, including the June 2, 2010 NMFS take prohibition (75 FR 30714), mandate that no green sturgeon can be taken or possessed in California (California Department of Fish and Game 2007a). If green sturgeon are caught incidentally and released while fishing for white sturgeon, anglers are asked to report it to CDFW on their white sturgeon report card. The level of hooking mortality that results following release of green sturgeon by anglers is unknown. Sport fishing captures have declined through time, but the factors leading to the decline are unknown. CDFW (California Department of Fish and Game 2002) indicates that sturgeon are highly vulnerable to the fishery in areas where sturgeon are concentrated, such as the Delta and Suisun and San Pablo Bays in late winter, and the upper Sacramento River during spawning migration. Because many sturgeon in the Columbia River, Willapa Bay, and Grays Harbor are likely from the Southern DPS, additional harvest closures in these areas would likely benefit the Southern DPS.

Poaching (illegal harvest) of sturgeon is known to occur in the Sacramento River, particularly in areas where sturgeon have been stranded (e.g., Fremont Weir) (Marshall pers. comm.), as well as throughout the Bay-Delta (Schwall pers. comm.). Catches of sturgeon are thought to occur during all years, especially during wet years. Green sturgeon inhabiting the San Joaquin River portion of the Delta experience heavy fishing pressure, particularly from illegal fishing (U.S. Fish and Wildlife Service 1995). Areas just downstream of Thermalito Afterbay outlet, Cox's Spillway, and several barriers impeding migration on the Feather River may be areas of high adult mortality from increased fishing effort and poaching. Poaching rates in the rivers and estuary and the impact of poaching on green sturgeon abundance and population dynamics are unknown.

2A.8.5.5 Reduced Rearing Habitat

Historical reclamation of wetlands and islands have reduced and degraded the availability of suitable in- and off-channel rearing habitat for green sturgeon. Further, channelization and hardening of levees with riprap has reduced in- and off-channel intertidal and subtidal rearing habitat. The resulting changes to river hydraulics, riparian cover, seasonal floodplain inundation, and geomorphology affect important ecoystem functions (Sweeney et al. 2004). The impacts of channelization and riprapping are thought to affect larval, post-larval, juvenile, and adult stages of sturgeon, as these life stages are dependent on the food web in freshwater and low-salinity regions of the Delta.

2A.8.5.6 Increased Water Temperature

Exposure to water temperatures greater than 63°F (17.2°F) can increase mortality of sturgeon eggs and larvae (Pacific States Marine Fisheries Commission 1992) and temperatures above 69°F (20.6°C) are lethal to embryos (Cech et al. 2000). Temperatures near the Red Bluff Diversion Dam on the Sacramento River historically occur within optimum ranges for sturgeon reproduction; however, temperatures downstream, especially later in the spawning season, were reported to be frequently above 63°F (17.2°F) (U.S. Fish and Wildlife Service 1995). High temperatures in the Sacramento River during the February to June period no longer appear to be a major concern for green sturgeon spawning, egg incubation, and juvenile rearing, as temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon. The Shasta temperature control device, installed at Shasta Dam in 1998, in combination with improved cold-water pool management and storage in Lake Shasta, have resulted in improved cool water stream conditions in the upper Sacramento River.

Water temperatures in the Feather River may be inadequate for spawning and egg incubation as the result of releases of warmed water from Thermalito Afterbay (Surface Water Resources, Inc. 2003). Warmed water may be one reason why neither green nor white sturgeon are found in the river during low-flow years (California Department of Fish and Game 2002). It is not expected that water temperatures will become more favorable in the near future and this temperature problem will continue to be a factor affecting habitat value for green sturgeon on the lower Feather River (California Department of Fish and Game 2002).

The lack of flow in the San Joaquin River from dam and diversion operations and agricultural return flows contribute to higher temperatures in the mainstem San Joaquin River, offering less water to keep temperatures cool for sturgeon, particularly during late summer and fall. Though these effects are difficult to measure, temperatures in the lower San Joaquin River continually exceed preferred temperatures for sturgeon migration and development during spring months. Temperatures at Stevenson on the San Joaquin River near the Merced River confluence recorded on May 31 (spawning typically occurs from April to June; Table 2A.8-1) between 2000 and 2004 ranged from 77 to 82°F (25 to 27.8°C) (California Department of Water Resources 2007). Juvenile sturgeon are also exposed to increased water temperatures in the Delta during the late spring and summer due to the loss of riparian shading and by thermal inputs from municipal, industrial, and agricultural discharges.

2A.8.5.7 Nonnative species

Recent introductions of invertebrates have greatly affected the benthic fauna in the Delta and Suisun Bay. CDFW (California Department of Fish and Game 2002) reviewed many of the recent nonnative invasive species introductions and the potential consequences to green sturgeon. The most notable species responsible for altering the trophic system of the Delta include *Potamocorbula*, *Corbicula*, and the Chinese mitten crab (*Eriocheir sinensis*). Sturgeon regularly consume *Potamocorbula* and *Corbicula*, which is of particular concern because of the high bioaccumulation rates of these clams (Doroshov 2006). Although Chinese mitten crabs may be eaten by adult green sturgeon, it is unlikely that they are a major prey item. The Chinese mitten crab population in the Delta has undergone a substantial decline since 2002 and currently occurs in very low abundance (Hieb pers. comm.) and, therefore has not been a major factor affecting green sturgeon during this period.

2A.8.5.8 Dredging

Hydraulic dredging to allow commercial and recreational vessel traffic is a common practice in the Sacramento and San Joaquin Rivers, navigation channels in the Delta, and Suisun, San Pablo, and San Francisco Bays. Such dredging operations pose risks to bottom-oriented fish such as green sturgeon. Studies by Buell (1992) reported approximately 2,000 sturgeon entrained in the removal of one million tons of sand from the bottom of the Columbia River at depths of 60 to 80 feet (18 to 24 meters). In addition, dredging operations can decrease the abundance of locally available prey species, and contribute to resuspension of toxics such as ammonia[1], hydrogen sulfide, and copper during dredging and dredge spoil disposal, and alter bathymetry and water movement patterns (National Marine Fisheries Service 2006).

2A.8.5.9 Reduction in Turbidity

Turbidity levels in the Delta have declined over the past few decades (Jassby et al. 2002), but little is known about the potential effects of reduced turbidity on green sturgeon.

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

2A.8.5.10 Entrainment

Larval sturgeon are susceptible to entrainment from nonproject water diversion facilities because of their migratory behavior and habitat selection in the rivers and Delta. The overall impact of entrainment of fish populations is typically unknown (Moyle and Israel 2005); however, there is enough descriptive information to predict where green sturgeon may be entrained. Herren and Kawasaki (2001) documented 431 nonproject diversions on the Sacramento River between Sacramento and Shasta Dam. Entrainment information regarding larval and post-larval individual green sturgeon is unreliable because entrainment at these diversions has not been monitored and field identification of green sturgeon larvae is difficult. USFWS staff are working on identification techniques and are optimistic that green sturgeon greater than 40 millimeters (1.6 inch) can be identified in the field (Poytress 2006). Sturgeon collected at the Glenn-Colusa Irrigation District diversion located on the upper Sacramento River are not identified to species, but are assumed to primarily consist of green sturgeon because white sturgeon are known to spawn primarily downstream (Schaffter 1997). Although screens at the Glenn-Colusa Irrigation District diversion satisfy both the NMFS and CDFW screening criteria for salmonids, the effectiveness of these criteria is unknown for sturgeon. Low numbers of green sturgeon (less than 1% of total present February to June) have also been identified and entrained at the Red Bluff Research Pumping Plant (Borthwick et al. 1999).

In the Feather River, there are eight large diversions greater than 10 cubic feet per second (cfs) and approximately 60 small diversions between 1 and 10 cfs between the Thermalito Afterbay outlet and the confluence with the Sacramento River (U.S. Fish and Wildlife Service 1995). Based on potential entrainment problems of green sturgeon elsewhere in the Central Valley and the presence of multiple screened and unscreened diversions on the Feather River, it is thought that operation of unscreened water diversions on the Feather River are a possible threat to juvenile green sturgeon.

Presumably, juvenile green sturgeon become less susceptible to entrainment as they grow and their swimming ability and capacity to escape diversions improves. The majority of North American green sturgeon captured in the Delta are between 200 and 500 millimeters (7.9 and 19.7 inches) long (California Department of Fish and Game 2002). Herren and Kawasaki (2001) inventoried water diversions in the Delta and counted a total of 2,209 diversions of various types, only 0.7% of which were screened. The majority of these diversions were between 12 and 24 inches (305 and 610 mm) in diameter. The vulnerability of juvenile green sturgeon to entrainment at these unscreened diversions is largely unknown, although in two multiyear studies (Nobriga et al. 2004; Pickard et al. 1982) no green sturgeon were caught. Results of these studies suggest that larger juvenile green sturgeon have a lower risk of entrainment mortality. The largest diversions in the Delta are the State Water Project (SWP) and Central Valley Project (CVP) export facilities, located in the southern Delta, where a low number of juvenile green sturgeon have been recorded as part of fish salvage monitoring (California Department of Fish and Game 2002). The average number of green sturgeon taken per year at the SWP Skinner Fish Facility was 87 individuals between 1981 and 2000, and 20 individuals from 2001 through 2007 (Donnellan pers. comm.). At the CVP Tracy Fish Collection Facility, green sturgeon counts averaged 246 individuals per year between 1981 and 2000, and 53 individuals per year between 2001 and 2007 (Donnellan pers. comm.). This reduction in salvage is consistent with a significant reduction in white sturgeon take at the salvage facilities in the same time periods (National Marine Fisheries Service 2005).

Green sturgeon that are attracted by high flows in the Yolo Bypass move onto the floodplain and eventually concentrate behind Fremont Weir and in various ponds and pools, where they are blocked from further upstream migration (California Department of Water Resources 2005). As the bypass recedes, these sturgeon become stranded behind the flashboards of the weir and can be subjected to heavy illegal fishing pressure (Marshall pers. comm.). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003:88–93). Methods to reduce stranding and increase passage have been investigated (Navicky pers. comm.).

2A.8.6 Relevant Conservation Efforts

The Anadromous Fish Restoration Program of the Central Valley Project Improvement Act contains a goal of supporting efforts that lead to doubling the natural production of anadromous fish in the Central Valley on a sustainable, long-term basis, at levels not less than twice the average levels attained during the period of 1967 to 1991. Although most efforts of the Anadromous Fish Restoration Program have focused on Chinook salmon because of their listing history and status, sturgeon may receive some unknown amount of incidental benefit from these restoration efforts. For example, the acquisition of water for flow enhancement on tributaries to the Sacramento River, fish screening for the protection of Chinook salmon and Central Valley steelhead, spawning gravel augmentation, or riparian revegetation and instream restoration projects would likely have some ancillary benefits to sturgeon. The Anadromous Fish Restoration Program has also invested in a green sturgeon research project that has helped improve our understanding of the life history requirements and temporal patterns of the Southern DPS of North American green sturgeon.

Many beneficial actions have originated from and been funded by the CALFED Bay-Delta Program (CALFED), including such projects as floodplain and instream restoration, riparian habitat protection, fish screening and passage projects, research on nonnative invasive species and contaminants, restoration methods, watershed stewardship, and education and outreach programs. Prior Federal Register notices have reviewed the details of the Central Valley Project Improvement Act and CALFED programs and potential benefits for anadromous fish, particularly Chinook salmon and Central Valley steelhead (69 FR 33102). Projects potentially benefiting sturgeon primarily consist of fish screen evaluation and construction projects, restoration evaluation and enhancement activities, and contaminant studies. Two evaluation projects specifically addressed green sturgeon, while the remaining projects primarily address listed salmonids and fishes of the area in general. The new information developed through these research investigations will be used to enhance the understanding of the risk factors affecting population dynamics and recovery, thereby improving the ability to develop effective management measures.

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) was formed to guide the implementation of CALFED Ecosystem Restoration Plan elements in the Delta (California Department of Fish and Game 2007b). The DRERIP team has created a suite of ecosystem and species conceptual models, including green sturgeon, that document existing scientific knowledge of Delta ecosystems. The DRERIP team is in the process of using these conceptual models to assess the suitability of actions proposed in the Ecosystem Restoration Plan for implementation. DRERIP conceptual models have been used in the analysis of proposed conservation measures.

In response to concerns about passage impediment to green sturgeon and other migratory species, operations of the Red Bluff Diversion Dam have been ceased and a new water pumping facility with a state-of-the –art fish screen has been constructed. The project now provides a reliable water supply for high-value crops in Tehama, Glenn, Colusa, and northern Yolo Counties while providing year-round unimpeded fish passage.

The combination of increased law enforcement and new sport fishing regulations adopted over the past several years specifically to protect sturgeon and reduce their harvest is expected to further reduce illegal fishing practices as well as the effects of incidental harvest of green sturgeon by recreational anglers throughout the range of the species. Mitigation under the Delta Fish Agreement has increased the number of wardens enforcing harvest regulations for steelhead and other fish in the Delta and upstream tributaries by creating the Delta Bay Enhanced Enforcement Program.

2A.8.7 Recovery Goals

On November 12, 2009, NMFS announced its intent to develop a recovery plan for the Southern DPS of North American green sturgeon (*Acipenser medirostris*) and has requested information from the public (74 FR 58245). An outline for the recovery plan was prepared December 2010 (National Marine Fisheries Service 2010), but the plan itself has not yet been completed.

2A.8.8 References Cited

2A.8.8.1 Literature Cited

Adams, P. B., C. B. Grimes, J. E. Hightower, S. T. Lindley, and M. L. Moser. 2002. *Status Review for North American Green Sturgeon,* Acipenser medirostris. National Marine Fisheries Service.

Adams, P. B., Grime, C. B. Grimes, J. E. Hightower, S. T. Lindley, M. L. Moser, and M. J. Parsley. 2007. Population Status of North American Green Sturgeon, *Acipenser medirostris*. *Environmental Biology of Fishes* 79:339–356.

Allen, P. J., B. Hodge, I. Werner, and Cech, J. J. 2006. Effects of Ontogeny, Season, and Temperature on the Swimming Performance of Juvenile Green Sturgeon (*Acipenser medirostris*). *Canadian Journal of Fisheries and Aquatic Sciences* 63(6):1360–1369.

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. *Historical and Current Information on Green Sturgeon Occurrence in the Sacramento and San Joaquin Rivers and Tributaries*. S.P. Cramer & Associates, Inc.

Bensen, R. L., S. Turo, and B. W. McCovey, Jr. 2007. Migration and Movement Patterns of Green Sturgeon (*Acipenser medirostris*) in the Klamath and Trinity Rivers, California, USA. *Environmental Biology of Fishes* 79:269–279.

Biological Review Team. 2005. *Green Sturgeon (*Acipenser medirostris*) Status Review Update*. NOAA Fisheries, Southwest Fisheries Science Center.

Borthwick, S. M., R. R. Corwin, and C. R. Liston. 1999. *Investigations of Fish Entrainment by Archimededs and Internal Helical Pumps at the Red Bluff Research Pumping Plant, Sacramento, California: February 1997*. June.

Brown, L. R. and D. Michniuk 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California 1980–1983 and 2001–2003. *Estuaries and Coasts* 30:186–200.

Buell, J. W. 1992. *Fish Entrainment Monitoring of the Western-Pacific Dredge R W Lofgren during Operations Outside the Preferred Work Period*. Portland, OR.

Bureau of Reclamation. 2008. *Biological Assessment of the Continued Long-Term Operations of the Central Valley Project and the State Water Project*. Available: <http://www.usbr.gov/mp/cvo/ocap_page.html>.

CALFED Bay-Delta Program. 2001. *Science in Action: Scrutinizing the Delta Cross Channel*. CALFED Science Program. June.

California Department of Fish and Game. 2002. *California Department of Fish and Game Comments to NMFS Regarding Green Sturgeon Listing*.

California Department of Fish and Game. 2003. *Species of Special Concern*. Revised May 2.

California Department of Fish and Game. 2007a. *2007–2008 California Freshwater Sport Fishing Regulations*. Available: <http://www.dfg.ca.gov/regulations/07-08-inland-fish-regs.pdf>.

California Department of Fish and Game. 2007b. *Delta Regional Ecosystem Restoration Implementation Plan*. Available: <http://www.delta.dfg.ca.gov/erpdeltaplan>. Accessed: February 25, 2008.

California Department of Water Resources. 2005. *Bulletin 250-2002: Fish Passage Improvement*. Sacramento, CA.

California Department of Water Resources. 2007. *California Data Exchange Center.* Available: <http://cdec.water.ca.gov>.Acessed: December 12, 2007.

California Fish Tracking Consortium. 2009 *California Fish Tracking Consortium*. Available: <http://californiafishtracking.ucdavis.edu>.

Cech, J. J., S. I. Doroshov, G. P. Moberg, B. P. May, R. G. Schaffter, and D. M. Kohlhorst. 2000. *Biological Assessment of Green Sturgeon in the Sacramento–San Joaquin Watershed (Phase 1)*. Final report to CALFED Bay-Delta Program. Project # 98-C-15.

Colway, C. and Stevenson, D. E. 2007. Confirmed Records of Two Green Sturgeon from the Bering Sea and Gulf of Alaska. *Northwestern Naturalist* 88:188–192.

Deng, X., J. P. Van Eenennaam, and S. I. Doroshov. 2002. Comparison of Early Life Stages and Growth of Green and White Sturgeon. *Transactions of the American Fisheries Society* 28:237–248.

Doroshov, S. 2006. *Potential Environmental Impacts on Reproduction of Green and White Sturgeon*. Presentation at the CALFED Science Conference, October 23. Sacramento, CA.

DuBois, J., M. Gingras, and R. Mayfield. 2009. *2008 Sturgeon Fishing Report Card: Preliminary Data Report.* Stockton, CA: California Department of Fish and Game.

DuBois, J., T. Matt, and B. Beckett. 2010. *2009 Sturgeon Fishing Report Card: Preliminary Data Report.* Stockton, CA: California Department of Fish and Game

DuBois, J., T. Matt, and T. MacColl. 2011. *2010 Sturgeon Fishing Report Card: Preliminary Data Report.* Stockton, CA: California Department of Fish and Game.

DuBois, J., T. MacColl, and E. Haydt. 2012. *2011. Sturgeon Fishing Report Card: Preliminary Data Report.* Stockton, CA: California Department of Fish and Game.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. *Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume II: Species Life History Summaries.* ELMR Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD.

Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California. 2001. *Petition to List the North American Green Sturgeon (*Acipenser medirostris*) as an Endangered or Threatened Species under the Endangered Species Act*. Available: <http://www.biologicaldiversity.org/swcbd/SPECIES/grnsturgeon/PETITION.PDF>

Erickson, D. L., J. A. North, J. E. Hightower, J. Weber, and L. Lauck. 2002. Movement and Habitat Use of Green Sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. *Journal of Applied Ichthyology* 18:565–569.

Gleason, E., M. Gingras, and J. DuBois. 2008. *2007 Sturgeon Fishing Report Card: Preliminary Data Report.* Stockton, CA: California Department of Fish and Game.

Hallock, R. J., R. F. Elwell, and D. H. Fry. 1970. *Migrations of Adult King Salmon* Oncorhynchus tshawytscha *in the San Joaquin Delta as Demonstrated by the Use of Sonic Tags*. California Department of Fish and Game. Fish Bulletin 151.

Harrell, W. C. and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. In: P. M. Faber (ed.), *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration. 2001 Riparian Habitat and Floodplains Conference Proceedings* Sacramento, CA: Riparian Habitat Joint Venture. Pages 88–93.

Healey, M. and R. Vincik. 2011. Internal Memorandum to Joseph R. Johnson, Department of Fish and Game. May 6. Rancho Cordova, CA: California Department of Fish and Game.

Herren, J. R. and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. Pages 343–355. In R.L. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids*. Volume 2. California Fish and Game. Fish Bulletin 179.

Heublein, J. C. 2006. *Migration of Green Sturgeon,* Acipenser medirostris*, in the Sacramento River*. Thesis. San Francisco State University, CA.

Heublein, J. C., J. T. Kelly, and A. P. Klimley. 2006. *Spawning Migration and Habitat of Green Sturgeon, Acipenser medirostris, in the Sacramento River*. Presentation at the CALFED Science Conference. October 23. Sacramento, CA.

Heublein, J. C., J. T. Kelly, C. E. Crocker, A. P. Klimley, and S. T. Lindley. 2009. Migration of Green Sturgeon *Acipenser medirostris* in the Sacramento River. *Environmental Biology of Fishes* 84(3):245–258.

Houston, J. J. 1988. Status of Green Sturgeon, *Acipenser medirostris*, in Canada. *Canadian Field-Naturalist* 102:286–290.

Israel, J. 2006. *North American Green Sturgeon Population Characterization and Abundance of the Southern DPS*. Presentation to NMFS on April 4.

Israel, J. A. and A. P. Klimley. 2008. *Life History Conceptual Model for North American Green Sturgeon (Acipenser medirostris)*. University of California, Davis.

Israel, J. A., J. F. Cordes, M. A. Blumberg, and B. May. 2004. Geographic Patterns of Genetic Differentiation among Collections of Green Sturgeon. *North American Journal of Fisheries Management* 24:922–931.

Jassby, A. D., J. E. Cloern, and B. E. Cole. 2002. Annual Primary Production: Patterns and Mechanisms Of Change in a Nutrient-Rich Tidal Ecosystem. *Limnology and Oceanography*47:698–712.

Kelly, J. T., A. P. Klimley, and C. E. Crocker. 2007. Movements of Green Sturgeon, *Acipenser medirostris*, in the San Francisco Bay Estuary, California. *Environmental Biology of Fishes* 79:281–295.

Klimley, A. P. 2002. *Biological Assessment of Green Sturgeon in the Sacramento–San Joaquin Watershed*. A proposal to the California Bay-Delta Authority.

Kynard, B., E. Parker, and T. Parker. 2005. Behavior of Early Life Intervals of Klamath River Green Sturgeon, *Acipenser medirostris*, with Note on Body Color. *Environmental Biology of Fishes* 72:85–97.

Lee, J.-W., N. De Riu, K. Zheng, D. F. Deng, S. S. O. Hung. 2008a. *Chronic Toxicity of Dietary L-Selenomethionin in Juvenile Green Sturgeon (*Acipenser medirostris*)*. Poster, Department of Animal Science, University of California, Davis.

Lee, J.-W., N. De Riu, K. Zheng, D. F. Deng, S. S. O. Hung. 2008b. *Chronic Toxicity of Dietary Methylmercury Chloride in Juvenile Green Sturgeon (*Acipenser medirostris*)*. Poster, Department of Animal Science, University of California, Davis.

Lindley, S. T. 2006. *Large-Scale Migrations of Green Sturgeon*. Presentation at Interagency Ecological Program 2006 Annual Workshop, Pacific Grove, California. March 3.

Lindley, S. T., R. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. *Population Structure of Threatened and Endangered Chinook Salmon ESU in California's Central Valley Basin.* Public review draft. Santa Cruz, CA: Southwest Science Center.

Linville, R. G. 2006. *Effects of Excess Selenium on the Health and Reproduction of White Sturgeon (*Acipenser medirostris*): Implications for San Francisco Bay-Delta*. Ph.D., Department of Animal Science, University of California, Davis.

Linville, R. G., S. N. Luoma, L. Cutter, and G.A. Cutter. 2002. Increased Selenium Threat as a Result of Invasion of the Exotic Bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. *Aquatic Toxicology* 57:51–64.

Mayfield, R. B. and Cech, J. J. 2004. Temperature Effects on Green Sturgeon Bioenergetics. *Transactions of the American Fisheries Society* 133(4):961–970.

McLaughlin, L. and J. McLain. 2004. *Comparison of Relative Abundance of Adult Chinook Salmon (*Oncorhynchus tshawytscha*) in the Delta Cross Channel, Georgiana Slough, and Sacramento River, California 2001*. Technical Report for the CALFED Bay-Delta Program.

Mora, E. 2006. *Modeling Green Sturgeon Habitat in the Central Valley*. Presentation at the 2006 CALFED Science conference, October 23. Sacramento, CA.

Moyle, P. B. 2002. *Inland Fishes of California, Revised and Expanded*. Berkeley, CA: University of California Press.

Moyle, P. B. and J. A. Israel. 2005. Untested Assumptions: Effectiveness of Screening Diversions for Conservation of Fish Populations. *Fisheries* 30(5):20–28.

Moyle, P. B., P. J. Foley, and R. M. Yoshiyama. 1992. *Status of Green Sturgeon,* Acipenser medirostris*, in California*. Final report sent to NMFS, Terminal Island, CA by UC Davis Department of Wildlife and Fisheries Biology.

Musick, J. A. 1999. Criteria to Define Extinction Risk in Marine Fishes. The American Fisheries Society Initiative. *Fisheries* 24(12):6–14.

Musick, J. A., M. M. Harbin, S. A. Berkeley, G. H. Burgess, A. M. Eklund, L. Findley, R. G. Gilmore, J. T. Golden, D. S. Ha, G. R. Huntsman, J. C. McGovern, S. J. Parker, S. G. Poss, E. Sala, T. W. Schmidt, G. R. Sedberry, H. Weeks, and S. G. Wright. 2000. Marine, Estuarine, and Diadromous fish stocks at Risk of Extinction in North America (exclusive of Pacific Salmonids). *Fisheries* 25:6–30.

Nakamoto, R. J., T. T. Kisanuki, and G. H. Goldsmith. 1995. *Age and Growth of Klamath River Green Sturgeon (*Acipenser medirostris*)*. U.S. Fish and Wildlife Service. Project # 93-FP-13. 20 pages.

National Marine Fisheries Service. 2005. *Green Sturgeon (*Acipenser medirostris*) Status Review Update, February 2005*. Biological review team, Santa Cruz Laboratory, Southwest Fisheries Science Center.

National Marine Fisheries Service. 2006. Memorandum from Tracy Collier, Environmental Conservation Division, Department of Commerce, to Russ Strach, Assistant Regional Administrator, Protected Resources Division regarding "Interim Criteria for injury of fish exposed to pile driving operations: a white paper." September 19.

National Marine Fisheries Service. 2007. *Southern DPS of Green Sturgeon Distribution Map.* Office of Protected Resources, NMFS. Available: <http://www.nmfs.noaa.gov/pr/images/fish/greensturgeon_dps_map.jpg>. Accessed: July 15, 2007.

National Marine Fisheries Service. 2009. *Biological and conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. Long Beach, CA. Available: <http://www.swr.noaa.gov/ocap/NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the _CVP_and_SWP.pdf>.

National Marine Fisheries Service. 2010. *Federal Recovery Outline, North American Green Sturgeon Southern Distinct Population Segment*. Prepared by National Marine Fisheries Service, Southwest Region. Available: <http://swr.nmfs.noaa.gov/gs/jd/Green_Sturgeon_sDPS_Recovery_Outline.pdf>.

National Marine Fisheries Service. 2012. *Green Sturgeon*. NOAA Fisheries Office of Protected Resources. Available: <http://www.nmfs.noaa.gov/pr/species/fish/greensturgeon.htm>. Updated March 14, 2012.

Neuman, M., S. Wang, S. T. Lindley, M. M. Moser, and E. Mora. 2007. *Development of Protective Regulations and Critical Habitat Designation for the Southern DPS of Green Sturgeon*. American Fisheries Society Meeting, San Francisco, CA.

Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes. *American Fisheries Society Symposium* 39:281–295.

Pacific States Marine Fisheries Commission. 1992. *White sturgeon Management Framework Plan*. Portland, OR.

Parsley, M. J., P. J. Anders, A. I. Miller, L. G. Beckman and G. T. McCabe, Jr. 2002. Recovery of White Sturgeon Populations through Natural Production: Understanding the Influence of Abiotic and Biotic Factors on Spawning and Subsequent Recruitment. *American Fisheries Society Symposium* 28:55–66.

Pickard, A., A. Baracco, and R. Kano. 1982. *Occurrence, Abundance, and Size of Fish at the Roaring River Slough Intake, Suisun Marsh, California during the 1980–81 and the 1981–82 Diversion Seasons*. Sacramento, CA: California Department of Water Resources, Interagency Ecological Program, Technical Report 3.

Poytress, B. 2006. *Abundance, Seasonal and Temporal Distribution Patterns of age-0 sturgeon Captured by Rotary Screw Traps at the Red Bluff Diversion Dam*. Presentation at the CALFED Science Conference. October 13.

Radtke, L. D. 1966. Distribution of Smelt, Juvenile Sturgeon, and Starry Flounder in the Sacramento–San Joaquin Delta with Observations on Food of Sturgeon. In J. L. Turner and D. W. Kelley (comp.), *Ecological Studies of the Sacramento–San Joaquin Delta, Part II*. Pages 115–129. California Department of Fish and Game. Fish Bulletin 136.

San Francisco Estuary Institute. 2007. *The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary*. SFEI Contribution 532. Oakland, CA.

Schaffter, R. 1997. *White Sturgeon Spawning Migrations and Location of Spawning Habitat in the Sacramento River, California*. California Department of Fish and Game 83:1–20.

Seesholtz, A. 2011. *Lower Feather River Sturgeon Information.* Compiled in July 2011. Attachment A of the Petition for Water Quality Recertification of the Oroville Hydroelectric Project . Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/oroville_ferc2100/oro_petition_attch.pdf>.

Surface Water Resources, Inc. 2003. *Volume V Appendix G-AQUA2 Aquatic Resources Methodology*. Oroville FERC Relicensing (Project No. 2100). Available: <http://orovillerelicensing.water.ca.gov/pdf_docs/004_Vol%20V_App%20G-AQUA2_Aquatics%20Methodology.pdf>.

Sweeney, B. W., T. L. Bott, J. K. Jackson, L. A. Kaplan, J. D. Newbold, L .J. Standley, W. C. Hession, and R. J. Horwitz. 2004. Riparian Deforestation, Stream Narrowing, and Loss of Stream Ecosystem Services. *National Academy of Sciences* 101:14132–14137.

The Nature Conservancy, Stillwater Sciences, and ESSA Technologies. 2008. *Sacramento River Ecological Flows Study: Final Report*. Prepared for CALFED Ecosystem Restoration Program. Sacramento, CA.

U.S. Fish and Wildlife Service. 1995. *Working Paper: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California*. Volume 2. May 9. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

U.S. Fish and Wildlife Service. 2002. *Spawning Areas of green Sturgeon Acipenser medirostris in the Upper Sacramento River California*. Red Bluff, CA.

Van Eenennaam, J. 2011. *Summary of Egg Verification by U.C. Davis Animal Sciences, Feather River Green Sturgeon Eggs Collected from Egg Mats During 2011*. Attachment B to the Petition For Water Quality Recertification of the Oroville Hydroelectric Project . Available: <http://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/oroville_ferc2100/oro_petition_attch.pdf>.

Van Eenennaam, J. P., J. Linares, S. I. Doroshov, D. C. Hillemeier, T. E. Willson, and A. A. Nova. 2006. Reproductive Conditions of the Klamath River Green Sturgeon. *Transactions of the American Fisheries Society* 135(1):151–163.

Van Eenennaam, J. P., J. Linares-Casenave, X. Deng, and S. I. Doroshov. 2005. Effect of Incubation Temperature on Green Sturgeon Embryos, *Acipenser medirostris*. *Environmental Biology of Fishes* 72(2):145–154.

Van Eenennaam, J. P., M. A. H. Webb, X. Deng, and S. I. Doroshov. 2001. Artificial Spawning and Larval Rearing of Klamath River Green Sturgeon. *Transactions of the American Fisheries Society* 130:159–165.

2A.8.8.2 Federal Register Notices

69 FR 33102. 2004. Endangered and Threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. *Federal Register* 69:33102.

71 FR 17757. 2006. Endangered and Threatened Wildlife and Plants: Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. *Federal Register* 71:17757.

73 FR 52084. 2008. Endangered and Threatened Wildlife and Plants: Proposed Rulemaking To Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon; Proposed Rule. *Federal Register* 73:52084.

2A.8.8.3 Personal Communication

Corwin, Richard. Biologist. Bureau of Reclamation, Red Bluff Fish Passage Program, Red Bluff, CA. August, 2010—Conversation with Danny Heilprin about green sturgeon spawners.

Donnellan, M. Fisheries Biologist, California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton, CA. April 11, 2007—Conversation with Rick Wilder, SAIC, about green sturgeon salvage.

Hieb, K. Biologist, California Department of Fish and Game, Stockton, California. 2008—Conversation with Chuck Hanson about Chinese mitten crab populations.

Marshall, M. Supervisory Fish Biologist, U.S. Fish and Wildlife Service, Stockton, California. February 9, 2007—Conversation with Rick Wilder, SAIC, about fish stranding at Fremont Weir.

Navicky, J. Environmental Scientist, California Department of Fish and Game, Sacramento, California), Conversation with Rick Wilder, SAIC, about Fremont Weir, November 9, 2007.

Schwall, Lt. L. Game Warden, California Department of Fish and Game, Sacramento, California. August 15, 2007—Conversation with Rick Wilder, SAIC, about sturgeon poaching in the Delta.

Van Eenennaam, J. Professor, Department of Animal Science, UC Davis. 2002—Conversation with Erin Strange, National Marine Fisheries Service.

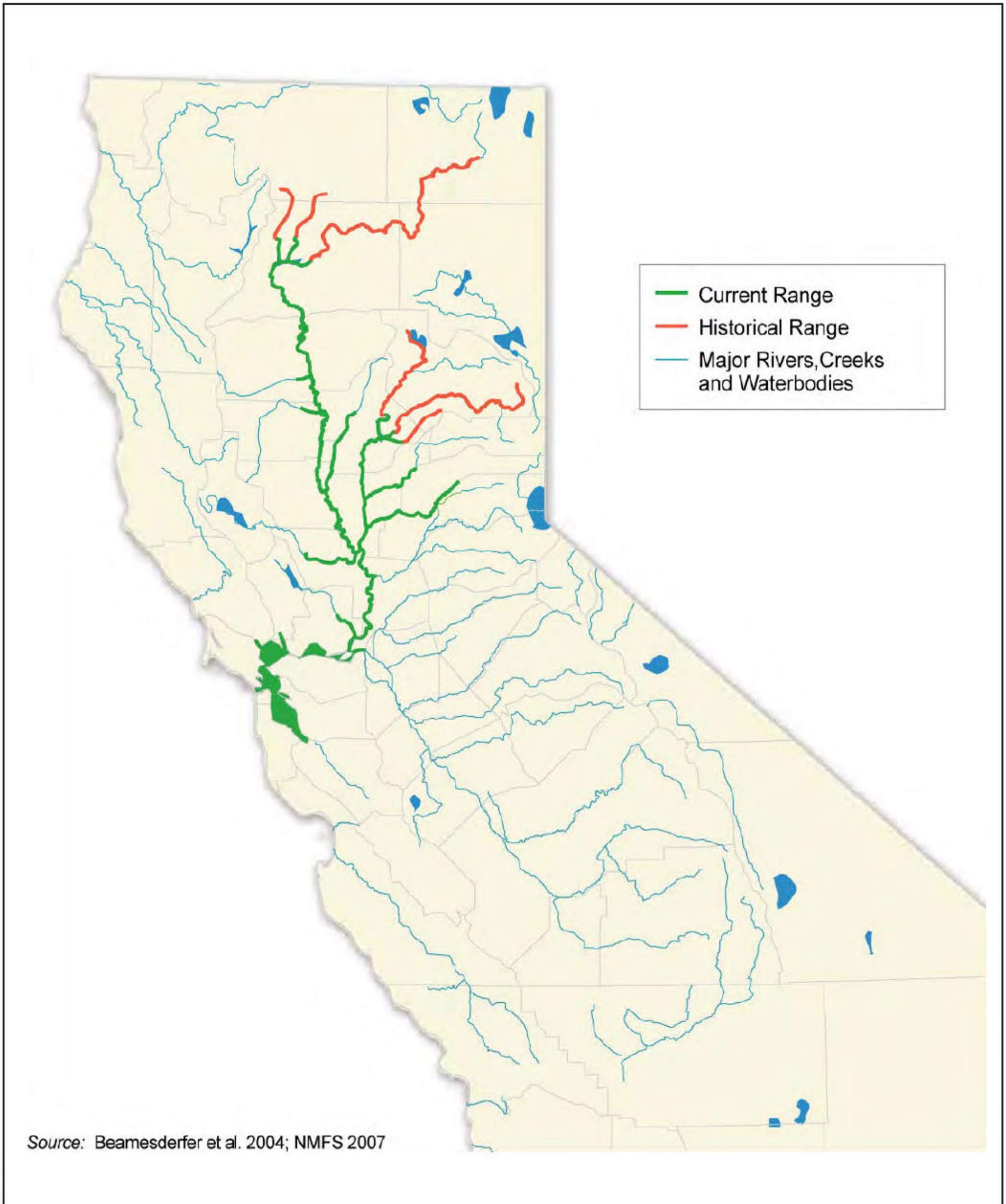


Figure 2A.8-1
Green Sturgeon Inland Range

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.8-2
Green Sturgeon Inland Critical Habitat

Appendix 2A.9
White Sturgeon (*Acipenser transmontanus*)

2A.9.1 Legal Status

The white sturgeon is not listed under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA).

2A.9.2 Species Distribution and Abundance

2A.9.2.1 Range

As a diadromous fish, white sturgeon inhabit riverine, estuarine, and occasionally marine habitats at various stages during their long life. Historically, white sturgeon ranged from Ensenada, Mexico to the Gulf of Alaska. Currently, spawning populations are found in the Sacramento–San Joaquin, Columbia, Snake, and Fraser River systems (Moyle 2002). In California, white sturgeon are most abundant in the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) and Sacramento River (Figure 2A.9-1) (Moyle 2002), but they have also been observed in the San Joaquin River system, particularly in wet years (California Department of Fish and Game 2002; Beamesderfer et al. 2004).

2A.9.2.2 Distribution in the Plan Area

The Delta and Suisun Bay serve as a migratory corridor, feeding area, and juvenile rearing area for white sturgeon. These corridors allow the upstream passage of adults and the downstream emigration of juveniles. Adult white sturgeon move from the waters of San Francisco Bay into the Delta and lower Sacramento River during the late fall and winter to spawn. They spawn preferentially in the Sacramento River between the Red Bluff Diversion Dam and Jelly's Ferry Bridge, at river mile 267, in areas characterized by swift currents and deep pools with gravel (U.S. Fish and Wildlife Service 1995; Schaffter 1997; California Department of Fish and Game 2002; Moyle 2002). Adult white sturgeon have been documented in the Yolo Bypass in the toe drain and at the base of Fremont Weir (Webber et al. 2007) and in other bypasses in the Sacramento watershed (Aquino-Carhart pers. comm.). Larval and juvenile white sturgeon inhabit the lower reaches of the Sacramento and San Joaquin Rivers and the Delta (Stevens and Miller 1970).

The abundance and age structure of the population fluctuates substantially in response to highly variable annual reproductive success. In recent decades the population tends to be dominated by strong year classes produced in years with high spring flows. High spring flows were the norm prior to the major dam building effort on the rim of the Central Valley (Moyle 2002). Recent analyses of the abundance of white sturgeon 117 to 168 centimeters based on harvest data from 2007 to 2009 indicate current populations between about 43,000 and 57,000 fish (DuBois and Gingras 2011). From 2000 to 2009 the abundance of age 15 white sturgeon ranged from 3,252 to 6,539 (DuBois et al. 2011). The abundance of age-15 fish is the metric by which progress toward the Central Valley Project Improvement Act (CVPIA) recovery goal (11,000 fish) is assessed.

2A.9.3 Life Stages

Israel et al. (2009) describe seven life stages of white sturgeon, although the adult stages are considered strategies rather than stages. Some adults migrate to the ocean, but most adult white sturgeon remain in tidally influenced areas of rivers and in estuaries where they feed and grow. Table 2A.9-1 lists the white sturgeon life stages of Israel et al. (2009) and the corresponding terms used in the BDCP.

Table 2A.9-1. White Sturgeon Life Stages

Israel et al. 2009	BDCP
Egg/embryo	Egg/embryo
Larvae	Larvae
Juvenile/young-of-year	Juvenile
Juvenile/sub-adult	Adult/tidal riverine-estuarine feeder
Adult/ocean migrant	Adult/spawning
Adult/tidal riverine-estuarine feeder	
Adult/spawner	

2A.9.4 Life History

White sturgeon spend most of their lives in the brackish portions of the upper estuary, although a small number of individuals move extensively in the ocean (Moyle 2002; Surface Water Resources, Inc. 2004; Welch et al. 2006). Individuals can live over 100 years and can grow to over 19.7 feet (6 meters), but sturgeon greater than 27 years old and over 6.6 feet (2 meters) are rare (Moyle 2002).

Male white sturgeon reach sexual maturity at 10 to 12 years of age, and females reach sexual maturity at 12 to 16 years (Moyle 2002). Maturation is thought to be a function of both photoperiod and temperature (Birstein et al. 1997). White sturgeon can spawn multiple times throughout their lives. Males are believed to spawn every 1 to 2 years, whereas females spawn every 2 to 4 years (Moyle 2002). Chapman et al. (1996) found that female white sturgeon on the Sacramento River produced on average 203,328 eggs. However, Skinner (1962) described a 9.2-foot (280-centimeter), 460-pound (206-kilogram) female white sturgeon that was estimated to yield 4.7 million eggs, a value that greatly exceeds the expected upper limit of the fecundity-weight relationship described by Chapman et al. (1996) (Israel et al. 2009). Other studies indicate that females can produce 100,000 to several million eggs (Pacific States Marine Fisheries Council 1996), with typical females producing approximately 200,000 eggs (Moyle 2002).

Spawning typically occurs between February and June when temperatures are 46 to 66°F (8 to 19°C) (Moyle 2002). Maximum spawning occurs at 58°F (14.4°C) in the Sacramento River (Kohlhorst 1976). It is thought that adults broadcast spawn in the water column in areas with swift current. Spawning success varies from year to year, but is most likely related to temperature and Delta outflow. Spring flows in wet years may be the single most significant factor for white sturgeon year class strength (Beamesderfer et al. 2005). Although the mechanism is unknown, it is hypothesized that higher flows may help disperse young sturgeon downstream, provide increased freshwater rearing habitat, increase spawning activity cued by higher upstream flows, increase nutrients in nursery areas, or increase downstream migration rate and survival through reduced exposure time to predators (Anadromous Fish Restoration Program 1995).

Fertilized eggs sink and attach to the gravel bottom, where they hatch after 4 days at 61°F (16°C) (Beer 1981), though hatching may take up to 2 weeks at lower water temperatures (Pacific States Marine Fisheries Council 1996). Newly hatched larvae are 7.5 to 19.5 millimeters (0.3 to 0.77 inch) long (Kohlhorst 1976) and generally remain in the gravel for 7 to 10 days before emergence into the water column (Moyle 2002). Newly emerged larvae are pelagic for approximately 7 to 10 days until the yolk-sac is absorbed, at which time they begin actively feeding on amphipods and other small benthic macroinvertebrates (Wang 1986). Juvenile white sturgeon feed primarily on algae, aquatic insects, small clams, fish eggs, and crustaceans, but their diet becomes more varied with age (Wang 1986; Pacific States Marine Fisheries Council 1996; Moyle 2002). Since the invasion by the overbite clam (*Potamocorbula amurensis*) in the western Delta and Suisun Bay during the late 1980s, *Potamocorbula* has become a major component of the diet of juvenile and adult white sturgeon.

2A.9.5 Threats and Stressors

A number of threats and stressors exist for white sturgeon. Stressor rankings and the certainty associated with these rankings for white sturgeon are provided in Chapter 5 of the BDCP. The discussion below outlines some of the main threats and stressors to white sturgeon.

2A.9.5.1 Operational Changes in River Flows

Operational changes that have reduced river flows, including spring peak flows, have affected white sturgeon spawning, habitat availability, and prey resources (Israel et al. 2009). Sturgeon recruitment is correlated to flow (Kohlhorst et al. 1991; Beamesderfer and Farr 1997), and the most successful spawning generally occurs in wet and above-normal water years (Fish 2010). Low flows reduce larval dispersal and increase vulnerability to predation (Israel et al. 2009). Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*, presents results of detailed modeling of flow relationships by life stage that indicate the importance of Delta outflow for white sturgeon.

2A.9.5.2 Water Exports

There is little evidence that the overall population of white sturgeon is influenced by entrainment. Adults are not likely to be entrained due to their large size and benthic habits. Larval sturgeon are more susceptible to entrainment as a result of their migratory behavior in the water column and reduced swimming ability. Herren and Kawasaki (2001) documented 431 water diversions on the Sacramento River between Sacramento and the Shasta Dam. In the Feather River, there are eight diversions greater than 10 cubic feet per second (cfs) and approximately 60 small diversions between 1 and 10 cfs between the Thermalito Afterbay outlet and the confluence with the Sacramento River (U.S. Fish and Wildlife Service 1995). White sturgeon have been reported in low numbers in fish salvage at both the State Water Project (SWP) and Central Valley Project (CVP) export facilities. White sturgeon observed in fish salvage have predominantly been juvenile and sub-adult life stages. Occasionally, adult white sturgeon have been observed impinged on the trash racks at the CVP intake; it has been hypothesized that these large adults were in weakened conditions or had previously died from stresses associated with spawning, angler mortality, or other causes before being impinged at the export intake. Given the large number of diversions, it is possible that larval white sturgeon are vulnerable to entrainment at these diversions; however, actual entrainment mortality and potential effects on the abundance and population dynamics of white sturgeon are unknown because most of the larval population is upstream of the south Delta export facilities. Appendix 5.B, *Entrainment,* includes a discussion of white sturgeon entrainment.

2A.9.5.3 Habitat Loss

2A.9.5.3.1 Spawning Habitat

Access to historical spawning habitat has been reduced by construction of barriers to upstream migration that block or impede access to spawning and juvenile rearing habitat. Major dams include Keswick Dam on the Sacramento River and Oroville Dam on the Feather River (Lindley et al. 2004; National Marine Fisheries Service 2005). White sturgeon adults have been observed periodically in the Feather River (U.S. Fish and Wildlife Service 1995; Beamesderfer et al. 2004). Habitat modeling by Mora (2006) suggests there is suitable habitat for sturgeon in the upstream reaches of the Feather River that have been blocked by Oroville Dam. This modeling also suggests that suitable conditions are present in the San Joaquin River upstream of Friant Dam, and in the tributaries such as Stanislaus, Tuolumne, and Merced Rivers upstream to their respective dams.

Other potential migration barriers include structures such as the Red Bluff Diversion Dam, Sacramento Deep Water Ship Channel locks, Sutter Bypass, and Delta Cross Channel Gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River (70 *Federal Register* [FR] 17386). The Red Bluff Diversion Dam is an important migration barrier for sturgeon on the Sacramento River (U.S. Fish and Wildlife Service 1995). Adult sturgeon can migrate past the Red Bluff Diversion Dam when gates are raised between mid-September and mid-May to allow passage of winter-run Chinook salmon. However, tagging studies by Heublein et al. (2006) found that, when the gates were closed, a substantial portion of tagged adult green sturgeon failed to use the fish ladders at the dam and were, therefore, unable to access upstream spawning habitats. The same behavioral response may be true for white sturgeon. Recent changes to water operations at the Red Bluff Diversion Dam, including placing dam gates in a permanent open position and constructing a new pumping facility with a state-of-the-art fish screen, are expected to eliminate passage issues at the dam for white sturgeon and other migratory fish species.

Sacramento River water passes through a set of locks at the end of the Sacramento River Deep Water Ship Channel at the connection with the Sacramento River. However, for fish that sense water coming from the Sacramento River, the locks prevent the migration of fish from the Deep Water Ship Channel back to the Sacramento River (California Department of Water Resources 2005).

Delta Cross Channel gate closures occur during the winter and early spring months (February through May) during sturgeon migration. The seasonal closure of the Delta Cross Channel gates is required by the State Water Resources Control Board water right Decision 1641 (D-1641) as a measure designed to improve the survival of downstream migrating juvenile Chinook salmon. Upstream migrating adult Chinook salmon are known to use the Delta Cross Channel as a migratory pathway when the gates are open (Hallock et al. 1970). When the gates are open, Sacramento River water flows into the central Delta providing migration cues. It is likely that attraction to flows passing into the central Delta from the Sacramento River causes migration delays and straying of white sturgeon, as it does to Chinook salmon (CALFED Bay-Delta Program 2001; McLaughlin and McLain 2004). Gate closures completely block juvenile and adult sturgeon migration.

The Fremont Weir is located at the upstream end of the Yolo Bypass, a 40-mile (64 kilometer)-long basin that functions as a flood control facility on the Sacramento River. When the Yolo Bypass is inundated by flood water, white sturgeon are attracted into the bypass and become trapped behind the Fremont Weir, which acts as a barrier and impediment to upstream migration (California Department of Water Resources 2005). Sturgeon that are trapped by the weir are then subject to heavy legal and illegal fishing pressure, or become stranded behind the flashboards when the flows recede. The current Fremont and Sacramento weirs create stranding and poaching problems for white sturgeon and green sturgeon (Israel et al. 2009; Israel and Klimley 2008). Sturgeon can also be attracted to small pulse flows and trapped during the descending hydrograph (Harrell and Sommer 2003). Efforts to improve passage and redesign weirs would reduce poaching and stranding. Methods to reduce stranding and increase passage have been investigated by the California Department of Water Resources (DWR) and the California Department of Fish and Wildlife (CDFW). Between 2002 and 2006, approximately 50 sturgeon (no species identification given) were rescued over the course of four rescue operations at the Fremont Weir. In 2011, 14 green sturgeon and 19 white sturgeon were rescued at the Fremont Weir (Healey and Vincik 2011).

Exact white sturgeon spawning locations in the Feather River are unknown; however, based on angler catches, most spawning is believed to occur downstream of Thermalito Afterbay and upstream of Cox's Spillway, just downstream of Gridley Bridge. Potential physical barriers to upstream migration include the rock dam associated with Sutter Extension Water District's sunrise pumps, shallow water caused by a head cut at Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to the Thermalito Afterbay outlet (U.S. Fish and Wildlife Service 1995). These structures are likely to present barriers or impediments during low-flow periods that block and or delay upstream sturgeon migration to spawning habitat.

2A.9.5.3.2 Rearing Habitat

Historical reclamation of wetlands and islands has reduced and degraded suitable in- and off-channel rearing habitat for white sturgeon. Furthermore, the channelization and hardening of levees with riprap has reduced in- and off-channel intertidal and subtidal rearing habitat as well as seasonal inundation of floodplains. The resulting changes to river hydraulics, riparian cover, and geomorphology affect important ecosystem functions (Sweeney et al. 2004). Because juvenile and adult white sturgeon feed primarily on benthic organisms such as clams and shrimp, habitat-related impacts of reclamation, channelization, and riprapping would be expected to contribute to ecosystem related impacts, such as changes in the availability of food sources and altered predator densities. The impacts of channelization and riprapping are thought to affect larval, post-larval, juvenile, and adult stages of sturgeon, as these life stages are dependent on the freshwater and estuarine foodwebs in the rivers and Delta.

The availability of rearing habitat is affected by water quality, including temperature and dissolved oxygen levels. Dissolved oxygen also affects the temperature tolerance of sturgeon, and is therefore important for sturgeon occurrence and habitat use throughout Delta habitats. Depressed levels of dissolved oxygen (less than 5 milligrams per liter [mg/L]) can also lead to increased stress levels, decreased feeding activity, and elevated mortality in sturgeon (Crocker and Cech 1997; Secor and Nkilitschek 2001; Israel and Klimley 2008; Israel et al. 2009).

2A.9.5.4 Dredging

Hydraulic dredging to allow commercial and recreational vessel traffic is a common practice in the navigational channels of the San Francisco, San Pablo, and Suisun Bays; the Delta; and the Sacramento and San Joaquin Rivers. White sturgeon are at risk of entrainment from dredging, with young-of-the-year fish at greatest risk (Boysen and Hoover 2009). Studies by Buell (1992) reported approximately 2,000 sturgeon entrained in the removal of one million tons of sand from the bottom of the Columbia River at depths of 60 to 80 feet (18 to 24 meters). In addition, dredging operations can result in the resuspension of toxics such as ammonia[1], hydrogen sulfide, and copper as a result of both dredging and dredge spoil disposal, and alter channel bathymetry and current patterns (National Marine Fisheries Service 2006).

2A.9.5.5 Water Temperature

Water temperature is considered important and potentially limiting for all life stages of white sturgeon (Israel et al. 2009). Juvenile and adult white sturgeon are tolerant of higher temperatures, although they appear to show signs of stress at temperatures at and above 68°F (20°C) (Cech et al. 1984; Geist et al. 2005). Elevated water temperatures can reduce the suitability of spawning habitat and white sturgeon egg and embryo development and survival. Exposure to water temperatures greater than 63°F (17.2°C) has also been shown to increase sturgeon egg and larval mortality (Pacific States Marine Fisheries Commission 1992).

Water temperatures in the upper Sacramento River near the Red Bluff Diversion Dam historically occurred within optimum ranges for sturgeon reproduction; however, temperatures downstream, especially later in the spawning season, were reported to be frequently above 63°F (17.2°C) (U.S. Fish and Wildlife Service 1995). Concern regarding exposure to high temperatures in the Sacramento River during the February to June period has been reduced in recent years because temperatures in the upper Sacramento River are actively managed for Sacramento River winter-run Chinook salmon. The Shasta temperature control device, which was installed at Shasta Dam in 1998, cold water pool management in Lake Shasta, and management to maintain higher reservoir storage have all contributed to improving cool water temperature conditions in the upper Sacramento River where white sturgeon spawning and juvenile rearing are thought to occur.

Water temperatures in the lower Feather River may be inadequate for sturgeon spawning and egg incubation as the result of releases of warmed water from Thermalito Afterbay (Surface Water Resources, Inc. 2003). The warmed water may be one reason that neither green nor white sturgeon are found in the river in low-flow years (California Department of Fish and Game 2002). Exposure to elevated water temperatures in the Feather River downstream of Thermalito Afterbay is thought to be a factor affecting habitat value and availability for sturgeon spawning and juvenile rearing on the lower Feather River (California Department of Fish and Game 2002).

Reduced flow on the San Joaquin River resulting from dam and diversion operations contributes to seasonally elevated water temperatures in the mainstem San Joaquin River, particularly during late summer and fall. Although these effects are difficult to measure, water temperatures in the lower San Joaquin River during spring months continually exceed preferred temperatures for sturgeon migration and development. Temperatures at Stevenson on the San Joaquin River near the Merced

[1] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

River confluence as recorded on May 31 (spawning typically occurs February to June) between 2000 and 2004 ranged from 77 to 82°F (25 to 27.8°C) (California Department of Water Resources 2007). Juvenile sturgeon are also exposed to increased water temperatures in the Delta during the late spring and summer, in part as a result of the loss of riparian shading and by thermal inputs from municipal, industrial, and agricultural discharges. Seasonally elevated water temperature in the San Joaquin River and in the Delta has been identified as a factor affecting habitat value and availability for sturgeon migration, spawning, and juvenile rearing.

2A.9.5.6 Turbidity

Turbidity levels in the Delta have decreased over the past few decades (Jassby et al. 2002). This reduction may have had detrimental effects on white sturgeon. Gadomski and Parsley (2005) found that larval white sturgeon predation by prickly sculpin was greater with reduced turbidity. However, larval sturgeon are found close to spawning locations generally upstream of the Delta, where turbidity is already lower than in the Delta.

The relationship between turbidity and the vulnerability of various life stages of white sturgeon to predation has not been established in the Delta. The dense colonization of local areas in the Delta by introduced species of submerged aquatic vegetation (SAV) such as Brazilian waterweed (*Egeria densa*) has been shown to be associated with increased water clarity (e.g., resulting from trapping and settlement of suspended sediments). Increased water clarity may contribute to increased vulnerability of sturgeon to predation. However, juvenile white sturgeon are expected to be less vulnerable to predation than other estuarine fish due to their scutes and protective armoring. In addition, the large size of subadult and adult white sturgeon further reduces their vulnerability to predation. As a result of these factors, the potential increase in vulnerability to predation due to localized reductions in turbidity is expected to be minor relative to other covered fish species.

2A.9.5.7 Exposure to Toxins

Water quality in the Sacramento and San Joaquin Rivers and the Delta is influenced by a variety of point and nonpoint source pollutants from urban, industrial, and agricultural land uses. Runoff from residential, agricultural, and industrial areas introduces pesticides, oil, grease, heavy metals, other organics, and nutrients that contaminate drainage waters and deteriorate the quality of aquatic habitats necessary for white sturgeon survival (National Marine Fisheries Service 1996; California Regional Water Quality Control Board 1998).

Organic contaminants from agricultural returns, urban and agricultural runoff from storm events, and high concentrations of trace elements, such as boron, selenium, and molybdenum, have been identified as factors that decrease sturgeon early life stage survival, causing abnormal development and high mortality in yolk-sac fry sturgeon at concentrations of only a few parts per billion (ppb) (U.S. Fish and Wildlife Service 1995; California Regional Water Quality Control Board 2004). Principal sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, Reclamation District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough (U.S. Fish and Wildlife Service 1995).

In recent years, changes have been made in the composition of herbicides and pesticides used on agricultural crops in an effort to reduce potential toxicity to aquatic and terrestrial species. Modifications have also been made to water system operations and discharges related to agricultural wastewater (e.g., agricultural drainage water system lock-up and holding prior to discharge) and municipal wastewater treatment and discharges. Concerns remain, however, regarding the toxicity to sturgeon of contaminants absorbed by sediments, such as pyrethroids and other chemicals including selenium and mercury.

Potamocorbula and other introduced clams that are now prominent in the diet of sturgeon are benthic filter feeders that can accumulate various toxic substances, such as selenium, mercury, and other compounds, in their tissue. *Potamocorbula*, due to its high filtration efficiency, accumulates selenium in high concentrations and loses it slowly (Luoma and Presser 2000; Linville et al. 2002; Doroshov et al. 2007). As a result, concentrations of selenium in white sturgeon have been observed at greater than threshold levels at which toxic effects have been observed in other fish species (Lemly 2002). Dietary selenium in high concentrations can adversely affect white sturgeon survival, activity, and growth (Tashjian et al. 2006).

The extent to which toxic pollution has affected the population of white sturgeon is unknown. White sturgeon is a long-lived species that feeds on invertebrates, such as clams and shrimp, and is vulnerable to the effects of toxicant bioaccumulation on the health and condition of sub-adult and adult sturgeon and their reproductive success in the estuary. However, sturgeon do not readily concentrate lipid-soluble toxins such as polychlorinated biphenyls (PCBs). Greenfield et al. (2003) found that dichlorodiphenyltrichloroethane (DDT) and chlordane concentrations in white sturgeon tissues have declined since the 1980s, while selenium concentrations have remained elevated. High levels of selenium can also be found in some white sturgeon prey (Johns and Luoma 1988; White et al. 1988), including *Potamocorbula* (Urquhart and Regalado 1991), as well as in sturgeon muscle, liver, and eggs (White et al. 1987, 1988, 1989; Kroll and Doroshov 1991; Urquhart and Regalado 1991). Early life history stages are especially sensitive to contaminant uptake (Kruse and Scarnecchia 2002), but the effects on the different life history stages of white sturgeon of contaminants, other than selenium, at concentrations found in the San Francisco Bay estuary are unknown, as are any additive or synergistic effects of multiple contaminants.

2A.9.5.8 Invasive Aquatic Vegetation

Introductions of nonnative invasive plant species such as water hyacinth (*Eichhornia crassipes*) and *Egeria* have altered habitat in the Delta and Suisun Bay and have affected local assemblages of fish in the Delta (Nobriga et al. 2005). *Egeria* forms thick "walls" along the margins of channels and shallow water habitat in the Delta. This growth may prevent juvenile sturgeon from accessing shallow water habitat along channel edges. By reducing water velocities near plants, these species reduce turbidity in the water column, potentially exposing sturgeon to higher predation risk. Dissolved oxygen levels beneath the mats often drop below suitable levels for fish due to the increased amount of decaying vegetative matter produced from the overlying mat and diel respiration by aquatic plants.

2A.9.5.9 Harvest

White sturgeon is a popular game species in the Delta and Sacramento River and supports a commercial fishery in estuaries in Oregon and Washington. In California, the recreational fishery for white sturgeon is open all year, but anglers are limited to three fish per year between 46 inches and 66 inches total length, and CDFW has established large closure areas (Section 27.90, Title 14 California Code of Regulations). Nevertheless, some illegal harvest occurs, particularly in areas where sturgeon have been stranded (e.g., Fremont Weir), as well as throughout the Delta.

The effects of legal and illegal harvest on the population dynamics and abundance of white sturgeon in the Delta are largely unknown. The small population of white sturgeon inhabiting the San Joaquin River experiences heavy fishing pressure, particularly from illegal fishing (U.S. Fish and Wildlife Service 1995). In addition, areas just downstream of Thermalito Afterbay outlet, Cox's Spillway, and several barriers impeding sturgeon migration on the Feather River, may be areas of high adult mortality from fishing and poaching. Poaching of white sturgeon females is a type of poaching that could be particularly detrimental to the white sturgeon population because it targets the oldest and largest adults with the highest fecundity, which affects both current and future stocks.

2A.9.6 Relevant Conservation Efforts

The Central Valley Project Improvement Act's Anadromous Fish Restoration Program has a goal of supporting efforts that lead to doubling the natural production of anadromous fish in the Central Valley on a sustainable, long-term basis, at levels not less than twice the average abundance reported during the period of 1967 to 1991. Though most efforts of the program have focused on Chinook salmon as a result of their listing history and status, sturgeon may receive some unknown incidental amount of benefit from these restoration efforts. For example, the acquisition of water for flow enhancement on tributaries to the Sacramento River, spawning gravel augmentation, fish screening for the protection of Chinook salmon and Central Valley steelhead, or riparian revegetation and instream restoration projects would likely have ancillary benefits to sturgeon.

Many beneficial actions have originated and been funded by the CALFED Bay-Delta Program (CALFED), including such projects as floodplain and instream restoration, riparian habitat protection, fish screening and passage projects, research regarding nonnative invasive species and contaminants, restoration methods, watershed stewardship, education, and outreach programs. Both the Central Valley Project Improvement Act and CALFED programs that target anadromous fish, particularly Chinook salmon and Central Valley steelhead (69 FR 33102), also may benefit sturgeon. Activities include fish screen evaluation and construction projects, restoration evaluation and enhancement activities, contamination studies, and dissolved oxygen investigations related to the San Joaquin River Deep Water Ship Channel.

New sport fishing regulations adopted over the past several years specifically to protect and reduce harvest of sturgeon and increased law enforcement are expected to further reduce illegal fishing practices, and reduce the effects of harvest of white sturgeon (Section 27.90, Title 14 California Code of Regulations).

2A.9.7 Recovery Goals

No recovery plan has been prepared for white sturgeon because the species is not listed under the ESA or CESA.

2A.9.8 References Cited

2A.9.8.1 Literature Cited

Anadromous Fish Restoration Program 1995. *Working Paper on Restoration Needs, Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California.* U.S. Fish and Wildlife Service under direction of the Anadromous Fish Restoration Program.

Beamesderfer, R. C. P., and R. A. Farr. 1997. Alternatives for the Protection and Restoration of 21 Sturgeons and their Habitat. *Environmental Biology of Fishes* 48:407–417.

Beamesderfer, R., G. Kopp, and D. Demko. 2005. *Review of the Distribution, Life History and Population Dynamics of Green Sturgeon with Reference to California's Central Valley*. S.P. Cramer and Associates, Inc.

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. *Historical and Current Information on Green Sturgeon Occurrence in the Sacramento and San Joaquin Rivers and Tributaries*. S.P. Cramer & Associates, Inc.

Beer, K. E. 1981. *Embryonic And Larval Development Of* Acipenser transmontanus Richardson. M. S. Thesis. University of California, Davis, CA, 53 pp.

Birstein, V. J., W. E. Bemis, and J. R. Waldeman. 1997. The Threatened Status o Acipenseriform Fishes: A Summary. *Environmental Biology of Fishes* 48: 427–435.

Boysen, K. A., J. J. Hoover. 2009. Swimming Performance of Juvenile White Sturgeon (*Acipenser transmontanus*): Training and the Probability Of Entrainment due to Dredging. *Journal of Applied Ichthyology* 25:54–59.

Buell, J. W. 1992. *Fish Entrainment Monitoring of the Western-Pacific Dredge R W Lofgren during Operations Outside the Preferred Work Period*. Portland, OR.

CALFED Bay-Delta Program. 2001. *Science in Action: Scrutinizing the Delta Cross Channel*. CALFED Science Program. June.

California Department of Fish and Game. 2002. *California Department of Fish and Game Comments to NMFS Regarding Green Sturgeon Listing*.

California Department of Water Resources. 2005. *Bulletin 250-2002: Fish Passage Improvement*. Sacramento, CA.

California Department of Water Resources. 2007. *California Data Exchange Center.* Available: <http://cdec.water.ca.gov>.Acessed: December 12, 2007.

California Regional Water Quality Control Board. 1998. Central Valley Region. *Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins*, fourth edition. Available:< http://www.swrcb.ca.gov/rwqcb5/water_issues/basin_plans/>.

California Regional Water Quality Control Board. 2004. Resolution no. R5-2004-0108. *Amending the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Salt and Boron Discharges into the Lower San Joaquin River.* Available: <http://www.swrcb.ca.gov/rwqcb5/board_decisions/adopted_orders/resolutions/r5-2004-0108.pdf>.

Cech, J. J., S. J. Mitchell, T. E. Wragg. 1984. Comparative Growth of Juvenile White Sturgeon and Striped Bass: Effects of Temperature and Hypoxia. *Estuaries* 7:12–18.

Chapman, F. A., J. P. Van Eenennaam, and S. I. Doroshov. 1996. The Reproductive Condition of White Sturgeon, *Acipenser transmontanus*, in San Francisco Bay, California. *Fishery Bulletin* 94:628–634.

Crocker, C.E., Cech, J. J., Jr, 1997. Effects of Environmental Hypoxia Onoxygen Consumption Rate and Swimming Activity in Juvenile White Sturgeon, *Acipenser transmontanus*, in Relation to Temperature and Life Intervals. *Environmental Biology of Fishes* 50:383–389.

Doroshov, S. I., J. P. Van Eenennaam, J. Linares, and R. G. Linville. 2007. *Potential Environmental Impacts on Reproduction of Green and White Sturgeons.* Presentation at the CalFed Science Conference.

DuBois, J. and M. Gringas. 2011. Using Harvest Rate and Harvest to Estimate White Sturgeon Abundance. *Interagency Ecological Program for the San Francisco Estuary Newsletter* 24 (3) Summer.

Dubois, J., M. Gringas, and G. Aasen. 2011. Status and Trends of San Francisco Estuary White Sturgeon. *Interagency Ecological Program Newsletter* 24(1):50–55.

Fish, M. 2010. A White Sturgeon Year-Class Index for the San Francisco Estuary and Its Relation to Delta Outflow. *Interagency Ecological Program Newsletter* 23(2):80–84.

Gadomski, D. M. and M. J. Parsley. 2005. Effects of Turbidity, Light Level, and Cover on Predation of White Sturgeon Larvae by Prickly Sculpins. *Transactions of the American Fisheries Society* 134:369–374

Geist, D. R., R. S. Brown, V. Cullinan, S. R. Brink, K. Lepla, P. Bates, and J. A. Chandler. 2005. Movement, Swimming Speed, and Oxygen Consumption of Juvenile White Sturgeon in Response to Changing Flow, Water Temperature, and Light Level in the Snake River, Idaho. *Transactions of the American Fisheries Society* 134(4):803–816.

Greenfield, B. K., J. A. Davis, R. Fairey, C. Roberts, D. B. Crane, G. Ichikawa, and M. Petreas. 2003. *Contaminant Concentrations in Fish from San Francisco Bay, 2000.* RMP Technical Report: SFEI Contribution 77. San Francisco Estuary Institute, Oakland, CA.

Hallock, R. J., R. F. Elwell, and D. H. Fry. 1970. *Migrations of Adult King Salmon* Oncorhynchus tshawytscha *in the San Joaquin Delta as Demonstrated by the Use of Sonic Tags*. California Department of Fish and Game. Fish Bulletin 151.

Harrell W. C. and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. In P. M. Faber (ed.). *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration*. Riparian Habitat Joint Venture, Sacramento, CA.

Healey, M., and R. Vincik. 2011. Internal Memorandum to Joseph R. Johnson, Department of Fish and Game. May 6. Rancho Cordova, CA: California Department of Fish and Game.

Herren, J. R. and S. S. Kawasaki. 2001. Inventory of Water Diversions in Four Geographic Areas in California's Central Valley. Pages 343–355. In R.L. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids*. Volume 2. California Fish and Game. Fish Bulletin 179.

Heublein, J. C., J. T. Kelly, and A. P. Klimley. 2006. *Spawning Migration and Habitat of Green Sturgeon, Acipenser medirostris, in the Sacramento River*. Presentation at the CALFED Science Conference. October 23. Sacramento, CA.

Israel, J. A. and A. P. Klimley. 2008. *Life History Conceptual Model for North American Green Sturgeon (Acipenser medirostris)*. University of California, Davis.

Israel, J., A. Drauch, and M. Gingras. 2009. *Life History Conceptual Model for White Sturgeon (Acipenser transmontanus).* Available: <https://nrm.dfg.ca.gov/documents/ContextDocs.aspx?sub=DRERIP_Documents_Models≥.

Jassby, A. D., J. E. Cloern, and B. E. Cole. 2002. Annual Primary Production: Patterns and Mechanisms Of Change in a Nutrient-Rich Tidal Ecosystem. *Limnology and Oceanography*47:698–712.

Johns, C. and S. N. Luoma, 1988. Selenium Accumulation in Benthic Bivalves and Fine Sediments of San Francisco Bay, the Sacramento-San Joaquin Delta, and Selected Tributaries *Estuarine, Coastal and Shelf Science* 27:381–396.

Kohlhorst, D. W. 1976. Sturgeon Spawning in the Sacramento River in 1973, as Determined by Distribution of Larvae. *California Fish and Game* 62:33–40.

Kohlhorst, D. W., L. W. Botsford, J. S. Brennan, and G. M. Cailliet. 1991. Aspects of the Structure and Dynamics of an Exploited Central California Population of White Sturgeon (*Acipenser transmontanus*). In P. Williot (ed.). Proceedings of the First International Symposium on the Sturgeon. CEMAGREF, Bordeaux, France. Pages 277–293.

Kratville, D. 2008. *Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, Semi-Final Species Life History Conceptual Model: Sacramento Splittail (*Pogonichthys macrolepidotus*).* Prepared by California Department of Fish and Game, Sacramento, CA.

Kroll, K. J. and S. I. Doroshov. 1991. Vitellogenin: Potential Vehicle For Selenium Bioaccumulation. In P.Williot (ed.). *Oocytes Of White Sturgeon*. Acipenser: Bordeaux, CEMAGREF. Pages 99–106.

Kruse, G. O., and D. L. Scarnecchia. 2002. Contaminant Uptake and Survival of White Sturgeon Embryos. *American Fisheries Society Symposium. Biology, Management, and Protection of North American Sturgeon,* American Fisheries Society: 151–160.

Lemly, A. D. 2002. *Selenium Assessment in Aquatic Ecosystems: A Guide for Hazard Evaluation and Water Quality Criteria*. Springer-Verlag, New York. pp. 161.

Lindley, S. T., R. Schick, B. P. May, J .J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. *Population Structure of Threatened and Endangered Chinook Salmon ESU in California's Central Valley Basin*. Public review draft. NMFS Southwest Science Center. Santa Cruz, CA.

Linville, R. G., S. N. Luoma, L. Cutter, and G.A. Cutter. 2002. Increased Selenium Threat as a Result of Invasion of the Exotic Bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. *Aquatic Toxicology* 57:51–64.

Luoma, S. N. and T. S. Presser. 2000. *Forecasting Selenium Discharges to the San Francisco Bay Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension*. U.S. Geological Survey. Open-file report 00-416.

McLaughlin, L. and J. McLain. 2004. *Comparison of Relative Abundance of Adult Chinook Salmon (*Oncorhynchus tshawytscha*) in the Delta Cross Channel, Georgiana Slough, and Sacramento River, California 2001*. Technical Report for the CALFED Bay-Delta Program.

Mora, E. 2006. *Modeling Green Sturgeon Habitat in the Central Valley*. Presentation at the 2006 CALFED Science conference, October 23. Sacramento, CA.

Moyle, P. B. 2002. *Inland Fishes of California, Revised and Expanded*. Berkeley: University of California Press.

National Marine Fisheries Service. 1996. *Factors for Decline: A Supplement to the Notice of Determination for West Coast Steelhead under the Endangered Species Act.*, Protected Resource Division, Portland, OR and Long Beach, CA.

National Marine Fisheries Service. 2005. *Green Sturgeon (*Acipenser medirostris*) Status Review Update, February 2005*. Biological review team, Santa Cruz Laboratory, Southwest Fisheries Science Center.

National Marine Fisheries Service. 2006. Memorandum from Tracy Collier, Environmental Conservation Division, Department of Commerce, to Russ Strach, Assistant Regional Administrator, Protected Resources Division regarding “Interim Criteria for injury of fish exposed to pile driving operations: a white paper.” September 19.

Nobriga, M. L., F. Feyrer, R. D. Baxter, and M. Chotkowski. 2005. Fish Community Ecology in an Altered River Delta: Spatial patterns in Species Composition, Life History Strategies, and Biomass. *Estuaries* 28(5):776–785.

Pacific States Marine Fisheries Commission. 1992. *White Sturgeon Management Framework Plan*. Portland, OR.

Pacific States Marine Fisheries Council. 1996. *White Sturgeon.* Available: <http://www.psmfc.org/habitat/edu_wsturg_fact.html>. Accessed: June 16, 2007.

Schaffter, R. 1997. *White Sturgeon Spawning Migrations and Location of Spawning Habitat in the Sacramento River, California*. California Department of Fish and Game 83:1–20.

Secor, D. H., and E. J. Niklitschek. 2001. *Hypoxia and Sturgeons: Report to the Chesapeake Bay Program Dissolved Oxygen Criteria Team.* Technical Report Series No. TS-314–01-CBL; Chesapeake Biological Laboratory, Solomons, MD.

Skinner, J. E. 1962. *An Historical Review of the Fish and Wildlife Resources of the San Francisco Bay Area*. California Department of Fish and Game, Water Projects Branch Report 1.Stevens, D. E. and L. W. Miller. 1970. Distribution of Sturgeon Larvae in the Sacramento-San Joaquin River System. *California Department of Fish and Game* 56:80–86.

Surface Water Resources, Inc. 2003. *Volume V Appendix G-AQUA2 Aquatic Resources Methodology*. Oroville FERC Relicensing (Project No. 2100). Available: <http://orovillerelicensing.water.ca.gov/pdf_docs/004_Vol%20V_App%20G-AQUA2_Aquatics%20Methodology.pdf>.

Surface Water Resources, Inc. 2004. *Matrix of Life History and Habitat Requirements for Feather River Fish Species, SP-F3.2 Task 2 - White Sturgeon.* Oroville Facilities Relicensing FERC Project No. 2100.

Sweeney, B. W., T. L. Bott, J. K. Jackson, L. A. Kaplan, J. D. Newbold, L .J. Standley, W. C. Hession, and R. J. Horwitz. 2004. Riparian Deforestation, Stream Narrowing, and Loss of Stream Ecosystem Services. *National Academy of Sciences* 101:14132–14137.

Tashjian D. H., S. J. Teh, A. Sogomonyan, and S. S. O Hung. 2006. Bioaccumulation and Chronic Toxicity of Dietary L-Selenomethionine in Juvenile White Sturgeon (*Acipenser transmontanus*). *Aquatic Toxicology* 79: 401–409.

U.S. Fish and Wildlife Service. 1995. *Working Paper: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California*. Volume 2. May 9. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

Urquhart, K. A. F. and K. Regalado. 1991. *Selenium Verification Study 1988-1990.* California Department of Fish and Game.

Wang, J. C. S. 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories.* IEP Technical Report No. 9. California Department of Water Resources, California Department of Fish and Game, Bureau of Reclamation, and U.S. Fish and Wildlife Service.

Webber, J. D., S. N. Chun, T. R. MacColl, L. T. Mirise, A. Kawabata, E. K. Anderson, T. S. Cheong, L. Kavvas, M. M. Rotondo, K. L. Hochgraf, R. Churchwell, and J. J. Cech. 2007. Upstream Swimming Performance of Adult White Sturgeon: Effects of Partial Baffles and a Ramp. *Transactions of the American Fisheries Society* 136:402–408.

Welch, D. W., S. Turo, and S. D. Batten. 2006. Large-Scale Marine and Freshwater Movements of White Sturgeon. *Transactions of the American Fisheries Society* 135:386–389.

White, J. R., P. S. Hofmann, D. Hammond, and S. Baumgartner. 1987. *Selenium Verification Study 1986.* California Department of Fish and Game.

White, J. R., P. S. Hofmann, D. Hammond, and S. Baumgartner. 1988. *Selenium Verification Study 1986-1987.* California Department of Fish and Game.

White, J. R., P. S. Hofmann, D. Hammond, and S. Baumgartner. 1989. *Selenium Verification Study 1987-1988.* California Department of Fish and Game.

2A.9.8.2 Federal Register Notices Cited

69 FR 33102. 2004. Endangered and Threatened Species: Proposed Listing Determinations for 27 ESUs of West Coast Salmonids. *Federal Register* 69: 33102.

70 FR 17386. 2005. Endangered and Threatened Wildlife and Plants: Proposed Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon. *Federal Register* 70:17386.

2A.9.8.3 Personal Communication

Aquino-Carhart, Erin. California Department of Fish and Game. Personal communication.

Source: Moyle & Randall 1997

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.9-1
White Sturgeon Inland Range

Appendix 2A.10
Pacific Lamprey (*Entosphenus tridentatus*)

2A.10.1 General

Pacific lamprey is the most widely distributed lamprey species on the west coast of the United States. The species occurs from Hokkaido Island, Japan (Morrow 1980) along the Pacific Rim to Rio Santo Domingo, Baja California, Mexico (Ruiz-Campos and Gonzalez-Guzman 1996). A single individual was caught in 1889 offshore of Clarion Island, Revillagigedo Islands, Mexico, approximately 386 kilometers (294 miles) southwest of Cabo San Lucas (Renaud 2008). Individuals inhabit major river systems, including the Columbia, Fraser-Trinity, Klamath, Eel, and Sacramento-San Joaquin Rivers and tributaries, as well as smaller coastal streams. Oceanic adults are thought to remain relatively close to the mouths of their home spawning streams where host/prey concentrations may be higher (Moyle 2002). Although still widely found in many of its native areas, it does not occur in the numbers that it once did. Large runs today are rare as evidenced from declining tribal fisheries for this species. In general, populations south of San Luis Obispo are scattered and irregular, although a regular run occurs on the Santa Clara River (Swift et al. 1993). Populations may exist in other rivers, but are often overlooked and have been the subject of few targeted sampling efforts (Moyle 2002). The species is usually absent from highly altered or polluted streams within its geographic range, although it appears to be persistent in currently occupied suitable streams (Moyle 2002).

2A.10.2 Legal Status

The Pacific lamprey is not listed under the California Endangered Species Act (CESA) or federal Endangered Species Acts (ESA).

A broad group of west coast conservation organizations petitioned the U.S. Fish and Wildlife Service (USFWS) on January 27, 2003 to list Pacific lamprey, along with three other lamprey species on the West Coast, as threatened or endangered (Klamath-Siskiyou Wildlands Center 2003). However, the petition was declined in a 90-day finding on December 27, 2004, citing insufficient evidence that listing was warranted (69 *Federal Register* [FR] 77158).

2A.10.3 Distribution and Abundance

In the Central Valley, Pacific lamprey occurs in the Sacramento and San Joaquin Rivers (Moyle 2002) and many of their tributaries including the Stanislaus, Tuolumne, Merced, and King Rivers (Brown and Moyle 1993) (69 FR 77158) (Figure 2A.10-1). Individuals emigrating from Sacramento and San Joaquin River watersheds pass through the Plan Area during winter and spring on their way to the Pacific Ocean. Emigrating adults pass through the Plan Area on their way upstream towards spawning grounds between March and June. It is unknown to what extent Pacific lamprey use the Plan Area for purposes other than a migration corridor, but some studies (Brown and Michniuk 2007; Conrad pers. comm.) have found ammocoetes within Sacramento–San Joaquin River Delta

(Delta) sloughs, especially in the North Delta subregion. Adults migrate within the ocean, but it seems that most adult Pacific lamprey remain in tidally influenced areas of rivers and within estuaries where they feed and grow.

Population trends are unknown in California, although anecdotal evidence indicates that populations have been in decline (Moyle 2002) (69 FR 77158). There are no monitoring programs that target Pacific lamprey in the Delta and those that catch Pacific lamprey do not catch them regularly enough to establish trends through time. In addition, Pacific lamprey are inconspicuous and often overlooked, and ammocoetes can be difficult to distinguish from ammocoetes of the co-occurring river lamprey (Webb pers. comm.).

2A.10.4 Life Stages

Moyle (2002) describes five general life stages of Pacific lamprey. Streif (2008) described seven similar life stages. Table 2A.10-1 compares the Pacific lamprey life stages of Moyle (2002), Streif (2008), and the BDCP.

Table 2A.10-1. Pacific Lamprey Life Stages

Moyle 2002	Streif 2008	BDCP
Egg/embryo	Eggs	Egg/embryo
Larvae (ammocoetes)	Ammocoetes	Larvae (ammocoetes)
Juveniles (macropthalmia)	Macropthalmia	Juveniles (macropthalmia)
Adult/ocean predator	Adult/parasitic	Adult/ocean predator
Adult/spawner	Adult/spawner	Adult/spawner

2A.10.5 Life History

Pacific lamprey are anadromous, beginning their migration into fresh water towards upstream spawning areas primarily between early March and late June, although upstream movements in January and February have also been observed (Moyle 2002). Most upstream migration occurs at night and in pulses. The habitat requirements of Pacific lamprey have not been well studied, but, like salmonids, spawning adults need clean, gravelly riffles in permanent streams to spawn successfully (Moyle 2002). There is some evidence that Pacific lamprey in larger river systems, such as the Klamath and Eel Rivers, have distinct runs similar to Chinook salmon (Moyle 2002).

Both sexes contribute to nest construction by removing larger stones from gravel or cobble substrate, creating a shallow depression. These simple nests occur in gravelly substrata at a depth of 30 to 150 centimeters (12 to 59 inches) with moderately swift currents and water temperatures typically of 12 to 18°C (53.6 to 64.4°F) (Moyle 2002). External fertilization of eggs occurs just in front of the nest, after which the fertilized eggs wash into the nest. Fecundity is unknown, but has been estimated at 98,000 to 238,400 eggs per female (Close et al. 2002). Spawning is repeated until both individuals are spent. Adults typically die after spawning.

It is unknown whether migrating adults cue solely on ammocoete (larvae) pheromones or on other upstream cues to guide them to natal streams to spawn. It is thought that if they cue solely on ammocoete pheromones, extirpation of local populations could have large effects on recolonization of natal streams (Luzier et al. 2009).

Eggs hatch into ammocoetes after approximately 19 days at 15°C (59°F) (Moyle 2002). The ammocoetes spend a short time in the nest, and then drift downstream, where they live in silty backwaters and eddies with muddy or sandy substrate into which they burrow. Ammocoetes remain in fresh water for approximately 5 to 7 years, where they feed on algae, organic material, and microorganisms. Meeuwig et al. (2004) found significant death or deformation of eggs and early stage ammocoetes in water greater than 22°C (72°F). Therefore, degraded streams with a water temperature greater than 22°C during early and midsummer while lamprey spawn and young ammocoetes develop could pose a problem for Pacific lamprey in the Sacramento–San Joaquin drainage (Luzier et al. 2009). Ammocoetes are found throughout all of the Delta, although no abundance estimates exist from Delta sampling programs.

Ammocoetes begin metamorphosis into macropthalmia (juveniles) when they reach 14 to 16 centimeters (5.5 to 6.3 inches) total length. Individuals develop external features (eyes, oral disc, and color changes) and experience internal and physiological changes that prepare them for their predatory life stage in the ocean (McPhail and Lindsey 1970). Downstream migration begins upon completion of this metamorphosis, generally coinciding with high-flow events in winter and spring (Moyle 2002).

Adults spend 3 to 4 years in the ocean in British Columbia, but in more southern areas this time period is likely shorter (Moyle 2002). Adults remain close to the mouths of the rivers from which they came, likely because their prey is most abundant in estuaries and other coastal areas (Moyle 2002). Individuals prey on a wide variety of fishes, including salmon, Pacific herring, and flatfishes in the ocean (Beamish 1980). Reduced availability of host/prey organisms in the ocean as a result of poor ocean conditions may negatively affect lamprey survival and growth, although very little is known about the oceanic stage of Pacific lamprey (Luzier et al. 2009).

2A.10.6 Threats and Stressors

A number of threats and stressors exist for Pacific lamprey. Stressor rankings and the certainty associated with these rankings for Pacific lamprey are provided in Chapter 5 of the BDCP. The discussion below outlines some of the main threats and stressors to Pacific lamprey.

2A.10.6.1 Habitat Loss and Habitat-Changing Structures

The high density and limited mobility of lamprey ammocoetes in streams can potentially make them more vulnerable to channel alterations such as channelization, loss of riffle and side channels, and scouring (Streif 2007; Luzier et al. 2009). Loss or alteration of habitat can also limit spawning if it occurs in spawning reaches.

Artificial barriers, including dams, culverts, water diversions, tidal gates, and other barriers, can impede or completely block the upstream migration of adults to spawning grounds. These structures also can impede or completely block the downstream migration of ammocoetes and macropthalmia towards the ocean (Luzier et al. 2009). Lamprey tend to out-migrate deeper in the water column such that traditional spill gates meant to aid migration of salmonids may not be effective for lamprey and may block passage (Moursund et al. 2003). Lamprey adults may have difficulty passing over barriers using ladders and other passage structures designed for salmonids, possibly due to high water velocity, sharp angles, culverts with drop-offs, or insufficient resting areas (Kostow 2002). Pacific lamprey populations cannot persist for more than a few years above impassable barriers (Beamish and Northcote 1989).

Rapid changes in stream flows resulting from reservoir management can dewater streambeds and strand ammocoetes residing in the substrate. Water diversions and instream construction projects, such as culvert replacements, may also dewater reaches of streams and strand ammocoetes (Streif 2007). Because Pacific lamprey ammocoetes burrow in upstream sediments for 5 to 7 years in high densities, a dewatering event may affect multiple age classes burrowing together in a single stream reach (Luzier et al. 2009). Hydroelectric projects and water diversions may entrain or impinge weak-swimming macropthalmia (Moursund et al. 2003).

Dredging associated with channel or irrigation screen maintenance and mining may affect many age classes at once due to their "colonial" nature and long upstream life stage (5 to 7 years) (Luzier et al. 2009). Beamish and Youson (1987) found that only 3 to 26% of lamprey that pass through a dredge survive. Further, it has been suggested that suction dredge mining was responsible for the decline or even loss of populations in some basins (Kostow 2002).

2A.10.6.2 Climate Change

Future climate change is expected to further increase water temperatures and modify the timing of flow-related environmental cues upon which Pacific lamprey rely for life history events (e.g., out-migration, spawning) (Luzier et al. 2009).

2A.10.6.3 Toxins

Ammocoetes spend 5 to 7 years living in silty areas that accumulate high levels of toxins. As a result, lamprey tend to have high body burdens of toxins relative to other fish species (Haas and Ichikawa 2007; Bettaso and Goodman 2008). Despite this apparent tolerance for high levels of toxins, lamprey are susceptible to toxicity (Kostow 2002).

2A.10.6.4 Predation

Mammals, birds, and other fish species consume lamprey at all life stages (Luzier et al. 2009). Pacific lamprey are thought to be preyed upon in the ocean by sharks, other fish, otters, seals, and sea lions (Roffe and Mate 1984; Moyle 2002). Ammocoetes are consumed by terrestrial mammals and birds, fish, and other species. Many nonnative species, including striped bass, sturgeon, centrarchids, and catfish, are believed to consume juvenile and adult lamprey and may pose a threat to population sizes (Streif 2007; Luzier et al. 2009; Baxter et al. 2008).

2A.10.6.5 Harvest

The extent to which harvest has a population-level effect on Pacific lamprey has not been well studied, but could represent a large proportion of spawning adults because Pacific lamprey adults and ammocoetes are harvested for use as bait to catch other species (Luzier et al. 2009). In addition, Pacific lamprey is important to tribes on the Pacific Coast for sustenance, medicine, and ceremonial purposes (Close et al. 2002). The use of Pacific lamprey for food and commercial purposes has declined from historical levels, and Washington and Oregon have banned harvest for bait. However, harvest has not declined in California, where there are no regulations on lamprey harvest (69 FR 77158).

2A.10.7 Relevant Conservation Efforts

Along with several tribes, state and federal agencies are increasingly incorporating Pacific lamprey into management and monitoring plans to increase the overall body of knowledge and conserve the species. There has been work in the Columbia River Basin to modify new or existing ladders and structures to facilitate lamprey passage, such as creating holding areas where lamprey can rest (Columbia River Basin Lamprey Technical Workgroup 2004). The Pacific Lamprey Conservation Initiative, led by USFWS, was initiated in 2007 to "facilitate communication and coordination relative to the conservation of Pacific lampreys throughout their range" (U.S. Fish and Wildlife Service 2007). The CALFED Bay-Delta Program Ecosystem Restoration Program designated the entire lamprey family as "Enhance and/or Conserve" (CALFED Bay-Delta Program 2000). This designation indicates that the program will undertake actions to conserve and enhance their abundance and distribution and the community diversity in which they live for their long-term stability.

2A.10.8 Recovery Goals

A recovery plan has not been prepared for Pacific lamprey because the species is not listed under the ESA or CESA.

2A.10.9 References Cited

2A.10.9.1 Literature Cited

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, B. Herbold, P. Hrodey, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. *Interagency Ecological Program 2008 Work Plan to Evaluate the Decline of Pelagic Species in the Upper San Francisco Estuary.* Available: <http://www.science.calwater.ca.gov/pdf/workshops/POD/2008_IEP-POD_Workplan_060208.pdf>.

Beamish, R. J. 1980. Adult Biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific Coast Of Canada. *Canadian Journal of Fish and Aquatic Science* 53:2898–2908.

Beamish, R. J. and J. H. Youson. 1987. Life History and Abundance of Young Adult *Lampretra ayresi* in the Fraser River and their Possible Impact on Salmon and Herring Stocks in the Strait of Georgia. *Canadian Journal of Fish and Aquatic Science* 44:525–537.

Beamish, R. J. and T. G. Northcote. 1989. Extinction of a Population of Anadromous Parasitic Lamprey, *Lampetra tridentata*, Upstream of an Impassable Dam. *Canadian Journal of Fisheries and Aquatic Science* 46:420–425.

Bettaso, J. and D. H. Goodman. 2008. *Mercury Contamination in Two Long-Lived Filter Feeders in the Trinity River Basin: A Pilot Project.* Arcata Fisheries Technical Report Number TR2008-09. Arcata, CA: U. S. Fish and Wildlife Service.

Brown, L. R. and P.B. Moyle. 1993. Distribution, Ecology, and Status of the Fishes of the San Joaquin River Drainage, California. *California Fish and Game* 79(3):96–114.

Brown, L. R., D. Michniuk. 2007. Littoral Fish Assemblages of the Alien-Dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. *Estuaries and Coasts* 30:186–200.

CALFED Bay-Delta Program. 2000. *Ecosystem Restoration Program Plan. Volume II: Ecological Management Zone Visions. Final Programmatic ESI/EIR Technical Appendix.* Available: <http://www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_2.pdf>.

Close, D. A., M. S. Fitzpatrick, and H.W. Li. 2002. The Ecological and Cultural Importance of a Species at Risk of Extinction, Pacific lamprey. *Fisheries* 27:19–25.

Columbia River Basin Lamprey Technical Workgroup. 2004. *Passage Considerations for Pacific Lamprey.* Available: <http://www.fws.gov/columbiariver/lampreywg/docs/LampreyPassageTechnicalDoc090304.pd>.

Haas, J. E. and G. Ichikawa. 2007. *Mercury Bioaccumulation in Pacific Lamprey Ammocoetes: The Role of Life History.* American Fisheries Society annual meeting. September 2–6.

Klamath-Siskiyou Wildlands Center, Siskiyou Regional Education Project, Umpqua Watersheds, Friends of the Eel, Northcoast Environmental Center, Environmental Protection Information Center, Native Fish Society, Center for Biological Diversity, Oregon Natural Resources Council, Washington Trout, and Umpqua Valley Audubon Society. 2003. A Petition for Rules to List: Pacific Lamprey (*Lampetra tridentate*), River Lamprey (*Lampetra ayresi*), Western Brook Lamprey (*Lampetra richardsoni*); and Kern Brook Lamprey (*Lampetra hubbsi*) as Threatened or Endangered under the Endangered Species Act. January 23, 2003.

Kostow, K. 2002. *Oregon Lampreys: Natural History, Status and Problem Analysis.* Oregon Department of Fish and Wildlife. January 24.

Luzier, C. W., J. Brostrom, C. Cook-Tabor, D. Goodman, R. D. Nelle, K. G. Ostrand, H. Schaller, and B. Streif. 2009. *Proceedings of the Pacific Lamprey Conservation Initiative Work Session – October 28–29, 2008*. Portland, OR: U. S. Fish and Wildlife Service, Regional Office. Available: <http://www.fws.gov/columbiariver/publications/Lamprey_Conservation_Proceedings_Final_09.pdf>.

McPhail, J. O. and C.C. Lindsey. 1970. Freshwater Fishes of Northwestern Canada and Alaska. *Fisheries Research Board of Canada Bulletin* 173.

Meeuwig, M. H., J. M. Bayer, and R. A. Reiche. 2004. *Identification of Larval Pacific Lampreys (*Lampetra tridentata*), River Lampreys (*L. ayresi*), and Western Brook Lampreys (*L. richardsoni*), and Thermal Requirements of Early Life History Stages Of Lampreys.* Amended Final Report for 2002-2004. Bonneville Power Administration. Project Number 2000-029. Portland, Oregon. Available: <http://www.efw.bpa.gov/Publications/I00004695-4.pdf>.

Morrow, J. E. 1980. The Freshwater Fishes of Alaska. Alaska Northwest Publishing, Anchorage.

Moursund, R. A., D. D. Dauble, and M. D. Bleich. 2000. *Effects of John Day Dam Bypass Screens and Project Operations on the Behavior and Survival of Juvenile Pacific Lamprey* (Lampetra tridentata). Portland, OR: U.S. Army Corps of Engineers.

Moursund, R. A., D. D. Dauble, and M. Langeslay. 2003. Turbine Intake Diversion Screens, Investigating Effects on Pacific Lamprey. *Hydro Review* XXII:40–46.

Moyle, P. B. 2002. *Inland Fishes of California*. Revised and Expanded. Berkeley, CA: University of California Press.

Renaud, C. B. 2008. Petromyzontidae, *Entosphenus tridentatus*: Southern Distribution Record, Isla Clarión, Revillagigedo Archipelago, Mexico. *Checklist* 4(1):82–85.

Roffe, T. J. and B. R. Mate. 1984. Abundances and Feeding Habits of Pinnipeds in the Rogue River, Oregon. *Journal of Wildlife Management* 48:1262–1274.

Ruiz-Campos, G. and S. González-Guzmán. 1996. First Freshwater Record of Pacific Lamprey, Lampetra tridentata, from Baja California, Mexico. *California Fish and Game* 82:144–146.

Streif, B. 2007. *Pacific Lamprey* – Lampetra tridentata*.* Portland, OR: U.S. Fish and Wildlife Service. Available: <http://www.fws.gov/pacific/Fisheries/sphabcon/lamprey/pdf/111407%20PL%20Fact%20Sheet.pdf>.

Streif, B. 2008. *Fact Sheet: Pacific Lamprey* (Lampetra tridentata). Portland, OR: U.S. Fish and Wildlife Service. Available: <http://www.fws.gov/oregonfwo/Species/Data/PacificLamprey/Documents/012808PL-FactSheet.pdf>.

Swift, C. C., T. R. Haglund, M. Ruiz, and R. N. Fisher. 1993. The Status And Distribution of the Freshwater Fishes of Southern California. *Bulletin Southern California Academy of Sciences* 92(3): 101–167.

U.S. Fish and Wildlife Service. 2007. *Pacific Lamprey Conservation Initiative. September.* Available: <http://www.fws.gov/filedownloads/ftp_lampreylit/101107%20FINAL%20Lamprey%20Conservation%20Initiative.pdf>.

2A.10.9.2 Federal Register Notices Cited

69 FR 77158. 2004. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition to List Three Species of Lampreys as Threatened or Endangered. *Federal Register* 69:77158.

2A.10.9.3 Personal Communications

Conrad, Louise. Department of Water Resources. unpublished data

Webb, H. Field Crew Leader, U.S. Fish and Wildlife Service. September 11, 2008—Email communication with R. Wilder about Pacific and river lamprey ammocoete field identification issues.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.10-1
Pacific Lamprey Inland Range

Appendix 2A.11
River Lamprey (*Lampetra ayresii*)

2A.11.1 General

River lamprey is an anadromous species that occurs from near Juneau, Alaska, to San Francisco Bay, California (Moyle 2002). Outside of California, there are widely scattered and isolated populations throughout its range. River lamprey are common in British Columbia, the center of their geographic range. In California, river lamprey is found in the Central Valley, Napa River, Sonoma Creek, Alameda Creek, Salmon Creek, and in tributaries of the lower Russian River (Figure 2A.11-1). In the Central Valley, river lamprey is found in small numbers in the lower Sacramento and San Joaquin River drainages, including the Stanislaus and Tuolumne Rivers. They may exist in other tributaries of these rivers, but are often overlooked and have been the subject of few targeted sampling efforts (Moyle 2002). Population trends are unknown in California, although declines are thought to have occurred concurrently with freshwater habitat degradation (Moyle 2002).The species appears to be more abundant in the Sacramento–San Joaquin River system than in other streams in California.

2A.11.2 Legal Status

The river lamprey is not listed under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA). On January 27, 2003, a broad group of West Coast conservation organizations petitioned the U.S. Fish and Wildlife Service (USFWS) to list river lamprey, along with three other lamprey species on the West Coast, as threatened or endangered (Klamath-Siskiyou Wildlands Center et al. 2003). However, the petition was declined in a 90-day finding on December 27, 2004, citing insufficient evidence that listing was warranted (69 *Federal Register* [FR] 77158).

2A.11.3 Distribution and Abundance

River lamprey individuals outmigrating from Sacramento and San Joaquin River watersheds pass through the Sacramento–San Joaquin River Delta (Delta) on their way to the Pacific Ocean, and emigrating adults pass through the Plan Area on their way upstream towards spawning grounds. The extent to which river lamprey use the Plan Area for purposes other than a migration corridor is unknown. However, outmigrating lamprey macropthalmia (juveniles) in the final stages of metamorphosis to adults hold just upstream of salt water until late spring. In most years, except for very wet years when the low-salinity zone is below the Carquinez Straight, this location would be in the Plan Area.

There are no monitoring programs that target river lamprey in the Delta and those that catch river lamprey do not catch them regularly enough to establish trends through time. River lamprey are inconspicuous, often overlooked, and ammocoetes (larvae) can be difficult to distinguish from ammocoetes of the co-occurring Pacific lamprey.

2A.11.4 Life Stages

Moyle (2002) describes seven life stages of river lamprey. Table 2A.11-1 compares the life stages of Moyle (2002) with those of the BDCP.

Table 2A.11-1. River Lamprey Life Stages

Moyle 2002	BDCP
Egg/embryo	Egg/embryo
Larvae/ammocoetes	Ammocoetes
Macropthalmia (juveniles)	Macropthalmia (juveniles)
Adult/ocean predator	Adult/ocean predator
Adult/spawner	Adult/spawner

2A.11.5 Life History

The biology of the river lamprey has not been well studied in California. As a result, much of this account is derived from information known for river lamprey from British Columbia. The fish in these two locations may have dissimilar life histories because of differences in physical factors (e.g., temperature, hydrology).

River lamprey are anadromous, but spend most of their lives in fresh water. Adults spend only 3 to 4 months in the ocean, migrating to freshwater in fall in search of suitable spawning sites, often returning to their natal streams (Moyle et al. 1995; Moyle 2002). Exact spawning locations are not known, although spawning habitat requirements are thought to be similar to those of salmonids. Spawning occurs from February through June in gravelly riffles in which individuals dig saucer-shaped depressions (Moyle 2002). Adults die after spawning. Fecundity is not well documented, but a study of two females in Cache Creek reported that one female about 23 centimeters (9 inches) total length produced approximately 11,400 eggs and another of 17.5 centimeters (7 inches) total length produced approximately 37,300 eggs (Vladykov and Follett 1958).

The eggs hatch into ammocoetes that remain in fresh water for approximately 3 to 5 years in silty or sandy low-velocity backwaters or stream edges where they bury into the substrate, tail first, and filter-feed on algae, detritus, and microorganisms (Moyle 2002). Ammocoetes begin metamorphosis into macropthalmia and then adults during summer at approximately 12 centimeters (4.7 inches) total length. This process takes 9 to 10 months during which individuals may shrink in length by up to 20% (Moyle 2002).

Prior to entering the ocean, macropthalmia congregate just upstream of salt water until their esophagus opens (Beamish and Youson 1987). Once the esophagus is opened, new adults can properly osmoregulate and can then enter the ocean (Moyle 2002). Adults spend approximately 3 to 4 months in the ocean where they grow rapidly to 25 to 31 centimeters (9.8 to 12.2 inches) total length. If the ammocoete stage is 3 to 5 years, the total life span of river lamprey is estimated to be 6 to 7 years (Moyle et al. 1995).

River lamprey adults are parasitic during both freshwater and saltwater phases. Adults feed on a variety of host fish species that are of small to intermediate sizes (4 to 12 inches [10.2 to

30.5 centimeters] total length) (Moyle et al 1995), the most common of which are thought to be herring and juvenile salmon (Beamish and Youson 1987). In Canada, predation by river lamprey is a significant cause of salmon mortality (Beamish and Neville 1995). Individuals feed by attaching to the back of their prey above the lateral line and eating the muscle tissue, even after the host fish dies (Moyle 2002). More than one lamprey can attach to a host salmon (Beamish and Youson 1987).

The habitat requirements of river lamprey are not well documented. It is thought that adults need clean, gravelly riffles in permanent streams to spawn successfully. These requirements are thought to be similar to those of salmonids. Ammocoetes live in silty backwaters and eddies with muddy or sandy substrate into which they burrow (Moyle et al. 1995). Ammocoetes require water temperatures lower than 25°C (77°F) (Moyle et al. 1995).

Although generally considered anadromous, river lamprey can live in fresh water as adults. For example, the population of river lamprey living in land-locked upper Sonoma Creek may spend their entire lives in fresh water. Most adults remain in tidally influenced areas of rivers and in estuaries where the concentration of potential host fishes is greatest.

2A.11.6 Threats and Stressors

A number of threats and stressors exist for River lamprey. Stressor rankings and the certainty associated with these rankings for River lamprey are provided in Chapter 5 of the BDCP. The discussion below outlines some of the main threats and stressors to River lamprey. There have been no formal evaluations conducted that assess the threats and stressors to river lamprey. Therefore, much of the following discussion has been derived from the co-occurring Pacific lamprey.

2A.11.6.1 Habitat Loss and Habitat-Changing Structures

The primary threat to river lamprey is thought to be loss or degradation of habitat resulting from dams, diversions, toxics, stream channelization, dredging, and urbanization (Moyle et al. 1995; Luzier et al. 2009). Dams have altered flows in channels and limited access to spawning grounds. Stream channelization, dredging, and diversions have altered flow patterns and rates in channels. Urbanization has degraded habitat by increasing loads of certain toxics, changing runoff patterns, and altering the configuration of some channels. Future climate change is expected to further increase water temperatures and modify the timing of flow-related environmental cues upon which lamprey rely for life history events (e.g., outmigration, spawning).

Large dams and other habitat modifications remain barriers to migration. Lamprey may have difficulty passing over barriers using ladders and other passage structures designed for salmonids, possibly due to high water velocity, sharp angles, culverts with drop-offs, or insufficient rest areas (Kostow 2002). There has been some work in the Columbia River basin to modify new or existing ladders and structures to facilitate lamprey passage, such as creating holding areas where lamprey can rest (Columbia River Basin Lamprey Technical Workgroup 2004).

2A.11.7 Relevant Conservation Efforts

There have been very few efforts to conserve river lamprey in the Central Valley of California. The CALFED Bay-Delta Program Ecosystem Restoration Program designated the entire lamprey family as Enhance and/or Conserve (CALFED Bay-Delta Program 2000). This designation indicates that the program will undertake actions to conserve and enhance their abundance and distribution and the community diversity in which they live for their long-term stability.

River lamprey is currently listed as a covered species under the *Butte Regional Conservation Plan*. (Butte County Association of Government 2011), but specific conservation measures have not yet been written.

2A.11.8 Recovery Goals

A recovery plan has not been prepared for this species and no recovery goals have been established because the species is not listed under the ESA or CESA.

2A.11.9 References Cited

2A.11.9.1 Literature Cited

Beamish, R. J. and C. M. Neville. 1995. Pacific Salmon and Pacific Herring Mortalities in the Fraser River Plume Caused by River Lamprey (*Lampetra ayresi*). *Canadian Journal of Fisheries and Aquatic Sciences* 52(3):644–650.

Beamish, R. J. and J. H. Youson. 1987. Life History and Abundance of Young Adult *Lampetra ayresi* in the Fraser River and their Possible Impact on Salmon and Herring Stocks in the Strait of Georgia. *Canadian Journal of Fish and Aquatic Science* 44:525–537.

Butte County Association of Governments. 2011. *Butte Regional Conservation Plan*. Available: <http://www.buttehcp.com/>. Accessed: July 12, 2012.

CALFED Bay-Delta Program. 2000. *Ecosystem Restoration Program Plan. Volume II: Ecological Management Zone Visions. Final Programmatic ESI/EIR Technical Appendix.* Available: <http://www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_2.pdf>.

Columbia River Basin Lamprey Technical Workgroup. 2004. *Passage Considerations for Pacific Lamprey.* Available: <http://www.fws.gov/columbiariver/lampreywg/docs/LampreyPassageTechnicalDoc090304.pd>.

Klamath-Siskiyou Wildlands Center, Siskiyou Regional Education Project, Umpqua Watersheds, Friends of the Eel, Northcoast Environmental Center, Environmental Protection Information Center, Native Fish Society, Center for Biological Diversity, Oregon Natural Resources Council, Washington Trout, and Umpqua Valley Audubon Society. 2003. A Petition for Rules to List: Pacific Lamprey (*Lampetra tridentate*), River Lamprey (*Lampetra ayresi*), Western Brook Lamprey (*Lampetra richardsoni*); and Kern Brook Lamprey (*Lampetra hubbsi*) as Threatened or Endangered under the Endangered Species Act. January 23, 2003.

Kostow, K. 2002. *Oregon Lampreys: Natural History, Status and Problem Analysis.* Oregon Department of Fish and Wildlife. January 24.

Luzier, C. W., J. Brostrom, C. Cook-Tabor, D. Goodman, R. D. Nelle, K. G. Ostrand, H. Schaller, and B. Streif. 2009. *Proceedings of the Pacific Lamprey Conservation Initiative Work Session – October 28–29, 2008*. Portland, OR: U. S. Fish and Wildlife Service, Regional Office. Available: <http://www.fws.gov/columbiariver/publications/Lamprey_Conservation_Proceedings_Final_09.pdf>.

Moyle, P. B. 2002. *Inland Fishes of California*. Revised and Expanded. Berkeley, CA: University of California Press.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. *Fish Species of Special Concern in California. Second Edition*. Prepared for California Department of Fish and Game, Rancho Cordova. Contract No. 2128IF.

Streif, B. 2008. *Fact Sheet: Pacific Lamprey* (Lampetra tridentata). Portland, OR: U.S. Fish and Wildlife Service. Available: <http://www.fws.gov/oregonfwo/Species/Data/PacificLamprey/Documents/012808PL-FactSheet.pdf>.

Vladykov, V. D. and W.I. Follett. 1958. Redescription of *Lampetra ayersi* (Gunther) of Western North America, a Species of Lamprey (Petromyzontidae) Distinct from *Lampetra fluviatilis* (Linnaeus) of Europe. *Journal of the Fisheries Research Board of Canada* 15(1):47–77.

2A.11.9.2 Federal Register Notices Cited

69 FR 77158. 2004. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition to List Three Species of Lampreys as Threatened or Endangered. *Federal Register* 69:77158.

BDCP-HCP 00343.12 (8-9-12) tm

Figure 2A.11-1
River Lamprey Inland Range

Appendix 2A.12

Riparian Brush Rabbit (*Sylvilagus bachmani riparius*)

2A.12.1 Legal Status

The riparian brush rabbit (*Sylvilagus bachmani riparius*) is listed as endangered under the state and federal endangered species acts. It was initially listed as endangered by the State of California on May 29, 1994. The U.S. Fish and Wildlife Service (USFWS) initially proposed the species for endangered species protection on November 21, 1997. The proposal was reopened for further public input on April 13, 1998, to include survey data from the 1998 winter floods in its final determination on whether or not to list the species. USFWS issued its final determination to list the species as endangered on February 23, 2000 (65 *Federal Register* [FR] 8881).

Critical habitat has not been designated for this species. USFWS believed it would not provide any additional benefit beyond that provided by being listed as endangered since the species was only known to occur within Caswell Memorial State Park (65 FR 8881). Subsequent rulings allow critical habitat to be designated after listing following further analysis.

In 2010, USFWS announced plans to perform a 5-year review of the status of the riparian brush rabbit (75 FR 28636).

2A.12.2 Species Distribution and Status

2A.12.2.1 Range and Status

One of eight subspecies of brush rabbit in California, the riparian brush rabbit occupies a range that is disjunct from other brush rabbits, near sea level on the northwestern floor of the San Joaquin Valley (U.S. Fish and Wildlife Service 1998). Documented occurrences are shown in Figure 2A.12-1. Its historical distribution may have extended along portions of the San Joaquin River and its tributaries on the valley floor from at least Stanislaus County to the Sacramento–San Joaquin River Delta (Delta) (Orr 1935 in U.S. Fish and Wildlife Service 1998). Populations are known to have historically occurred in riparian forests on the valley floor along the San Joaquin and Stanislaus Rivers and some tributaries of the San Joaquin River (U.S. Fish and Wildlife Service 1998). One population estimate within this historical range was about 110,000 individuals (U.S. Fish and Wildlife Service 1998).

The dramatic decline of the riparian brush rabbit began in the 1940s with the building of dams constructed for irrigation and flood control on the major rivers of the Central Valley. Protection from flooding resulted in conversion of floodplains to croplands and the consequent reduction and fragmentation of remaining riparian communities. By the mid-1980s, the riparian forest within the species' former range had been reduced to a few small and widely scattered fragments totaling about 5,189 acres (2,100 hectares) (U.S. Fish and Wildlife Service 1998).

Within this area, remaining populations of riparian brush rabbits occur in only two areas of San Joaquin County. One is an approximately 258-acre (104-hectare) patch in Caswell Memorial State

Park on the Stanislaus River immediately southeast of the Plan Area. The remaining area consists of several small, isolated or semi-isolated patches immediately west and southwest of Lathrop, totaling approximately 270 acres (109 hectares) along Paradise Cut and Tom Paine Slough and channels of the San Joaquin River in the south Delta within the Plan Area (Kelly et al. 2011; Williams et al. 2002a; Williams et al. 2008). The recent capture of one nonreproductive female between the levee and the San Joaquin River at Durham Ferry suggests a third naturally occurring population located approximately half way between the Caswell Memorial State Park and Paradise Cut/Tom Paine Slough populations (Kelly pers. comm. 2012a).

While the Caswell Memorial State Park population has been known and considered to be the last occupied location for riparian brush rabbit for many years, the latter location has been known only since 1998 (Williams et al. 2008). Recent surveys conducted by staff at the Endangered Species Recovery Program (ESRP) have not detected additional occurrences in the Plan Area. However, their researchers have identified additional suitable habitat and some potentially occupied unsurveyed areas (Kelly and Edgarian pers. comm.).

In 2005, a captive-bred population of approximately two dozen animals was introduced to the Faith Ranch along the San Joaquin River in Stanislaus County adjacent to the San Joaquin River National Wildlife Refuge.

The most serious ongoing problem has been the lack of suitable habitat above the level of regular floods where the animals could find food and cover for protection from weather and predators. Flooding during the 1970s resulted in additional population declines, with estimates of the extant population ranging from just 15 to 20 individuals (California Department of Fish and Game 2000). In January 1993, Caswell Memorial State Park was thought to support the only extant population, with an estimate of between 213 and 312 individuals. Flooding of the park in 1996 inundated more than 80% of the park, which contributed to additional population declines. The 1993 census was the last for which a reliable population estimate could be generated for the Caswell Memorial State Park population. Surveys conducted in 2002 (Williams et al. 2002a) resulted in the highest number of captures since the 1993 census, but are still not sufficient to generate a population estimate.

Access restrictions to the south Delta population prevent sufficient sampling to reliably estimate the population size; however, based on trapping conducted during 1998 and 1999, this population is estimated to include between 25 and 100 individuals (Williams et al. 2002b).

2A.12.2.2 Distribution and Status in the Plan Area

Of the two extant populations of riparian brush rabbit, only the south Delta population (Paradise Cut and Tom Paine Slough) occurs in the Plan Area (Figure 2A.12-2). As indicated above, occurrence locations in this area are on private land, and watercourses are managed for flood control, not wildlife management. Surveys conducted by the ESRP under contract with the California Department of Water Resources (DWR) have not detected other occurrences in the Plan Area; however, surveys are incomplete because of lack of property access.

2A.12.3 Habitat Requirements and Special Considerations

The following are important components of riparian brush rabbit habitat.

- Large patches of dense brush composed of riparian vegetation such blackberry (*Rubus* spp.), California wild rose (*Rosa californica*), and low-growing willows (*Salix* spp.), or other dense shrub species.
- Ecotonal edges of brushy species to grasses and herbaceous forbs.
- Scaffolding plants (dead or alive) for blackberry and rose to grow tall enough to withstand flood events.
- A tree overstory that is not closed, if present.
- High-ground refugia from flooding (Kelly et al. 2011).

The brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Seasonally available weedy/ruderal cover, including patches of tall grass, forbs, and perennial pepperweed (*Lepidium latifolium*) is also used, particularly where it connects to more suitable woody cover (Williams et al. 2008). Generally, riparian forests that support a closed overstory canopy lack sufficient understory shrubs to support riparian brush rabbits (U.S. Fish and Wildlife Service 1998). Small herbaceous openings in close proximity to cover are also required for foraging, and higher-elevation areas are required to sustain populations during floods (U.S. Fish and Wildlife Service 1998).

Sites inhabited by riparian brush rabbits usually have a mix of wild roses, blackberries, coyote bush (*Baccharis pilularis*), and grape vines (*Vitis californica*), with high volumes of roses and coyote bush in comparison to uninhabited sites (Williams 1988; Basey 1990; U.S. Fish and Wildlife Service 1998). Williams and Basey (1986) also note that brush rabbit sites support significantly more ground litter and surface area of roses and significantly fewer willows than sites occupied by desert cottontails. This condition may indicate the presence of higher-elevation areas that are not flooded regularly or heavily, an important element of brush rabbit habitat (Williams and Basey 1986).

Patch size is important, and fragmentation of intact riparian forests is a major issue restricting occupancy and overall distribution of the species. Brushy clumps smaller than 0.08 acre (0.03 hectare) are rarely occupied.

Flooding is a key issue for this species and thought to be responsible for major population declines. Riparian brush rabbits are closely tied to brushy cover and will generally not cross large, open areas. Thus, they are unable to disperse beyond the dense brush, making them susceptible to mortality during flood events (Williams 1988; U.S. Fish and Wildlife Service 1998).

2A.12.4 Life History

2A.12.4.1 Description

The riparian brush rabbit is a small, brownish cottontail-like rabbit with a white belly, relatively short ears, and a small, inconspicuous tail. The hind legs are short and hind feet are slender and not covered with long or dense hair. The white belly and ventral tail hairs are gray near the skin, and the ears lack dark tips (Orr 1940; Ingles 1965; Chapman 1974). Adult riparian brush rabbits are about 13 inches (33 centimeters) long and can be distinguished from other subspecies by their relatively pale color, gray sides, darker back (Orr 1935 in U.S. Fish and Wildlife Service 1998), restricted range and habitat requirements, and skull characteristics. When looking down at the head from above, the riparian brush rabbit cheeks protrude outward rather than being straight or curving inward as in other subspecies (Orr 1935 in U.S. Fish and Wildlife Service 1998; Orr 1940).

Features that distinguish the riparian brush rabbit from the desert cottontail (*S. audubonii*) include size and coloration. The riparian brush rabbit is smaller and darker grayish-brown, though populations of desert cottontails living along Central Valley rivers are about the same color as the riparian brush rabbit (which is more lightly colored than many of the other subspecies). The tail of the brush rabbit is small and inconspicuous compared with the desert cottontail, and its ears are uniformly colored. The tail of the desert cottontail shows much white when viewed from behind, and the inner (medial) tips of the ears are black. When looked at from above, the cheeks of the brush rabbit protrude, whereas those of the desert cottontail are slightly concave (Sandoval et al. 2006)

2A.12.4.2 Activity

Riparian brush rabbits are active throughout the year and are most active during the twilight hours around dawn and dusk. Depending on the season, the main activity periods generally last from 2 to 4 hours. The period of least activity is from about 10:30 hours to 16:00 hours (10:30 a.m. to 4:00 p.m.) (Chapman 1974).

Riparian brush rabbits typically remain hidden under protective shrub cover. They seldom venture more than 1 meter from cover. They often remain motionless while searching for signs of danger before moving short distances. When pursued, they leap back into the cover of shrubs instead of heading into open ground (Chapman 1974). Williams (1988) reported that they will generally not cross large, open areas, and hence are unable to disperse beyond the dense brush of the riparian forest. More recent observations, however, have suggested a somewhat wider range of conditions and that in some settings riparian brush rabbits will use larger, more exposed herbaceous habitats (Kelly and Edgarian pers. comm.).

Riparian brush rabbits have a limited ability to climb into bushes and trees. This trait probably has significant survival value, given that the riparian forests that are its preferred habitat are subject to inundation by periodic flooding (Chapman 1974; Williams 1988). Prolonged flooding of riparian areas can dramatically impact riparian brush rabbit populations (Kelly pers. comm. 2012a).

When weather conditions are appropriate, individuals may spend time in the early mornings and afternoons basking in the sun on a log or a dry form (a resting place for a rabbit). Ideal basking sites are a few inches from cover no more than about 18 inches (46 centimeters) above ground, with a partial, low-overstory canopy (Williams 1988; U.S. Fish and Wildlife Service 1998).

2A.12.4.3 Reproduction

The breeding season is generally from January to May, although it can extend through the late summer (Kelly pers. comm. 2012a). The gestation period for brush rabbits is about 27 days, the usual litter size is three to four, and the females may produce three to four litters during the season. Females average nine to 16 offspring per year, which remain in the nest for about 24 days. Although this is a relatively high reproductive rate, five out of six rabbits do not survive to the next breeding season (Mossman 1955; Chapman and Harman 1972). Their eyes open at 10 days, but they remain in the nest for another 2 weeks. The nest is a shallow burrow or depression (3 to 4 inches [7.6 to 10.2 centimeters] deep), lined with grasses and fur and covered by a plug of residual vegetation. The young mature at approximately 4 months of age (Williams 1988; Larsen 1993; U.S. Fish and Wildlife Service 1998).

2A.12.4.4 Home Range and Territory Size

The average home range for the riparian brush rabbit varies from year to year but is within the range of 3.1 to 7.4 acres (1.3 to 3 hectares). Breeding season home ranges are typically larger than nonbreeding home ranges. Male home ranges are usually larger than female ranges, but not dramatically so. The average core use area is typically less than half of the home range area (1.2 to 1.9 acres [0.5 to 0.8 hectares]) (Kelly pers. comm. 2012a). Home ranges generally conform to the size of the available brushy habitat (U.S. Fish and Wildlife Service 1998). Individuals are intolerant of each other when they come too close, but there is no well-defined territoriality. Young are more tolerant of approach by another rabbit than are adults (Chapman 1974; U.S. Fish and Wildlife Service 1998).

2A.12.4.5 Foraging Behavior and Diet

Riparian brush rabbits feed at the edges of shrub cover rather than in large openings. Their diet consists of herbaceous vegetation, such as grasses, sedges, clover, forbs and buds, bark, and leaves of woody plants. They consume herbaceous plants found along trails, firebreaks, or at the edge of brushy areas, and they eat the leaves, bark, and buds of many types of woody shrubs and vines. Grasses and other herbs are the most important food for brush rabbits, but shrubs such as California wild rose, coyote bush, and blackberry also are eaten. When available, green cow clover (*Trifolium wormskioldii*) is preferred over all other foods (Orr 1940; Larsen 1993; U.S. Fish and Wildlife Service 1998; Sandoval et al. 2006).

2A.12.5 Threats and Stressors

2A.12.5.1 Restricted Range and Habitat Availability

The primary threats to the survival of the riparian brush rabbit are the limited extent of its existing habitat, extremely low numbers of individual animals, and few extant populations. The small sizes of its remaining populations, the localization of the behavior of the species, and the highly limited and fragmented nature of remaining habitat restrict natural dispersal and put the species at risk from a variety of environmental factors. The existing population sizes do not meet the minimum population sizes that Thomas (1990) suggests are required to assure the medium- to long-term persistence of birds or mammals (i.e., the geometric mean of population size should be 1,000 for species with normally varying numbers and about 10,000 for species exhibiting a high variability in population size). Therefore, the species is considered at a high risk of imminent extinction from several consequent threats related to population genetics, demographics, and environmental stochasticity (U.S. Fish and Wildlife Service 1998).

2A.12.5.2 Flooding

Periodic flooding still occurs along all major rivers in the Valley (Kindle 1984). With behavioral restrictions on its freedom of movement (low mobility) and the shortage of habitat that is suitably protected from frequent floods downstream of Caswell Memorial State Park, there is little chance that individuals escaping drowning or predation will be able to meet mates or reproduce (U.S. Fish and Wildlife Service 1998).

2A.12.5.3 Fire

Wildfire also poses a major threat. Long-term fire suppression of Caswell Memorial State Park, combined with prolonged drought, has caused the buildup of high fuel loads from dead leaves, woody debris, and senescent flammable shrubs. The dense, brushy habitat to which the rabbits are restricted is thus highly susceptible to catastrophic wildfire that would cause both high mortality and destruction of habitat. Recovery of the riparian brush rabbit population from such a devastating event would be improbable (U.S. Fish and Wildlife Service 1998).

2A.12.5.4 Disease

Like most rabbits, the riparian brush rabbit is subject to a variety of common diseases, including tularemia, plague, myxomatosis, silverwater, encephalitis, listeriosis, Q-fever, and brucellosis. These contagious, and generally fatal, diseases could be transmitted easily to riparian brush rabbits from neighboring populations of desert cottontails. In a widespread, genetically heterogeneous population, such an outbreak would be of less concern. However, in these small remnant brush rabbit populations, this kind of epidemic could quickly eliminate the entire population (Williams 1988; U.S. Fish and Wildlife Service 1998).

2A.12.5.5 Predation

A wide variety of aerial and terrestrial predators prey on riparian brush rabbit, including various raptors, coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), long-tailed weasel (*Mustela frenata*), mink (*Neovison vison*), raccoon (*Procyon lotor*), snakes, feral dogs (*Canis lupus familiaris*), and feral cats (*Felis catus*) (Kelly et al. 2011). A robust population of the riparian brush rabbit should be able to withstand predation, but habitat adjacent to residential properties or along public roads or waterways, or subject to human disturbance, can exacerbate predation risk (Kelly et al. 2011). The black rat (*Rattus rattus*) is an exotic invasive species that may be a threat to riparian brush rabbit populations by preying on offspring and competing for resources. Black rats appear to be ubiquitous in riparian natural communities in the Central Valley (Kelly et al. 2011).

2A.12.6 Relevant Conservation Efforts

The *Recovery Plan for Upland Species of the San Joaquin Valley, California* (Upland Species Recovery Plan) (U.S. Fish and Wildlife Service 1998) describes conservation efforts undertaken through the end of the 1990s.

In 1986, after surveys along rivers within its historical range indicated that there was only a single, small extant population in Caswell Memorial State Park (Williams and Basey 1986), the riparian brush rabbit was designated as a "Mammalian Species of Special Concern" by the California Department of Fish and Game Wildlife Management Division. It was given federal category-1 candidate status by USFWS in 1985 and remained a candidate for listing in USFWS's Notice of Review (61 FR 7596). The riparian brush rabbit was proposed for listing by USFWS on November 21, 1997 (62 FR 62276). The subspecies was listed as endangered by the State of California in May 1994 (Title 14, Division 1, California Administrative Code, Section 670.5, Animals of California declared to be endangered or threatened).

In addition to the passive protection afforded to the species by the status of Caswell as a State Park, the California Department of Parks and Recreation (DPR) funded a study of ecology and habitat management of riparian brush rabbits (Williams 1988; Basey 1990) and a small mammal inventory (Cook 1992). DPR, Bureau of Reclamation, and USFWS, through the ESRP, funded a population assessment in the winters of 1993 and 1996–1997 (Williams 1993). DPR has expanded fire trails in Caswell Memorial State Park, which provides additional edge habitat for rabbits and better access to fight fires. DPR also has an ongoing control program for feral animals, has curtailed measures intended to control ground squirrels (brush rabbits will eat treated bait meant for ground squirrels), and is developing ongoing planning for habitat protection for wildlife in the park.

In 1999, the ESRP at California State University Stanislaus began implementing the *Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit* (Williams et al. 2002a), which was recommended in the Upland Species Recovery Plan (U.S. Fish and Wildlife Service 1998). The primary goal of the program is to prevent extinction by providing animals for reintroduction to establish new populations or augment existing populations. The controlled propagation program provides a source of individuals for reintroduction to restored habitat for establishing new, self-sustaining populations; augments existing populations when needed; and reduces risk of extinction of the species in the wild. This effort differs from traditional captive breeding and reintroduction plans in that no animals are held permanently in captivity. Breeding of successive generations in captivity is not planned, to prevent genetic adaptation to conditions in confinement. This controlled propagation program is ongoing.

In response to development activities in the city of Lathrop, mitigation lands have been acquired along the San Joaquin River and Paradise Cut for purposes of preserving and restoring habitat for the riparian brush rabbit. The San Joaquin River Oxbow Preserve is a 30-acre (12-hectare) riparian forest established in 2004 as mitigation for the Union Pacific Homes development in Lathrop; this preserve is currently under ownership and management of the Center for Natural Lands Management. The preserve was established primarily to protect the riparian brush rabbit. The River Islands project also intends to implement a plan to manage and restore riparian and other wetland habitats in the Paradise Cut in part to enhance habitat for the riparian brush rabbit.

In 2005, USFWS and the ESRP at California State University Stanislaus introduced a captive-bred population of approximately two dozen animals to the Faith Ranch along the San Joaquin River in Stanislaus County adjacent to the San Joaquin River National Wildlife Refuge. In 2011, the ESRP completed its report on appropriate conservation principles for the riparian brush rabbit (Kelly et al. 2011).

The riparian brush rabbit is a covered species under the *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan* (San Joaquin Council of Governments 2000) which prohibits removal or disturbance of occupied riparian habitat that could affect the subspecies as a result of the implementation of covered activities.

The *CALFED Bay-Delta Ecosystem Restoration Program Plan's Multi-Species Conservation Strategy* designates the riparian brush rabbit as a "Contribute to Recovery" species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements for delisting a species under federal and state endangered species acts.

2A.12.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.12.7.1 GIS Model Data Sources

The riparian brush rabbit model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta]; Boul and Keeler-Wolf 2008 [Suisun Marsh]; TAIC 2008 [Yolo Basin]), and the ESRP grassland habitat layer (Kelly pers. comm. 2012b). Using these data sets, the model maps the distribution of suitable riparian brush rabbit habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

2A.12.7.2 Habitat Model Description

A geographic information system (GIS) constraint layer was developed to limit the suitable habitat model to qualifying habitat south of State Route 4 and Old River Pipeline (Figure 2A.12-2). The habitat model for riparian brush rabbit includes the following vegetation types mapped in the valley/foothill riparian natural community in the BDCP composite vegetation layer.

- White alder (*Alnus rhombifolia*)
- Box elder (*Acer negundo*)
- Oregon ash (*Fraxinus latifolia*)
- White alder (*Alnus rhombifolia*)–Arroyo willow (*Salix lasiolepis*) restoration
- *Alnus rhombifolia*/*Salix exigua* (*Rosa californica*)
- *Acer negundo*–*Salix gooddingii*
- Hinds walnut (*Juglans hindsii*)
- Black willow (*Salix gooddingii*)
- *Salix gooddingii*–*Populus fremontii* (*Quercus lobata*–*Salix exigua*–*Rubus discolor*)
- *Salix gooddingii*/*Rubus discolor*
- *Salix gooddingii*/wetland herbs
- *Salix lasiolepis*–(*Cornus sericea*)/*Scirpus* (now *Schoenoplectus*) spp. (*Phragmites australis*–*Typha* spp.) complex unit
- Valley oak (*Quercus lobata*)

- Valley oak (*Quercus lobata*) restoration
- *Quercus lobata*/*Rosa californica* (*Rubus discolor*–*Salix lasiolepis*/*Carex* spp.)
- *Quercus lobata*–*Acer negundo*
- *Quercus lobata*–*Alnus rhombifolia* (*Salix lasiolepis*–*Populus fremontii*–*Quercus agrifolia*)
- *Quercus lobata*–*Fraxinus latifolia*
- *Salix lasiolepis*–mixed brambles (*Rosa californica*–*Vitis californica*–*Rubus discolor*)
- *Salix exigua*–(*Salix lasiolepis*–*Rubus discolor*–*Rosa californica*)
- Coyote bush (*Baccharis pilularis*)
- *Baccharis pilularis*/annual grasses and herbs
- California wild rose (*Rosa californica*)
- Blackberry (*Rubus discolor*)
- Buttonbrush (*Cephalanthus occidentalis*)
- California dogwood (*Cornus sericea*)
- *Cornus sericea*–*Salix exigua*
- *Cornus sericea*–*Salix lasiolepis* (*Phragmites australis*)
- Microphyllous shrubland
- Intermittently or temporarily flooded deciduous shrublands
- Arroyo willow (*Salix lasiolepis*)
- Mexican elderberry (*Sambucus mexicana*)
- Fremont cottonwood (*Populus fremontii*)
- *Alnus rhombifolia*/*Cornus sericea*
- *Salix gooddingii*–*Quercus lobata*/wetland herbs
- Narrow-leaf willow (*Salix exigua*)
- Shining willow (*Salix lucida*)
- Black willow (*Salix gooddingii*)–valley oak (*Quercus lobata*) restoration

Grassland habitat provided by Kelly (pers. comm. 2012) was included where a grassland polygon abuts selected valley/foothill riparian and coastal scrub types, regardless of distance it extends from the riparian habitat. The valley/foothill riparian vegetation types were selected based on a review of understory and overstory composition from Hickson and Keeler-Wolf (2007) and species habitat requirements, but were not further differentiated based on percentage composition or species associations. The grassland modeled habitat component is restricted to the types listed above with a minimum patch size of 0.05 acre (0.02 hectare).

2A.12.7.3 Assumptions

- **Assumption**: Riparian brush rabbit habitat is geographically constrained to areas south of State Route 4 and Old River Pipeline.

  Rationale: Known occurrences of riparian brush rabbit are limited to the southern portion of the Plan Area, near Paradise Cut and Tom Paine Slough in the south Delta. For purposes of this model, the model boundary is considered to represent the northern extent of all potentially occupied habitat in the Plan Area. This assumption is based on the known distribution of the species and results of recent surveys in the Plan Area. While survey access was not permitted in some portions of this area, the model may nevertheless overestimate the extent of potentially occupied habitat for this species.

- **Assumption:** Riparian brush rabbit habitat is restricted to the vegetation types described in Section 2A.12.7.2, *Habitat Model Description*.

  Rationale: Riparian brush rabbits inhabit the brushy understory shrub layer of valley riparian forests. Closely associated with dense shrub vegetation, occupied sites tend to be in riparian settings with an open overstory canopy or savannah-like settings that support patches of low-growing wild rose, wild grape, blackberry, and coyote bush, where the brush rabbits move through the dense brush and thickets by creating tunnels through the vegetation. Generally, riparian forests that support a closed overstory canopy lack sufficient understory shrubs to support riparian brush rabbits (Williams 1988; Basey 1990; U.S. Fish and Wildlife Service 1998).

- **Assumption**: All mapped riparian categories with a minimum patch size of 0.05 acre (0.02 hectare) provide potentially occupied habitat for the riparian brush rabbit.

  Rationale: Patch size is important, and fragmentation of intact riparian forests is a major issue restricting occupancy and overall distribution of the species. Brushy clumps smaller than 0.08 acre (0.03 hectare) are rarely occupied. A minimum patch size of 0.05 acre (0.02 hectare) ensures that all potential habitat is included. This may overestimate the extent of potentially occupied habitat for this species.

- **Assumption:** All grassland patches adjacent to riparian habitat provide potentially occupied habitat for the riparian brush rabbit.

  Rationale: Grasslands adjacent to dense brush provide foraging opportunities for riparian brush rabbits (Kelly et al. 2011). No scientific literature specifies the distance from riparian habitat at which riparian brush rabbits will forage. Therefore, the entire adjacent grassland polygon was assumed to be habitat. However, the model likely overestimates the extent of adjacent grasslands used by riparian brush rabbits as some of the polygons consist of narrow, linear corridors that extend over 1 mile from the riparian habitat.

2A.12.8 Recovery Goals

The following recovery actions for the riparian brush rabbit are outlined in the Upland Species Recovery Plan (U.S. Fish and Wildlife Service 1998).

Because of the small size of remaining blocks of potential habitat and the severely limited dispersal capability of the riparian brush rabbit, the species is likely to require continuing special protection of its habitat and population. Realization of these limitations should remove barriers to the rapid establishment of as many populations in remnant habitat as possible and sustainment of these populations by reintroduction should any one become extirpated. In furtherance of these objectives, the following actions are needed.

- Establish an emergency plan and monitoring system to provide swift action to save individuals and habitat at Caswell Memorial State Park in the event of flooding, wildfire, or a disease epidemic.
- Develop and implement a cooperative riparian brush rabbit conservation program that will include, at a minimum:
  - Identifying and obtaining biological information needed in management decisions, such as researching captive breeding methodology using surrogate species, conducting genetic composition analysis on the source and recipient rabbits prior to any captive breeding or introduction/reintroduction, and continuing to implement the captive breeding program.
  - Creating a riparian brush rabbit management plan for Caswell Memorial State Park that will incorporate elements detailed by Williams (1988) relating to predator and pest control, fire lines and access roads, recreation areas, brush and fuel control, mosquito abatement, habitat enhancement, and expansion of the park.
  - Establishing at least three additional wild populations in the San Joaquin Valley in restored and/or expanded suitable habitat within the rabbit's historical range.
  - Creating a monitoring program of all riparian brush rabbit populations to assess population trends and status.
  - Creating a long-term reintroduction preplan for the prompt reestablishment of eliminated populations.
  - Establishing a cooperative program, to take effect once the minimum of four protected populations are established, to place excess young (or other animals as appropriate) from populations at carrying capacity onto private parcels with suitable habitat where and when owners are willing to enter into a management agreement.

The ESRP recently developed the following set of guiding principles and considerations for riparian brush rabbit conservation in the Plan Area (Kelly et al. 2011).

- **Conservation of lands:** protection of existing habitat occupied by riparian brush rabbit.
- **Connectivity:** establishment of permanent corridors with suitable habitat components between known populations to facilitate dispersal of the species and genetic interchange between adjacent populations.
- **Restoration:** active restoration (planting and management) of core areas and connecting lands (the ESRP does not recommend passive restoration as a means to restore riparian brush rabbit habitat).
- **Range:** prioritizing lands in the south Delta near extant populations (south of Highway 12 and particularly south of Highway 4 within Conservation Zones 7 and 8).
- **High-water refugia:** building and restoring high-ground habitat mounds or berms to provide refuge during seasonal flood events and sea level rise.
- **Invasive species management:** control of feral predators (cats and dogs) and invasive rodents (black rats).

- **Additional research:** further ecological research on the ecology of riparian brush rabbit (e.g., population and habitat management, distribution, diet, and roles of predators and competitors).

2A.12.9 References Cited

2A.12.9.1 Literature Cited

Basey, G. E. 1990. *Distribution, Ecology, and Population Status of the Riparian Brush Rabbit* (Sylvilagus bachmani riparius). MS thesis. California State University, Stanislaus, Turlock.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2000. *The Status of Rare, Threatened, and Endangered Animals and Plants in California, 2000*. Sacramento, CA

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area* - Version 3 GIS dataset. Sacramento, CA.

Chapman, J. A. 1974. *Sylvilagus bachmani*. *Mammalian Species* 34:1–4.

Chapman, J. A. and A. L. Harman. 1972. The Breeding Biology of a Brush Rabbit Population. *Journal of Wildlife Management* 36:816–823.

Cook, R. R. 1992. *An Inventory of the Mammals of Caswell Memorial State Park*. Lodi, CA: California Department of Parks and Recreation.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Ingles, L. G. 1965. *Mammals of the Pacific States*. Stanford, CA: Stanford University Press.

Kelly, P. A., T. K. Edgarian, M. R. Lloyd, and S. E. Phillips. 2011. *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat.* Prepared for the U.S. Fish and Wildlife Service, California Department of Fish and Game, and California Department of Water Resources.

Kindle, F. 1984. Riparian Protection from Corps of Engineers Projects. In: R. E. Warner and K. M. Hendrix (eds.). *California Riparian Systems Ecology, Conservation, and Productive Management*. Berkeley, CA: University of California Press. Pages 895–898.

Larsen, C. J. 1993. *Report to the Fish and Game Commission: Status Review of the Riparian Brush Rabbit (*Sylvilagus bachmani riparius*) in California*. California Department of Fish and Game, Sacramento. Nongame Bird and Mammal Section Report 93-12:1-39.

Mossman, A. S. 1955. Reproduction of the Brush Rabbit in California. *Journal of Wildlife Management* 19:177–184.

Orr, R. T. 1935. Description of Three New Races of Brush Rabbit from California. Proceedings of the Biological Society Washington 48:27–30. As cited in U.S. Fish and Wildlife Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Region 1, Portland, OR.

Orr, R. T. 1940. The Rabbits of California. *Occasional Papers of the California Academy of Science* 19:1–227.

San Joaquin Council of Governments. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan.* Available: <http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm>. Accessed: December 22, 2011.

Sandoval T. M. Sandoval, D. F. Williams, and G. W. Colliver. 2006. *Riparian Brush Rabbit*. Endangered Species Recovery Program, California State University Stanislaus, Turlock, CA. Available: <http://esrp.csustan.edu/speciesprofiles>.

TAIC. 2008. Yolo *County Regional Vegetation, July 2008*. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

Thomas, A. 1990. A Comparison of an Exact and a Simulation Method for Calculating Gene Extinction Probabilities in Pedigrees. *Zoo Biology* 9:257–274.

U.S. Fish and Wildlife Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Region 1, Portland, OR.

Williams, D. F. 1988. *Ecology and Management of the Riparian Brush Rabbit in Caswell Memorial State Park*. California Department of Parks and Recreation, Lodi, CA. Interagency Agreement 4-305-6108.

Williams, D. F. 1993. *Population Censuses of Riparian Brush Rabbits and Riparian Woodrats at Caswell Memorial State Park during January 1993*. Lodi, CA: California Department of Parks and Recreation.

Williams, D. F. and G. E. Basey. 1986. *Population Status of the Riparian Brush Rabbit* (Sylvilagus bachmani riparius). Sacramento, CA: California Department of Fish and Game. Wildlife Management Division, Nongame Bird and Mammal Section Report.

Williams, D. F., L. P. Hamilton, M. R. Lloyd, E. Vincent, C. Lee, A. Edmondson, J. J. Youngblom, K. Gilardi, and P. A. Kelly. 2002a. *Controlled Propagation and Translocation of Riparian Brush Rabbits: Annual Report for 2002*. Report to the Bureau of Reclamation, U.S. Fish and Wildlife Service, and California Department of Fish and Game, Sacramento, CA.

Williams, D. F., P. A. Kelly, and L. P. Hamilton. 2002b. *Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit*. Turlock, CA: Endangered Species Recovery Program, California State University. Available: <http://esrp.csustan.edu/publications/pdf/rbr_prop_plan_final.pdf>.

Williams, D. F., P. A. Kelly, L. P. Hamilton, M. R. Lloyd, E. A. Williams, and J. J. Youngblom. 2008. Recovering the Endangered Riparian Brush Rabbit (*Sylvilagus bachmani riparius*): Reproduction and Growth in Confinement and Survival after Translocation. In:P. C. Alves, N. Ferrand, and K. Hacklander (eds.), *Lagomorph Biology: Evolution, Ecology, and Conservation.* Proceedings of the Second World Lagomorph Conference, Vairao, Portugal, July 2004. Berlin/Heidelberg, Germany: Springer-Verlag. Pages 349–361.

2A.12.9.2 Federal Register Notices Cited

61 FR 7596. 1996. Notice of Review: Endangered and Threatened Wildlife and Plants: Review of Plant and Animal Taxa That Are Candidates for Listing as Endangered or Threatened Species: Notice of Review. *Federal Register* 61:7596.

62 FR 62276. 1997. Proposed Rule: Endangered and Threatened Wildlife and Plants; Proposed Endangered Status for the Riparian Brush Rabbit and Riparian Woodrat. *Federal Register* 62:62276.

65 FR 8881. 2000. Final Rule: Endangered and Threatened Wildlife and Plants; Final Rule to List the Riparian Brush Rabbit and the Riparian, or San Joaquin Valley, Woodrat as Endangered. *Federal Register* 65:8881.

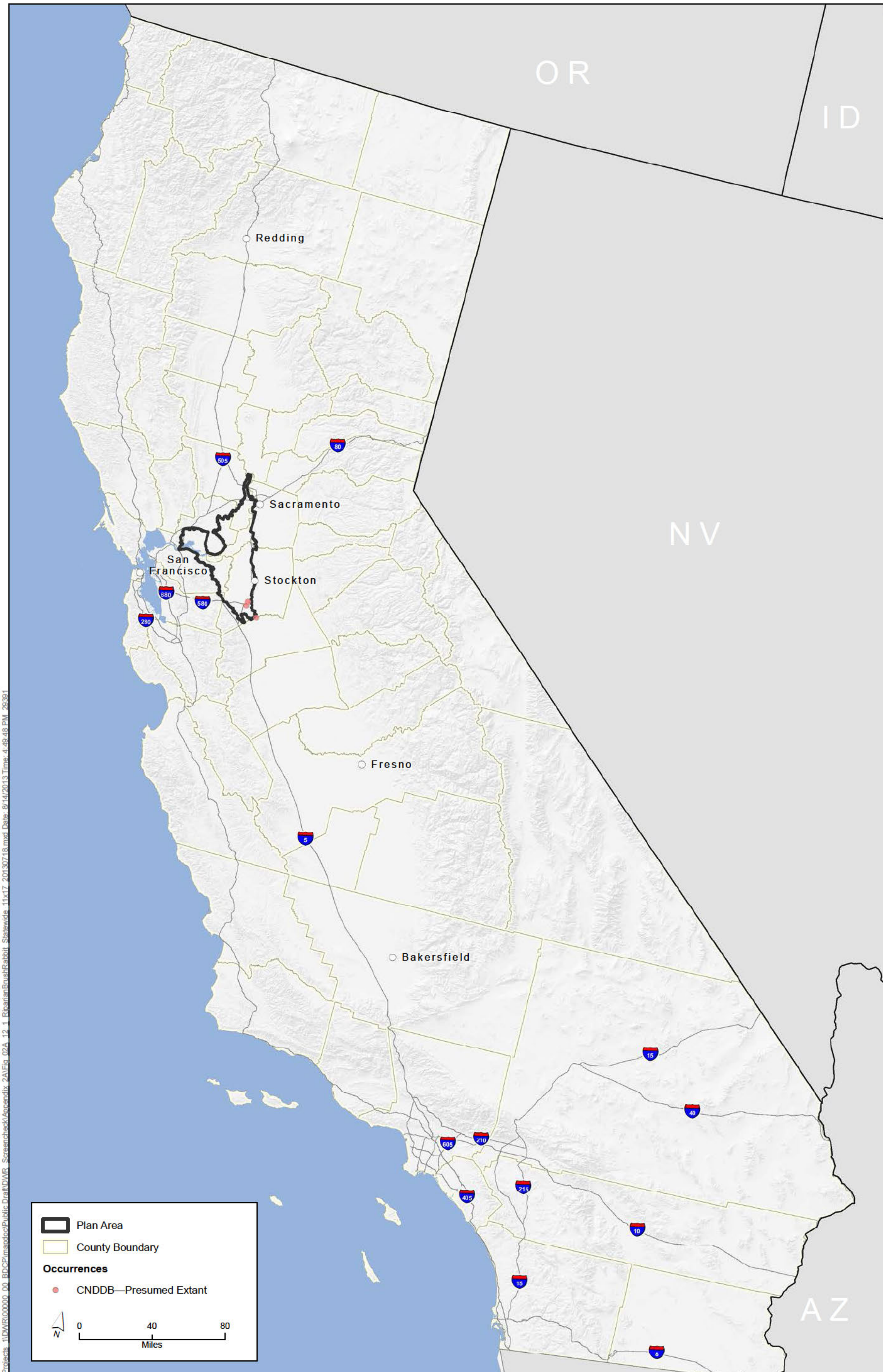
75 FR 28636. 2010. Initiation of 5-Year Reviews of 34 Species in California and Nevada; Availability of 96 Completed 5-Year Reviews in California and Nevada. *Federal Register* 75:28636.

2A.12.9.3 Personal Communications

Kelly, Patrick. Director, Endangered Species Recovery Program, California State University, Stanislaus, CA. Written comments on earlier draft; October 12, 2012a—Email to Mike Bradbury, California Department of Water Resources, regarding new occurrence.

Kelly, Patrick. Director, Endangered Species Recovery Program. California State University, Stanislaus, CA. December 28, 2012b—Potential grassland habitat GIS dataset

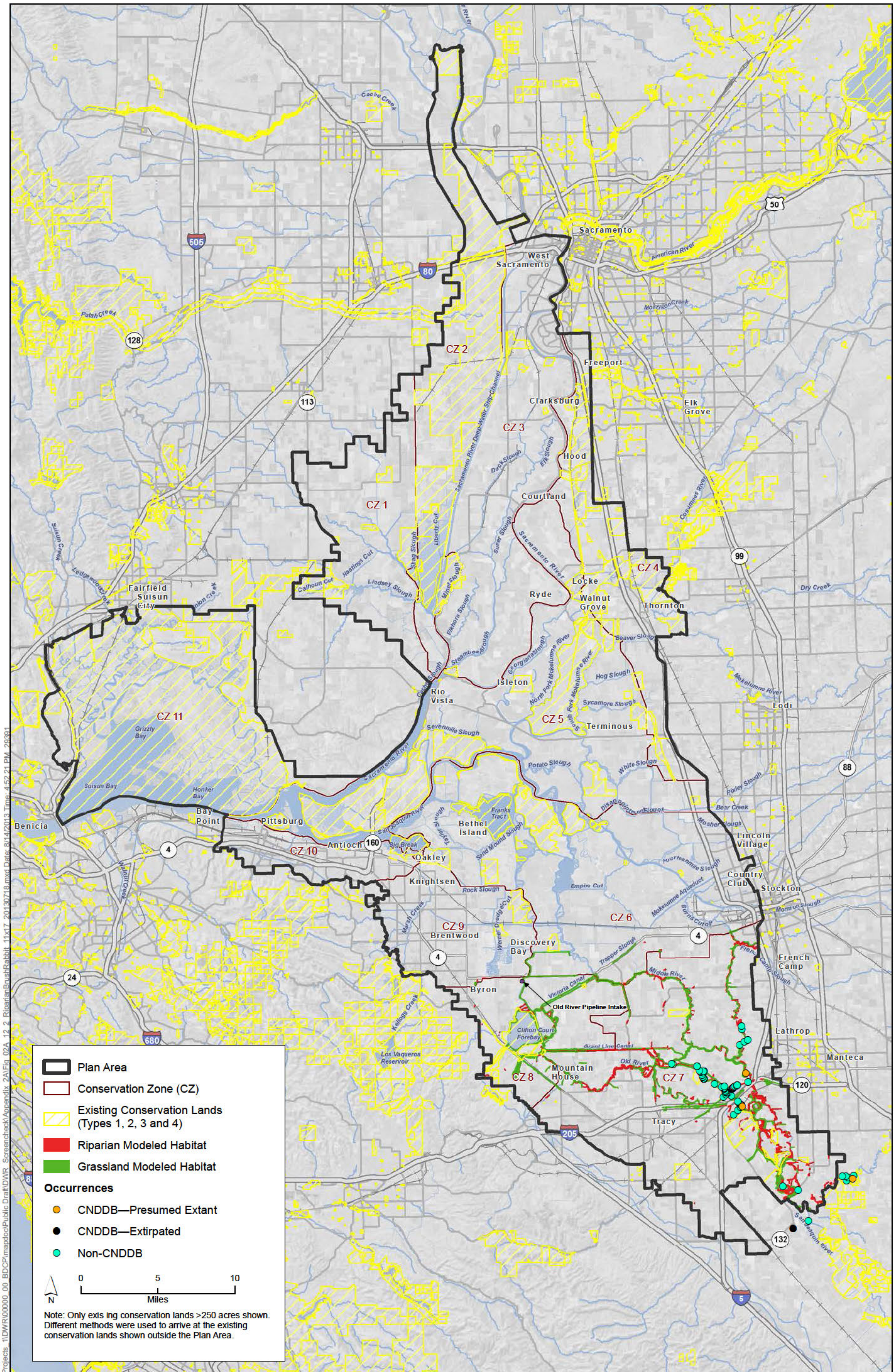
Kelly, Patrick, and Tristan Edgarian. Graduate students, California State University, Stanislaus, CA. October 5, 2010—Presentation to SAIC, Sacramento, CA.



K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix_2A\Fig_02A_12_1_RiparianBrushRabbit_Statewide_11x17_20130718.mxd Date: 8/14/2013 Time: 4:49:48 PM 29391

GIS Data Sources: Occurrences, CNDDB June 2013.

Figure 2A.12-1
Riparian Brush Rabbit Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013, ESRP 2003-2012, USFWS 1998, and Williams et al. 2002.

Figure 2A.12-2
Riparian Brush Rabbit Habitat Model and Recorded Occurrences

Appendix 2A.13
Riparian Woodrat (*Neotoma fuscipes riparia*)

2A.13.1 Legal Status

The riparian woodrat (*Neotoma fuscipes riparia*) is a federally listed species and a state species of special concern (Williams 1986). It was listed pursuant to the federal Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS) as endangered on February 23, 2000 (65 *Federal Register* [FR] 8881). Critical habitat has not been designated for this species.

In 2010, USFWS announced its intention to perform a 5-year review of the status of the riparian woodrat (75 FR 28636).

2A.13.2 Species Distribution and Status

2A.13.2.1 Range and Status

The riparian woodrat is one of 11 recognized subspecies of the dusky-footed woodrat (*Neotoma fuscipes*). The species range extends from the Columbia River and the Willamette Valley of Oregon to northwestern Baja California. It is generally found in dense chaparral, oak and riparian woodland, and mixed coniferous forest that has a well-developed understory. Generally preferring fairly moist habitats, *N. fuscipes* is also found in drier communities, such as pinyon-juniper woodland, and favors brushy habitat or woodland that has an oak component (U.S. Fish and Wildlife Service 1998).

The riparian woodrat has a limited distribution associated primarily with valley oak (*Quercus lobata*)-dominated riparian habitats of the Central Valley (Figure 2A.13-1). Historical records indicate the subspecies was distributed along the San Joaquin, Stanislaus, and Tuolumne Rivers, and possibly Corral Hollow, in San Joaquin, Stanislaus, and Merced Counties; although Hooper (1938) thought the distribution could have extended south to northern Fresno County.

The current distribution is highly restricted and is limited to riparian habitats along the lower portions of the San Joaquin and Stanislaus Rivers in northern San Joaquin County. The riparian woodrat is found in a 100-hectare (247-acre) patch of riparian forest on the Stanislaus River in Caswell Memorial State Park (Williams 1986), and in San Joaquin River National Wildlife Refuge (Kelly pers. comm.). Williams (1993) estimated the population at Caswell State Park at 437 individuals. Since confirming their presence at San Joaquin River National Wildlife Refuge in 2003, more than 30 individual riparian woodrats have been captured at this location (Kelly pers. comm.).

2A.13.2.2 Distribution and Status in the Plan Area

While there are no current records of riparian woodrat occurrences in the Plan Area, the species is considered extant in the California Natural Diversity Database (California Department of Fish and Game 2011). This is based on recorded occurrences northeast of Vernalis along the San Joaquin River, near the extreme southeastern tip of the Plan Area (Figure 2A.13-2). The Caswell Memorial

State Park population along the Stanislaus River is approximately 2 miles east of the Plan Area. The population of riparian woodrats at San Joaquin River National Wildlife Refuge is directly adjacent the Plan Area.

Small patches of potentially occupied valley oak riparian forest occur along the San Joaquin River from the southern tip of the Plan Area north to approximately the Interstate 5 overcrossing near Lathrop. Sufficiently large patches of oak-dominated riparian forest are lacking elsewhere in the Plan Area. A survey effort, coordinated by the California Department of Water Resources (DWR) was completed in December 2011 (California Department of Water Resources et al. 2011), detected no riparian woodrats in the Plan Area.

2A.13.3 Habitat Requirements and Special Considerations

The following are important components of riparian woodrat habitat.

- A high level of structure appropriate for nesting and nest building.
- Tree canopy, especially oak (*Quercus* spp.), but also Fremont cottonwood (*Populus fremontii*), California sycamore (*Platanus racemosa*), large willows (*Salix* spp.), and other large trees;
- Large patches of dense brush understory such as willows, blackberries (*Rubus* spp.), wild rose (*Rosa californica*), currant (*Ribes* spp.), or other shrub species.
- Canopy and understory connected by a mid-story composed of vines (e.g. California wild grape, *Vitis californica*), willows, or other native shrubs and trees.
- High-ground refugia from flooding (Kelly et al. 2011).

The riparian woodrat occurs in riparian woodland with an overstory canopy of trees and a moderate-to-dense shrub understory with abundant dead branches and downed woody material (Williams 1986). Riparian woodrats are found primarily where there is a valley oak overstory and are most numerous in areas of dense shrub cover. While they will also occur in riparian habitats with other dominant overstory species, such as Oregon ash (*Fraxinus latifolia*), box elder (*Acer negundo*), and Hinds' walnut (*Juglans hindsii*) (Kelly pers. comm.), highest densities of woodrats and their houses (middens) have been found in willow thickets with an oak overstory (U.S. Fish and Wildlife Service 1998).

The riparian woodrat typically lives in colonies of conical houses constructed with sticks, bark, plant cuttings, and other objects (Collins 1998); the houses range in height from 60 to 150 centimeters (24 to 59 inches) and can be 120 to 240 centimeters (47 to 94 inches) in basal diameter. Unlike other subspecies that may construct arboreal houses, riparian woodrat houses appear to be mainly terrestrial (Williams 1993). Houses typically are constructed on the ground against or straddling a log or exposed roots of a standing tree and are often located in dense brush. While the woodrat itself can be arboreal and can escape flooding, its terrestrial houses, which are essential for survival, can be affected by flooding and thus potentially affect population viability (U.S. Fish and Wildlife Service 1998).

2A.13.4 Life History

2A.13.4.1 Description

The riparian woodrat is a medium-sized rodent, with total length ranging from 434 to 452 millimeters (17.1 to 17.8 inches), tail length ranging from 207 to 217 millimeters (8.2 to 8.5 inches), and an average weight of 243 grams (8.57 ounces) in females and 266 grams (9.38 ounces) in males (Hooper 1938). It is distinguished from other subspecies of woodrats by its larger size, more grayish color, white hind feet, and a more bicolored tail, which is lighter below contrasting with the darker dorsal color. The riparian woodrat's tail is well-furred and not scaled.

Woodrats as a group are generalist herbivores, consuming a wide variety of nuts and fruits, fungi, foliage, and some forbs (Linsdale and Tevis 1951). Riparian woodrat may be considered to be more specialized feeders, but there are no available studies on riparian woodrat diet.

2A.13.4.2 Activity and Social Structure

Riparian woodrats are primarily nocturnal, with peak activity at dawn and dusk. While riparian woodrat houses are generally constructed on the ground, woodrats themselves may be found on the ground or in the foliage of trees and shrubs (Linsdale and Tevis 1951).

Little information is available on the social structure of riparian woodrats. Assuming their activity and social structure are similar to other subspecies of *N. fuscipes*, they probably live in loosely cooperative societies and have a matrilineal (mother-offspring associations; through the maternal line) social structure that results in populations that are female-biased, and in which adjacent females are closely related (Kelly 1990). Females remain at their natal site throughout their lives. Males disperse away from their birth den and are highly territorial and aggressive, especially during the breeding season. Males mate with more than one female in a single breeding season, known as a polygynous mating system. The effective population size (i.e., successful breeders) is generally much smaller than the actual population size. This breeding system, in combination with the small size of the only known extant population, means that the riparian woodrat is at an increased risk of extinction because small, isolated populations are more susceptible to genetic, demographic, and environmental stochasticity risks than large, widely distributed populations (U.S. Fish and Wildlife Service 1998).

2A.13.4.3 Reproduction

Little information is available on reproduction and dispersal of riparian woodrat. Again, assuming it is similar to other subspecies of *N. fuscipes*, the riparian woodrat likely breeds from December to September, with the majority of litters born in mid-spring (Carraway and Verts 1991). Following a gestation period of 28 to 33 days (Carraway and Verts 1991), females give birth to one annual litter (Vestal 1938). Litter size averages 2.6 young per litter, but ranges from 1 to 4 (Carraway and Verts 1991). Juveniles rarely disperse more than 50 feet to establish home ranges in or adjacent to the maternal range (Linsdale and Tevis 1951; Collins 1998).

2A.13.5 Threats and Stressors

2A.13.5.1 Loss of Genetic Variability

Because there is only one known extant population of riparian woodrat of limited size and occupancy, it is at increased risk of reduced biological fitness or extinction because of genetic, demographic, and/or naturally occurring catastrophic events (e.g., drought, flooding, fire) that threaten small, isolated populations. In addition, because of its breeding behavior, the effective size of woodrat populations is generally much smaller than the actual population size, which increases the risk of inbreeding depression.

2A.13.5.2 Habitat Loss and Fragmentation

There has been a nearly 90% reduction of historical riparian communities throughout the riparian forests along major streams flowing onto the floor of the northern San Joaquin Valley (Katibah 1983). While the extent to which this reduction of available habitat has affected populations of the riparian woodrat is unknown, it must be considered significant. The loss and fragmentation of habitat are considered the principal reasons for the decline of this subspecies (Kelly et al. 2011). Much of this loss was the result of conversion to agricultural land uses and the construction of large dams and canals, which diverted water for the irrigation of crops and permanently altered the hydrology of valley streams. Historically, cattle probably impacted riparian woodrat populations since the thick undergrowth, which is particularly important to woodrats, is sensitive to trampling, browsing, and grazing by livestock (U.S. Fish and Wildlife Service 1998).

2A.13.5.3 Flooding and Fire

The increase of habitat conversion to agriculture, combined with construction of dams, has altered the timing, frequency, duration, and intensity of flooding. Although woodrats can easily climb trees and avoid drowning, their nests, which are essential to survival, can be destroyed (U.S. Fish and Wildlife Service 1998). Wildfires are also of great concern because of habitat degradation and mortality of individuals unable to avoid the fire. A catastrophic fire at Caswell Memorial State Park would potentially eliminate the only known occupied site for this species.

2A.13.5.4 Other Threats

Other threats that would potentially affect the remaining occupied site for this subspecies include disease, predation, the use of rodenticides, and trampling by grazing animals.

A wide variety of aerial and terrestrial predators prey on riparian woodrat, including various raptors, coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), long-tailed weasel (*Mustela frenata*), mink (*Neovison vison*), raccoon (*Procyon lotor*), snakes, feral dogs (*Canis lupus familiaris*), and feral cats (*Felis catus*) (Kelly et al. 2011). A robust population of riparian woodrat should be able to withstand predation, but habitat adjacent to residential properties or along public roads or waterways, or subject to human disturbance, can exacerbate predation risk (Kelly et al. 2011).

The black rat (*Rattus rattus*) is an exotic invasive species that may be a threat to riparian woodrat populations by preying on offspring and competing for resources. Black rats appear to be ubiquitous in riparian natural communities in the Central Valley. Recent research at Caswell Memorial State Park suggests that the reproductive success of riparian woodrats is lower in areas with high black rat densities, but further research on riparian woodrat and black rat ecology is needed (Kelly et al. 2011).

2A.13.6 Relevant Conservation Efforts

Although the only known population has some protection by residing in Caswell Memorial State Park, no conservation efforts are under way to benefit the riparian woodrat specifically. The California Department of Parks and Recreation has supported some general small-mammal studies and studies on the woodrat population at the park (Cook 1992; Williams 1993) and has developed a fire management plan to protect its habitat.

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the riparian woodrat as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Successful recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

The riparian woodrat is a covered species in the San *Joaquin County Multi-Species Habitat Conservation and Open Space Plan* (San Joaquin Council of Governments 2000), which prohibits removal or disturbance of occupied riparian habitat that would potentially affect the subspecies as a result of the implementation of covered activities.

The Endangered Species Recovery Program recently developed the following set of guiding principles and considerations for riparian woodrat conservation in the Plan Area (Kelly et al. 2011).

- Conservation of lands: protection existing habitat occupied by riparian brush rabbit.
- Connectivity: establishment of permanent corridors with suitable habitat components between known populations to facilitate dispersal of the species and genetic interchange between adjacent populations.
- Restoration: active restoration (planting and management) of core areas and connecting lands (the Endangered Species Recovery Program does not recommend passive restoration as a means to restore riparian brush rabbit habitat).
- Range: prioritizing lands in the south Delta near extant populations (south of Highway 12 and particularly south of Highway 4 within Conservation Zones 7 and 8).
- High-water refugia: building and restoring high-ground habitat mounds or berms to provide refuge during seasonal flood events and sea level rise.
- Invasive species management: control of feral predators (cats and dogs) and invasive rodents (black rats).
- Additional research: further ecological research on the ecology of riparian brush rabbit (e.g., population and habitat management, distribution, diet, and roles of predators and competitors).

2A.13.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2.A.0.17, Species *Habitat Suitability Model Methods.*

2A.13.7.1 GIS Model Data Sources

The riparian woodrat model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005), and land use survey of the Sacramento–San Joaquin River Delta and Suisun Marsh area - version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable riparian woodrat habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.13.7.2 Habitat Model Description

Modeled riparian woodrat habitat consists of the following valley/foothill riparian vegetation types from the BDCP composite vegetation layer in Conservation Zone 7.

- Valley oak–*Quercus lobata*
- *Salix gooddingii*–*Quercus lobata*/wetland herbs
- *Salix gooddingii*–*Populus fremontii* (*Quercus lobata*–*Salix exigua*–*Rubus discolor*)
- *Quercus lobata*/*Rosa californica* (*Rubus discolor*–*Salix lasiolepis/Carex* spp.)
- *Quercus lobata*–*Acer negundo*
- *Quercus lobata*–*Alnus rhombifolia* (*Salix lasiolepis*–*Populus fremontii*–*Quercus agrifolia*)
- *Quercus lobata*–*Fraxinus latifolia*
- Box elder (*Acer negundo*)
- *Acer negundo*–*Salix gooddingii*)
- *Alnus rhombifolia*/*Cornus sericea*
- *Alnus rhombifolia*/*Salix exigua* (*Rosa californica*)
- Black willow (*Salix gooddingii*)–valley oak (*Quercus lobata*) restoration)
- Fremont cottonwood (*Populus fremontii*)
- Hinds' walnut (*Juglans hindsii*)
- Oregon ash (*Fraxinus latifolia*)
- Valley oak (*Quercus lobata*) restoration
- White alder (*Alnus rhombifolia*) and
- White alder (*Alnus rhombifolia*)–arroyo willow (*Salix lasiolepis*) restoration
- Salix exigua (*Salix lasiolepis*–*Rubus discolor*–*Rosa californica*)

A geographic information system (GIS) constraint layer was developed to limit mapped, suitable habitat to areas south of State Route 4 and Old River Pipeline along the Stanislaus, San Joaquin, Old, and Middle Rivers (Figure 2A.12-2).

2A.13.7.3 Assumptions

- **Assumption**: Riparian woodrat habitat is geographically constrained to areas south of State Route 4 and Old River Pipeline along the Stanislaus, San Joaquin, Old, and Middle Rivers (Figure 2A.12-2).

  Rationale: While somewhat arbitrary, for purposes of this model, this boundary is considered to represent the northern extent of all potentially occupied habitat within the Plan Area based on the known distribution of the species and results of recent surveys in the Plan Area. While survey access was not permitted within some portions of this area, it may also greatly overestimate the extent of potentially occupied habitat for this species.

- **Assumption:** Riparian woodrat habitat is restricted to the vegetation types described in Section 2A.13.7.2, *Habitat Model Description*.

  Rationale: The riparian woodrat occurs in riparian woodland with an overstory canopy of trees and a moderate-to-dense shrub understory (Williams 1986). Riparian woodrats are found primarily where there is a valley oak overstory, but will also occur with other overstory species and are most numerous in areas of dense shrub cover. In riparian areas, highest densities of woodrats and their houses have been found in willow thickets with a valley oak overstory (U.S. Fish and Wildlife Service 1998).

2A.13.8 Recovery Goals

A recovery strategy for the riparian woodrat is included in the USFWS (1998) *Recovery Plan for the Upland Species of the San Joaquin Valley, California* (Upland Recovery Plan). The Upland Recovery Plan has not been updated since the 2000 listing of the riparian woodrat; however, in 2010, USFWS announced plans to conduct a 5-year review of the status of the riparian woodrat (75 FR 28636).

The Upland Recovery Plan establishes an overall goal of three or more areas of occupied habitat, each supporting 400 or more individuals, with a total population of 5,000 or more independent individuals (i.e., excluding dependent young) during average precipitation years. The following initial conservation actions are included in the Upland Recovery Plan to help achieve these goals.

- Survey and map all riparian areas along the San Joaquin River and its major tributaries; this is the highest priority of the proposed conservation actions. A cost-effective survey can be carried out through a combination of aerial photo interpretation, selective field-truthing of these photos on the ground, and judicious trapping where permission is required and given.
- Develop an incentive program for preserving cover and riparian vegetation in collaboration with owners of riparian land and local levee-maintenance districts.
- Develop a plan for the restoration of riparian habitat, the establishment of riparian corridors, and the reintroduction, if necessary, of riparian woodrats to suitable habitat.
- Initiate a genetic study of the Caswell Memorial State Park woodrats, and any other riparian woodrat populations, to determine inbreeding levels, and devise a procedure for ensuring that

translocations neither reduce genetic diversity in the parent population nor unduly restrict it in the translocated population.

- Establish conservation agreements with willing landowners that do not already have conservation easements, as appropriate and necessary, to accomplish habitat restoration, linkage, and reintroduction goals.
- Begin efforts to restore and link riparian habitat, and reintroduce woodrats, as appropriate.

2A.13.9 References Cited

2A.13.9.1 Literature Cited

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2011. California Natural Diversity Database. Records search of quadrangles in the BDCP Plan Area. Sacramento, CA.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area* - Version 3 GIS dataset. Sacramento, CA.

California Department of Water Resources, Bureau of Reclamation, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 2011. *Draft 2009 to 2011 Bay Delta Conservation Plan EIR/EIS Environmental Data Report*. Report prepared in support of the Bay Delta Conservation Plan EIR/EIS.

Carraway, L. N. and B. J. Verts. 1991. *Neotoma fuscipes*. *Mammalian Species* 386:1–10.

Collins, P. W. 1998. *Riparian Woodrat,* Neotoma fuscipes riparia. In: B. C. Bolster (ed.), *Terrestrial Mammal Species of Special Concern in California*. Prepared by P.V. Brylski, P.W. Collins, E.D. Pierson, W.E. Rainey and T.E. Kucera. Report submitted to California Department of Fish and Game Wildlife Management Division, Nongame Bird and Mammal Conservation Program for Contract No.FG3146WM. Pages 120–124.

Cook, R. R. 1992. *An Inventory of the Mammals of Caswell Memorial State Park.* Lodi, CA: California Department of Parks and Recreation.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Hooper, E. T. 1938. Geographical Variation in Wood Rats of the Species *Neotoma fuscipes*. *University of California Publications in Zoology* 42:213–246.

Katibah, E. F. 1983. A Brief History of Riparian Forests in the Central Valley of California. In: R. E. Warner and K. M. Hendrix (eds.). *California Riparian Systems: Ecology, Conservation, and Productive Management*. Berkeley, CA: University of California Press. Pages 23–29.

Kelly, P. A. 1990. *Population Ecology and Social Organization of Dusky-Footed Woodrats*, Neotoma fuscipes. PhD dissertation. University of California, Berkeley.

Kelly, P. A., T. K. Edgarian, M. R. Lloyd, and S. E. Phillips. 2011. *Conservation Principles for the Riparian Brush Rabbit and Riparian Woodrat.* Prepared for the U.S. Fish and Wildlife Service, California Department of Fish and Game, and California Department of Water Resources.

Linsdale, J. M., and L. Tevis. 1951. *The Dusky-Footed Wood Rat*. Berkeley and Los Angeles, CA: University of California Press.

San Joaquin Council of Governments. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan.* Available: <http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm>. Accessed: December 22, 2011.

TAIC. 2008. *Yolo County Regional Vegetation, July 2008*. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program.* Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

U.S. Fish and Wildlife Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Region 1, Portland, OR.

Vestal, E. H. 1938. Biotic Relations of the Wood Rat (*Neotoma fuscipes*) in the Berkeley Hills. *Journal of Mammalogy* 19:1–36.

Williams, D. F. 1986. *Mammalian Species of Special Concern in California*. Administrative Report 86-1:1-112. Wildlife Management Division, California Department of Fish and Game.

Williams, D. F. 1993. *Population Censuses of Riparian Brush Rabbits and Riparian Woodrats at Caswell Memorial State Park during January 1993*. Lodi, CA: California Department of Parks and Recreation.

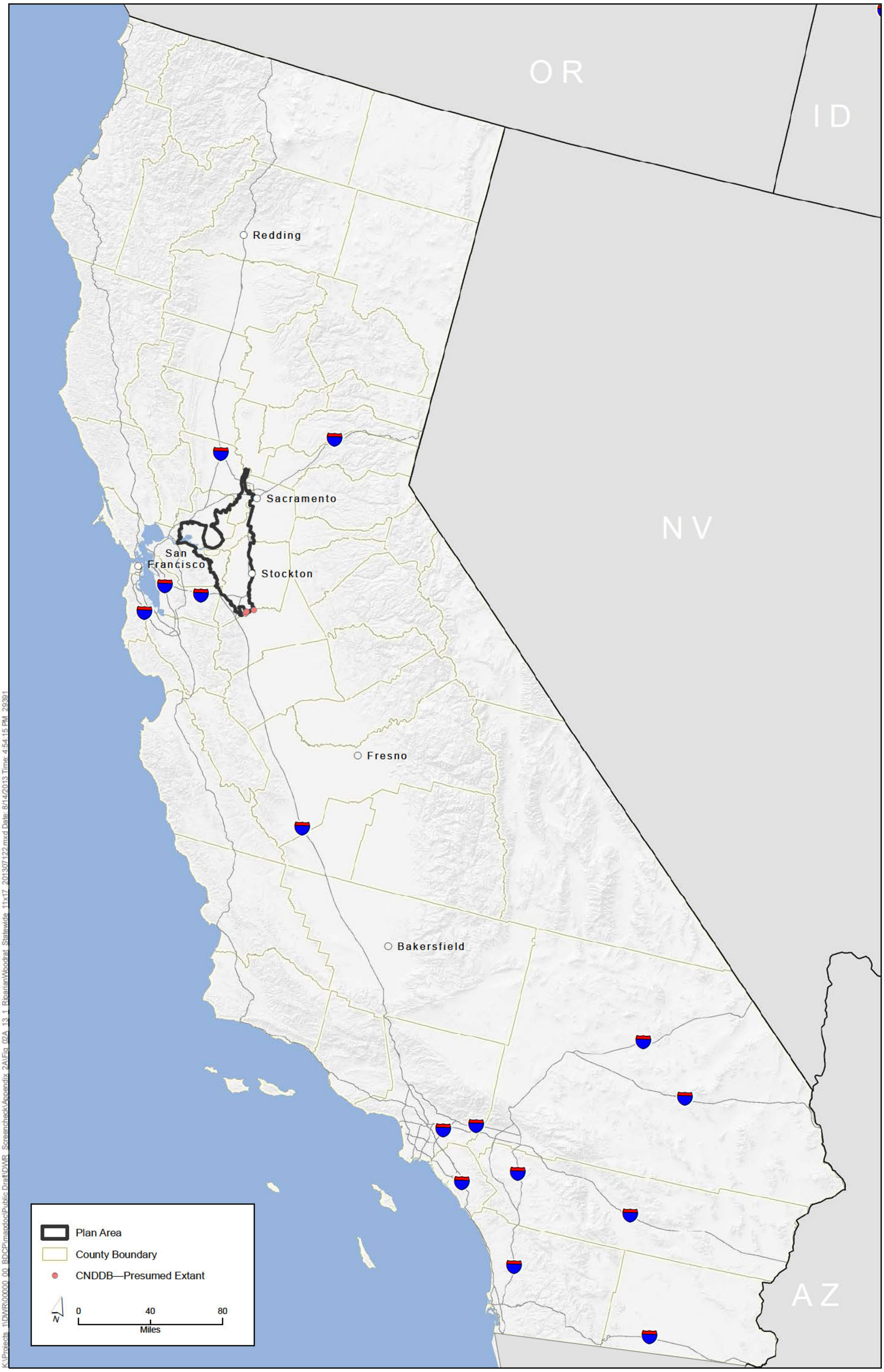
2A.13.9.2 Federal Register Notices Cited

65 FR 8881. 2000. Final Rule: Endangered and Threatened Wildlife and Plants; Final Rule to List the Riparian Brush Rabbit and the Riparian, or San Joaquin Valley, Woodrat as Endangered. *Federal Register* 65:8881.

75 FR 28636. 2010. Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Reviews of 34 Species in California and Nevada; Availability of 96 Completed 5-Year Reviews in California and Nevada. *Federal Register*75:28636.

2A.13.9.3 Personal Communications

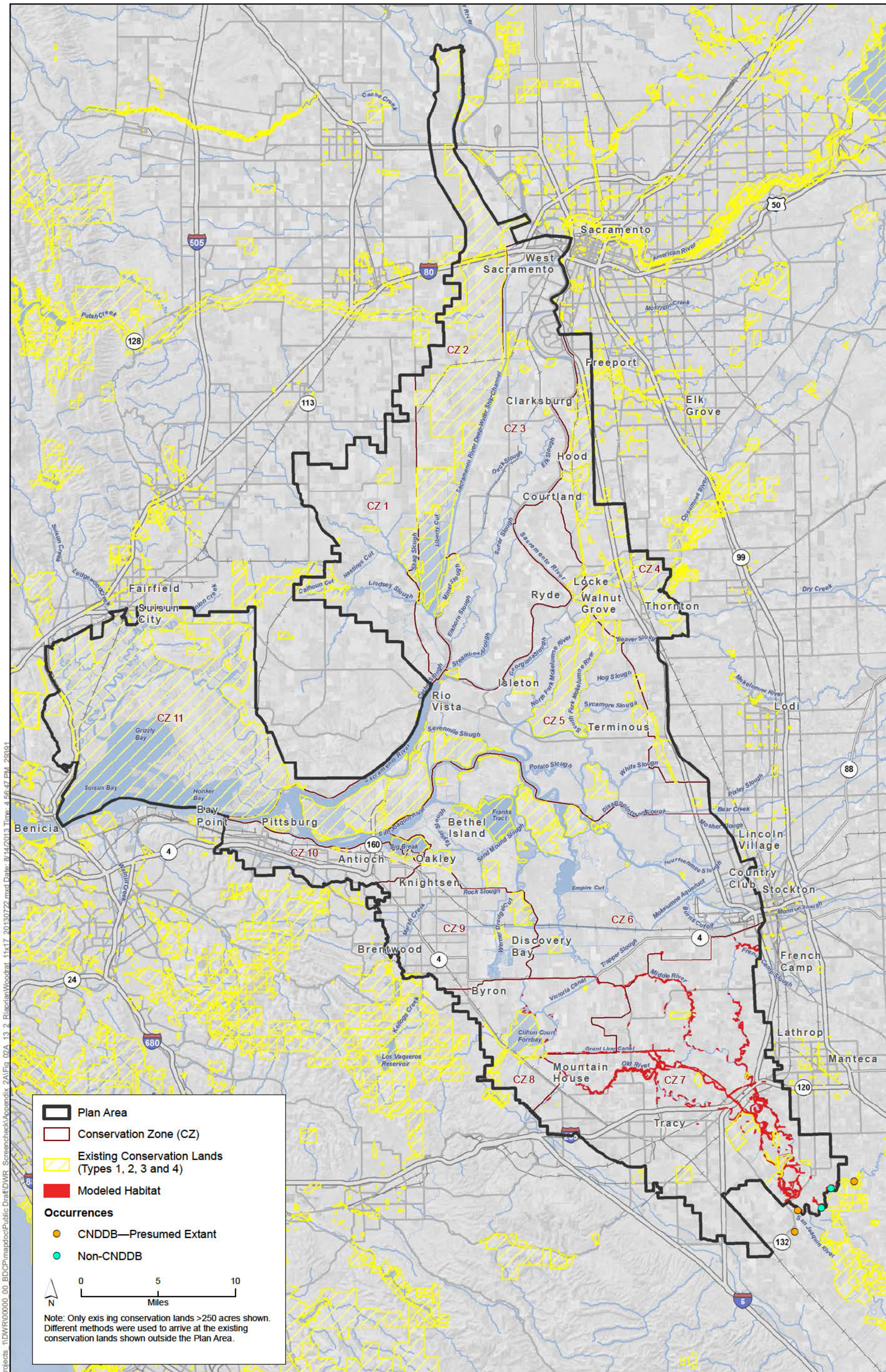
Kelly, Patrick. Professor of Zoology and Coordinator of Endangered Species Recovery Program, California State University Stanislaus, CA. September 17 and October 5, 2010—Comments from email and during a presentation at SAIC.



K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix_2A\Fig_02A_13_1_RiparianWoodrat_Statewide_11x17_20130712.mxd Date: 8/14/2013 Time: 4:54:15 PM 29391

GIS Data Sources: Occurrences, CNDDB June 2013.

Figure 2A.13-1
Riparian Woodrat Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013 and ESRP 1999.

Figure 2A.13-2
Riparian Woodrat Habitat Model and Recorded Occurrences

Appendix 2A.14
Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*)

2A.14.1 Legal Status

The U.S. Fish and Wildlife Service (USFWS) listed the salt marsh harvest mouse (*Reithrodontomys raviventris*) as endangered in 1970 (35 *Federal Register* [FR] 16047). The State of California listed the mouse as endangered in 1971 (Fish and Game Code, Sections 2050 *et seq*.). The salt marsh harvest mouse is also designated as a state Fully Protected species. A recovery plan for the species was initially prepared in 1984 but has since been revised under the USFWS (2010) *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (Draft Tidal Marsh Recovery Plan). Critical habitat has not been designated for this species.

2A.14.2 Species Distribution and Status

2A.14.2.1 Range and Status

The salt marsh harvest mouse is a small, native rodent endemic to the salt marshes of San Francisco, San Pablo, and Suisun Bays (Figure 2A.14-1). The historical range of the species likely included most of the marshland in the San Francisco Bay Area. Closely associated with saline habitats, the species' eastern distribution is generally considered to extend as far as approximately Collinsville and all islands west of, but not including, Sherman Island. The waters of wetlands and marshes east of these points are currently considered too fresh to support the habitat of this species (U.S. Fish and Wildlife Service 2001).

The species has been divided into two subspecies. The southern subspecies (*R. r. raviventris*) occurs in the marshes of Corte Madera, Richmond, and South San Francisco Bay. The northern subspecies (*R. r. halicoetes*) is found in the marshes of San Pablo and Suisun Bays, from San Rafael Bridge to approximately Collinsville on the north and from Martinez to Pittsburg on the south (U.S. Fish and Wildlife Service 2001).

Today, the species potentially occupies an area representing approximately 15% of the historical salt marsh habitat that formerly occurred in the San Francisco Bay Area (Dedrick 1989).

2A.14.2.2 Distribution and Status in the Plan Area

Reported occurrences of the salt marsh harvest mouse in the Plan Area are restricted to salt and brackish diked and tidal wetlands and adjacent uplands of Suisun Marsh, the Contra Costa shoreline, and the Sacramento–San Joaquin River Delta (Delta) west of Sherman Island (Figure 2A.14-2).

This is consistent with the range of the species as described by USFWS (2001).

2A.14.3 Habitat Requirements and Special Considerations

Salt marsh harvest mice depend on dense cover of native halophytes (salt-tolerant plants). Deep (60 to 75 centimeters) and dense pickleweed (*Salicornia pacifica*, formerly *Salicornia virginica*), intermixed with fat-hen (*Atriplex prostrata [triangularis]* or *A. patula*) and alkali heath (*Frankenia salina*), is preferred in many areas. Salt marsh harvest mice are rarely found in alkali bulrush (*Bolboschoenus* maritimus subsp. *paludosus,* formerly *Scirpus maritimus*), pure stands of salt grass (*Distichlis spicata*), or cordgrass (*Spartina* spp.) (Shellhammer et al. 1982), which can displace pickleweed. However, more recent research has documented the species in dense stands of three-square bulrush (*Schoenoplectus americanus*) in densities similar to that found in pickleweed (Patterson pers. comm.), as well as other kinds of dense halophytic vegetation. Thick thatch is apparently an important habitat component found in three-square bulrush communities (Shellhammer pers. comm.). Nonsubmerged escape cover is also required during high tides (Shellhammer et al. 1982). Fisler (1965) reported that populations can be concentrated on high marsh levels during periods of high tides. They have also been found in the top zone of tidal marshes and in transitional zones, which rarely flood (Shellhammer 1989). They will also move into adjacent grasslands during high tides. Fisler (1965) and Shellhammer et al. (1982) reported that the species will occupy adjoining grasslands during the highest winter tides and will occasionally use grasslands during spring and summer, when new growth affords sufficient cover. WESCO (1991) also reported use of nontidal uplands up to 150 feet from the wetland edge. Further, Sustaita et al. (2011) found salt marsh harvest mouse populations in Suisun Marsh managed wetlands in equal or higher abundance than in adjacent tidal brackish marsh. In Suisun Marsh, salt marsh harvest mice apparently respond well to managed diked wetlands, where they have been observed in densities equal to those found in tidal wetlands (Sustaita et al. 2011).

Salt marsh harvest mice have shown an ability to disperse considerable distances (Geissel et al. 1988); however, movement through unvegetated areas may be limited, and fragmentation of salt marsh habitats has limited dispersal opportunities for the species. A corridor of suitable vegetation is probably necessary for movement and dispersal into adjacent habitats.

2A.14.4 Life History

2A.14.4.1 Description

The salt marsh harvest mouse is buff or brownish in color and has a long, weakly bicolored and sparsely haired, tail, moderate-sized ears, and grooves in the outer surface of its upper incisors (Reid 2006). The underside is variable in color, ranging from white to a cinnamon- or rufous-colored belly. Adult salt marsh harvest mice are 118 to 175 millimeters in length and weigh between 0.28 and 0.42 ounces (8 and 12 grams).

2A.14.4.2 Activity

The maximum life expectancy for salt marsh harvest mice is approximately 1 year; however, California Department of Water Resources (DWR) data indicate that the life expectancy can be longer (Patterson pers. comm.). A generally solitary animal outside of the breeding season, this species typically remains beneath the canopy of dense low-lying vegetation and will sometimes use the ground runways of other rodents. Active year-round and primarily at night, this species responds to tidal action and can escape tidal or seasonal flooding by swimming or climbing, and will move into adjoining grasslands during the highest winter tides. Grasslands are otherwise only used as habitat primarily when new grass growth affords suitable cover in spring and summer months. These movements probably occur only on a daily basis and do not represent a seasonal shift in habitat use. Young are able to disperse considerable distances, but can be restricted by the fragmentation of suitable marsh habitats (Fisler 1965; Shellhammer et al. 1982 in LSA Associates 2007).

2A.14.4.3 Reproduction

Salt marsh harvest mice breed from spring through autumn, with females reproductively active from March to November. The breeding season for *R. r. halicoetes* begins as early as March (Quickert pers. comm.). Adults typically construct an aboveground nest of grasses and sedges about 150 to 175 millimeters (6 to 7 inches) in diameter. They sometimes construct the nest on top of bird nests and have been reported to use the nests of song sparrows. Females have a relatively low reproductive potential, bearing an average of four young per litter, following a gestation period of 21 to 24 days. However, they can produce up to three or four litters per year (Quickert pers. comm.) Adults make up the majority of the population.

Reproduction can also be suppressed by increasing populations of California meadow voles (*Microtus californicus*) in some areas, which respond to decreasing salinities and vegetation cover. In years when *Microtus* populations are high, breeding for salt marsh harvest mice may be suppressed further into the spring. However, competition with meadow voles has not been identified at Suisun Marsh (Sustaita et al. 2011).

2A.14.4.4 Diet

The diet of the salt marsh harvest mouse consists of seeds, grasses, forbs, and insects. During winter, fresh green grasses are preferred. During the rest of the year, the stems and leaves of pickleweed and fat-hen are main food sources (Fisler 1965). As noted, salt marsh harvest mice can tolerate high salinities in both food and drink intake, which can give them a competitive advantage over *Microtus* when the salinity of the marsh increases (Geissel et al. 1988).

2A.14.5 Threats and Stressors

Loss and degradation of tidal marsh habitats continue to be the most significant threats to the salt marsh harvest mouse and other tidal marsh species. Tidal marshes have been reduced by 84% since historical times (Dedrick 1989). The loss and fragmentation of suitable habitats from commercial and residential development in South Bay and San Pablo Bay have isolated populations and reduced dispersal opportunities. The loss of tidal marsh habitat through filling and diking has largely been curtailed. Cover removal from adjacent upland habitat by cattle grazing is a threat to salt marsh harvest mouse survival (Shellhammer pers. comm.).

However, other current factors associated with declining populations include the conversion of salt marshes to brackish marshes as a result of freshwater discharges from sewage treatment plants; introduction of nonnative cordgrass, saltgrass, and other plant species; predation by nonnative red foxes and feral cats; and invasion of runoff, industrial discharges, and sewage effluent (Shellhammer et al. 1982; California Department of Fish and Game 2000; LSA Associates 2007). Probably the most significant long-term issue is the predicted sea level rise as high as 1.2 meters within this century.

2A.14.6 Relevant Conservation Efforts

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the salt marsh harvest mouse as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Successful recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to issues related to development and water quality. The Suisun Marsh Program (California Department of Water Resources 2009) summarizes the major agreements, management plans, and legislation that have directed management of Suisun Marsh since the mid-1970s. These efforts focus on the preservation of diked wetlands and restoration of tidal marsh habitats.

2A.14.6.1 The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974)

The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

2A.14.6.2 Suisun Marsh Protection Plan (1976)

This plan was developed by the Bay Conservation and Development Commission and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the State of California purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

2A.14.6.3 The Suisun Marsh Protection Act (1977)

This act adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the Bay Conservation and Development Commission as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land in Suisun Marsh, when no longer managed for waterfowl, should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

2A.14.6.4 State Water Resources Control Board Water Rights Decision 1485 (1978)

The State Water Resources Control Board (State Water Board) adopted the Water Quality Control Plan for the Sacramento–San Joaquin Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the California Department of Fish and Wildlife (CDFW) recommendations, which were based on the following elements:

- The relative value of marsh plants as food for ducks.
- The influence of soil salinity and other factors on distribution and growth of marsh plants.
- The relationships between channel water salinity and soil salinity.

CDFW concluded that improved management practices, improved drainage, water control facilities, and adequate water quality were needed to achieve desired soil salinity conditions for waterfowl food plants.

2A.14.6.5 Plan of Protection for Suisun Marsh (1984)

DWR and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) developed and began implementing the Plan of Protection in accordance with Water Rights Decision 1485. The implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant State Water Project (SWP)/Central Valley Project (CVP) storage releases estimated as high as 2 million acre-feet in dry/critical water years. The six-phase plan was the programmatic blue print (required by the State Water Board and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

2A.14.6.6 Suisun Marsh Preservation Agreement (1987)

This contractual agreement between DWR, Reclamation, CDFW, and Suisun Resource Conservation District contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP/CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and Reclamation to meet salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in Suisun Marsh.

2A.14.6.7 Bay-Delta Accord (1994)

On December 15, 1994, federal and state agencies, working with agricultural, environmental, and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow.
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life.
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon.
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

2A.14.6.8 State Water Resources Control Board Water Quality Control Plan (1995 to 1998)

In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May 1995, the State Water Board modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the Suisun Marsh Preservation Agreement agreed could be mitigated by more active water control by landowners.

2A.14.6.9 State Water Resources Control Board Water Rights Decision 1641 (1999)

The State Water Board issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to Suisun Marsh. DWR proposed that the State Water Board adopt the Amendment Three actions for Suisun Marsh in this decision. However, the State Water Board was unable to adopt Amendment Three actions because the Section 7 consultation with USFWS had not concluded. However, the State Water Board did relieve Reclamation and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

2A.14.6.10 CALFED Multi-Species Conservation Strategy and Record of Decision (2000)

In August 2000, the Programmatic Record of Decision for the CALFED Bay-Delta Program was signed by 13 federal and state agencies with management and regulatory responsibilities in the San Francisco Bay estuary. Based on the analysis in the multispecies conservation strategy and the final programmatic environmental impact statement/environmental impact report, the CALFED agencies fulfilled the regulatory requirement for programmatic evaluation of the CALFED program.

2A.14.6.11 Suisun Marsh Charter Implementation Plan (2001)

The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in Suisun Marsh.

2A.14.6.12 Habitat Management, Preservation, and Restoration Plan (2010)

The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that would balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement, and other management and restoration programs in Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based on voluntary participation by private landowners. The Suisun Marsh Plan balances the benefits of tidal wetland restoration with other habitat uses in the marsh by evaluating alternatives that prescribe beneficial changes in marsh-wide land uses, such as salt marsh harvest mouse habitat, managed wetlands, public use, and upland habitat. The Suisun Marsh Plan addresses habitats and ecological process, public and private land use, levee system integrity, and water quality through restoration and managed wetland activities. The plan guides near-term and future actions related to restoration of tidal wetlands and managed wetland activities.

In addition, several facilities have been constructed in Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat.

- Roaring River Distribution System (1979 to 1980)
- Morrow Island Distribution System (1979 to 1980)
- Goodyear Slough Outfall (1979 to 1980)
- Suisun Marsh Salinity Control Gates (1988)
- Cygnus and Lower Joice Facilities (1991)

2A.14.6.13 Additional Restoration Projects

Several tidal marsh restoration projects are also planned or being implemented within the range of the salt marsh harvest mouse. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge, National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, CDFW, and the City of San Jose include the following.

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay.
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward, to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract, located just north of the west approach to the Dumbarton Bridge from the Port of Oakland.

The salt marsh harvest mouse is also proposed for coverage under the *Solano County Multispecies Habitat Conservation Plan* (Solano County 2009).

2A.14.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.14.7.1 GIS Model Data Sources

The salt marsh harvest mouse model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], and TAIC 2008 [Yolo Basin]). Using these data sets, the model maps the distribution of suitable salt marsh harvest mouse habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.14.7.2 Habitat Model Description

Primary salt marsh harvest mouse habitat consists of *Salicornia, Juncus* spp., *Schoenoplectus americanus*, and *Phragmites australis* plant alliances found in both tidal (tidal brackish emergent wetland primary habitat) and managed wetlands (managed wetland primary habitat). Secondary habitat includes low marsh dominated by *Schoenoplectus acutus* and *S. californicus* (tidal brackish emergent wetland secondary and managed wetland secondary habitats), upland areas within 150 feet and adjacent to the tidal wetland edge (upland secondary habitat), and all upland areas within the diked managed wetland boundaries (managed wetland upland secondary habitat). A minimum patch size of 1 acre was applied to collective regions of qualifying vegetation types.

Salt marsh harvest mouse tidal brackish emergent wetland primary habitat in the Delta and Suisun Marsh consists of the following wetland types from the BDCP geographic information systems (GIS) composite vegetation layer (unless indicated, all vegetation types listed below are considered primary habitat for the salt marsh harvest mouse).

- Tidal brackish emergent wetland
  - Tall wetland graminoids
    - *Phragmites/Scirpus*
    - *Scirpus americanus/Potentilla*
    - *Scirpus americanus/S. Californicus–S. acutus*
    - *Scirpus americanus* (generic)
    - *Typha angustifolia/S. americanus*
    - *Scirpus americanus/Lepidium*
    - Otherwise unclassified tall wetland graminoids
  - Medium wetland graminoids
    - *Juncus balticus*
    - *Juncus balticus/Conium*
    - *Juncus balticus/Lepidium*

    - *Juncus balticus/Potentilla*
    - *Scirpus maritimus*
    - *Scirpus maritimus/Salicornia*
    - *Scirpus maritimus/Sesuvium*
    - Otherwise unclassified medium wetland graminoids
  - Short wetland graminoids
    - *Distichlis spicata*
    - *Distichlis/Juncus*
    - *Distichlis/Salicornia*
    - *Distichlis/S. americanus*
    - *Distichlis/S. maritimus*
    - *Distichlis* (generic)
    - *Scirpus* (*californicus* or *acutus*)/wetland
    - *Distichlis–Juncus–Triglochin–Glaux*
    - Otherwise unclassified short wetland graminoids
  - Tall wetland herbs
    - Otherwise unclassified tall wetland herbs
  - Medium wetland herbs
    - *Atriplex triangularis*
    - *Atriplex/Distichlis*
    - *Atriplex/S. maritimus*
    - *Atriplex/Sesuvium*
    - *Frankenia/Agrostis*
    - *Frankenia/Distichlis*
    - *Frankenia* (generic)
    - *Grindelia stricta* var. *stricta*
    - *Lepidium/Distichlis*
    - *Lepidium* (generic)
    - *Polygonum–Xanthium–Echinochloa*
    - *Rumex* (generic)
    - *Atriplex*/annual grasses
    - *Potentilla anserina* (generic)
    - Otherwise unclassified medium wetland herbs

- Short wetland herbs
    - *Salicornia virginica*
    - *Salicornia*/annual grasses
    - *Salicornia*/*Atriplex*
    - *Salicornia*/*Crypsis*
    - *Salicornia*/*Sesuvium*
    - *Sesuvium verrucosum*
    - *Sesuvium*/*Distichlis*
    - *Sesuvium*/*Lolium*
    - *Salicornia* (generic)
    - *Salicornia*/*Polygonum–Xanthium–Echinochloa*
    - *Salicornia*/*Cotula*
    - Otherwise unclassified short wetland herbs

Salt marsh harvest mouse managed wetland primary habitat in the Delta and Suisun Marsh consists of the following wetland types from the GIS composite vegetation layer.

- Managed wetland
    - Tall wetland graminoids
        - *Phragmites*/*Scirpus*
        - *Scirpus americanus*/*Potentilla*
        - *Scirpus americanus*/*S. Californicus–S. acutus*
        - *Scirpus americanus* (generic)
        - *Typha angustifolia*/*S. americanus*
        - *Scirpus americanus*/*Lepidium*
        - Otherwise unclassified tall wetland graminoids
    - Medium wetland graminoids
        - *Juncus balticus*
        - *Juncus balticus*/*Conium*
        - *Juncus balticus*/*Lepidium*
        - *Juncus balticus*/*Potentilla*
        - *Scirpus maritimus*
        - *Scirpus maritimus*/*Salicornia*
        - *Scirpus maritimus*/*Sesuvium*
        - Otherwise unclassified medium wetland graminoids

- Short wetland graminoids
  - *Distichlis spicata*
  - *Distichlis/Juncus*
  - *Distichlis/Salicornia*
  - *Distichlis/S. americanus*
  - *Distichlis/S. maritimus*
  - *Distichlis* (generic)
  - *Scirpus* (*californicus* or *acutus*)/wetland
  - *Distichlis–Juncus–Triglochin–Glaux*
  - Otherwise unclassified short wetland graminoids
- Tall wetland herbs
  - Otherwise unclassified tall wetland herbs
- Medium wetland herbs
  - *Atriplex triangularis*
  - *Atriplex/Distichlis*
  - *Atriplex/S. maritimus*
  - *Atriplex/Sesuvium*
  - *Frankenia/Agrostis*
  - *Frankenia/Distichlis*
  - *Frankenia* (generic)
  - *Grindelia stricta* var. *stricta*
  - *Lepidium/Distichlis*
  - *Lepidium* (generic)
  - *Polygonum–Xanthium–Echinochloa*
  - *Rumex* (generic)
  - *Atriplex*/annual grasses
  - *Potentilla anserina* (generic)
  - Otherwise unclassified medium wetland herbs
- Short wetland herbs
  - *Sarcocornia virginica*
  - *Salicornia*/annual grasses
  - *Salicornia/Atriplex*
  - *Salicornia/Crypsis*

    - *Salicornia/Sesuvium*
    - *Sesuvium verrucosum*
    - *Sesuvium/Distichlis*
    - *Sesuvium/Lolium*
    - *Salicornia* (generic)
    - *Salicornia/Polygonum–Xanthium–Echinochloa*
    - *Salicornia/Cotula*
    - Otherwise unclassified short wetland herbs

Salt marsh harvest mouse tidal brackish emergent wetland secondary and managed wetland secondary habitats in the Delta and Suisun Marsh consists of the following wetland types from the BDCP GIS composite vegetation layer.

- Tidal brackish emergent wetland
  - *Phragmites australis*
  - *Scirpus* (*californicus* or *acutus*)–*Typha* sp.
  - *Scirpus californicus/S. acutus*
  - *Typha angustifolia/Phragmites*
  - *Scirpus* (*californicus* or *acutus*)/*Rosa*
- Managed wetland upland
  - *Phragmites australis*
  - *Scirpus* (*californicus* or *acutus*)–*Typha* sp.
  - *Scirpus californicus/S. acutus*
  - *Typha angustifolia/Phragmites*
  - *Scirpus* (*californicus* or *acutus*)/*Rosa*

Salt marsh harvest mouse tidal brackish emergent wetland secondary and managed wetland secondary habitats in the Delta and Suisun Marsh also consists of the following upland types (secondary habitat) that occur within 150 feet of the tidal wetland edge (upland secondary habitat) and within managed wetlands (managed wetland upland secondary habitat).

- Tidal brackish emergent wetland
  - Medium upland graminoids
    - *Elytrigia pontica*
    - *Leymus* (generic)
    - *Lolium* (generic)
    - *Lolium/Lepidium*
    - *Lolium /Rumex*

        - *Phalaris aquatica*
    - Cultivated annual graminoids
    - Perennial grass
    - Annual grasses and weeds
        - *Agrostis avenacea*
    - Short upland graminoids
    - Annual grasses (generic)
        - *Bromus* spp./*Hordeum*
        - *Hordeum*/*Lolium*
        - *Vulpia*/*Euthamia*
        - *Polypogon monspeliensis* (generic)
        - *Baccharis pilularis*/annual grasses
- Managed wetland
    - Medium upland graminoids
        - *Elytrigia pontica*
        - *Leymus* (generic)
        - *Lolium* (generic)
        - *Lolium*/*Lepidium*
        - *Lolium*/*Rumex*
        - *Phalaris aquatica*
    - Cultivated annual graminoids
    - Perennial grass
    - Annual grasses and weeds
        - *Agrostis avenacea*
    - Short upland graminoids
    - Annual grasses (generic)
        - *Bromus* spp./*Hordeum*
        - *Hordeum*/*Lolium*
        - *Vulpia*/*Euthamia*
        - *Polypogon monspeliensis* (generic)
        - *Baccharis pilularis*/annual grasses

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model*

Methods. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. Additional detail regarding crop types was available for cultivated lands and was incorporated into the mapping. In the new analysis areas, the following natural communities were assumed to provide salt marsh harvest mouse habitat.

- Tidal brackish emergent wetland
- Managed wetland
  - *Crypsis* spp.–wetland grasses–wetland forbs NFD super alliance (secondary)

Additional mapped areas of secondary habitat (within 150 feet of primary habitat) include the following natural community types.

- Alkali seasonal wetland complex
- Grassland
  - Pasture (Conservation Zone 11 only)
  - Upland annual grasslands and forbs formation
- Valley/foothill riparian

2A.14.7.3 Assumptions

- **Assumption**: Salt marsh harvest mouse habitat in the Plan Area is geographically limited to Suisun Marsh and the Delta west of Sherman Island.

  Rationale: Historical and current records of this species indicate that its distribution extends eastward to approximately Collinsville and Antioch (Figure 2A.14-1), but there are no records of occurrence on Sherman Island (Quickert pers. comm.). Therefore, a GIS constraint layer was developed to limit suitable habitat to include the Suisun Marsh and the Delta west of Sherman Island, plus upland areas adjacent to Suisun tidal wetlands.

- **Assumption**: Salt marsh harvest mouse habitat in the Plan Area consists of *Salicornia, Juncus spp., Schoenoplectus americanus, and Phragmites australis* plant alliances found in both tidal (tidal brackish emergent wetland primary habitat) and managed wetlands, and uplands within 150 feet of tidal wetlands. The uplands provide secondary habitat for the species.

  Rationale: This species is dependent on dense cover of native halophytes (salt-tolerant plants) and prefers pickleweed-dominated (*Salicornia pacifica,* formerly *S. virginica*) saline emergent wetlands and mixed-halophyte wetlands as its habitat (Shellhammer et al. 1982; Sustaita et al. 2011). The species also uses adjacent upland habitats during periods of high tides (Fisler 1965; Shellhammer et al. 1982; WESCO 1991).

  Shellhammer (pers. comm.) has suggested that important upland habitat may actually extend 200 to 500 feet from the wetland edge, but additional research is needed to verify. Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, data regarding the effects of these factors on potential occupancy for the salt marsh harvest mouse are insufficient. Thus, potential habitat for the salt marsh harvest mouse is not further restricted in this habitat model on the basis of these factors; in this respect, the model may overestimate potentially occupied habitat for the salt marsh harvest mouse.

2A.14.8 Recovery Goals

The *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* was finalized in 1984, but has since been replaced by the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010). Critical habitat has not been designated for this species.

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the salt marsh harvest mouse as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery actions are listed in the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010).

2A.14.9 References Cited

2A.14.9.1 Literature Cited

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2000. *California's Plants and Animals: Salt Marsh Harvest Mouse*. Habitat Conservation Planning Branch, Sacramento, CA. Available: <http://www.dfg.ca.gov/hcpb/species/jsp/more_info.jsp?specy=mammals&idNum=47>.

California Department of Water Resources. 2009. *Suisun Marsh Program.* Last revised: December 22, 2009. Available: <http://www.water.ca.gov/suisun/program/>. Accessed: June 12, 2012.

Dedrick, K. G. 1989. San Francisco Bay Tidal Marshland Acreages: Recent and Historic Values. In: *Proceedings of the 6th Symposium in Coastal and Ocean Management (Coastal Zone 1989).* American Society of Engineers. Pages 383–398.

Fisler, G. F. 1965. Adaptations and Speciation in Harvest Mice of the Marshes of San Francisco Bay. *University of California Publications in Zoology* 77. Berkeley, CA: University of California Press.

Geissel, W. H., H. S. Shellhammer, and H. T. Harvey. 1988. The Ecology of the Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*) in a Diked Salt Marsh. *Journal of Mammalogy* 69:696–703.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land-Use Classification and Map of the Sacramento–San Joaquin River Delta.* Report to the Bay Delta Region of the California Dept. of Fish and Game. Sacramento, CA. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

LSA Associates. 2007. Salt Marsh Harvest Mouse. Working draft 2.2, *Solano County Habitat Conservation Plan, Natural Community and Species Accounts.* Elmira, CA: Solano County Water Agency.

Reid, F.A. 2006. *Mammals of North America.* New York: Houghton-Mifflin.

Shellhammer, H. S. 1989. Salt Marsh Harvest Mice, Urban Development, and Rising Sea Levels. *Conservation Biology* 3(1):59–65.

Shellhammer, H. S., R. Jackson, W. Davilla, A. M. Gilroy, H. T. Harvey, and L. Simons. 1982. Habitat Preferences of Salt Marsh Harvest Mice (*Reithrodontomys raviventris*). *The Wasmann Journal of Biology* 40 (1–2):102–114.

Solano County Water Agency. 2009. *Solano Multispecies Habitat Conservation Plan.* Final Administrative Draft. June 15. Available: <http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx>. Accessed: December 22, 2011.

Sustaita, D., P. F. Quickert, L. Patterson, L. Barthman-Thompson, and S. Estrella. 2011. Salt Marsh Harvest Mouse Demography and Habitat Use in the Suisun Marsh, California. *Journal of Wildlife Management* 75:1498–1507.

TAIC. 2008. *Yolo County Regional Vegetation.* July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Fish and Wildlife Service. 2001. *Salt Marsh Harvest Mouse*. Endangered Species Division, Sacramento Fish and Wildlife Office, CA. Available: <http://sacramento.fws.gov/es/animal_spp_acct/salt_marsh_harvest_mouse.htm>.

U.S. Fish and Wildlife Service. 2010. *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Sacramento, CA. Available: <http://www.fws.gov/ecos/ajax/docs/recovery_plan/TMRP_Intro_1.pdf>. Accessed: August 3, 2012.

WESCO. 1991. *Final White Slough Retention Pond Enhancement Plan*. Prepared for the City of Vallejo and the California Coastal Conservancy.

2A.14.9.2 Federal Register Notices Cited

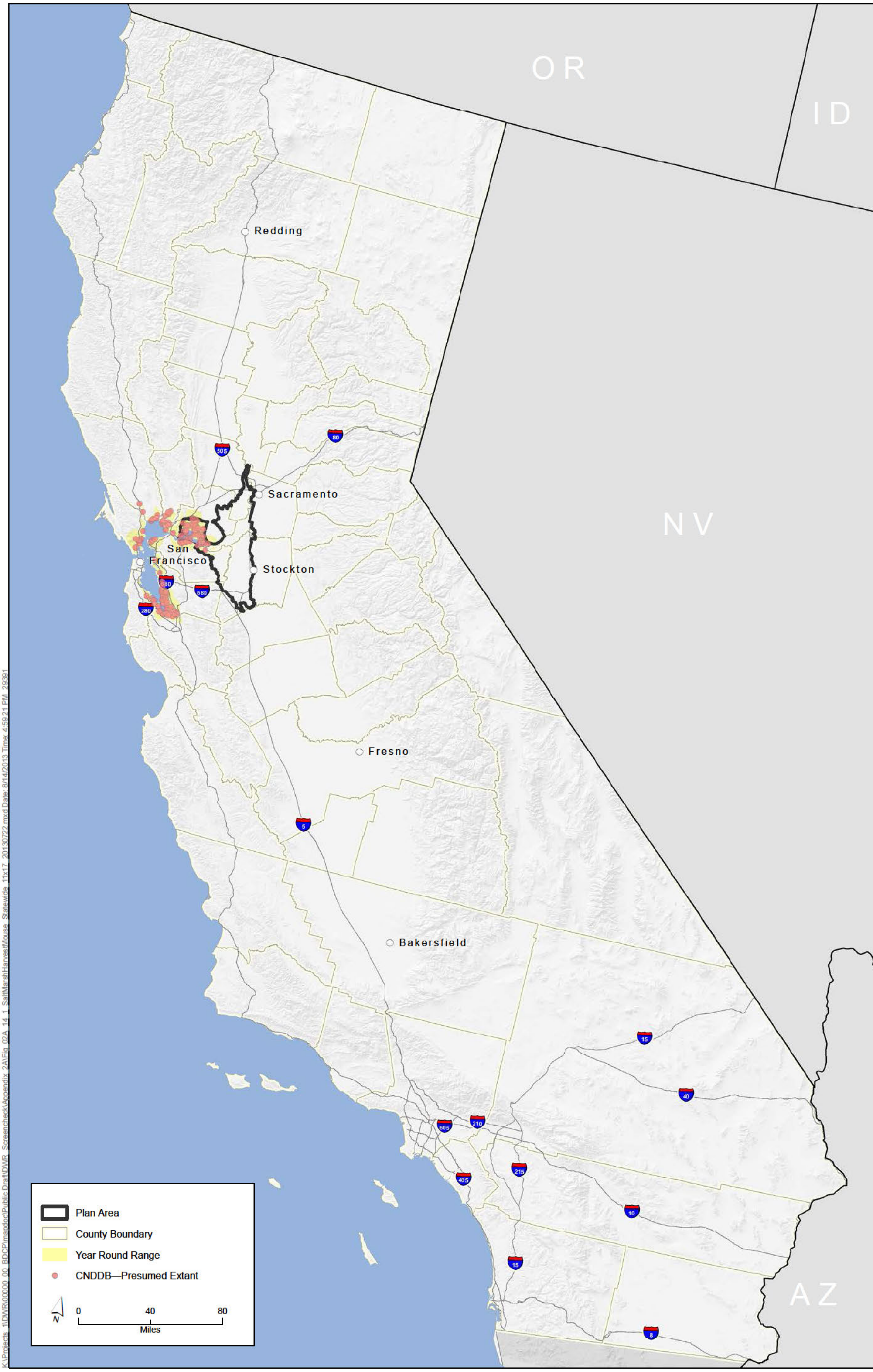
35 FR 16047. 1970. United States List of Endangered Native Fish and Wildlife. *Federal Register* 35:16047.

2A.14.9.3 Personal Communications

Patterson, Laura. Wildlife Biologist, California Department of Water Resources. Written comments on earlier draft of species accounts.

Quickert, Patty. Wildlife Biologist, California Department of Water Resources. Written comments on earlier draft of species account.

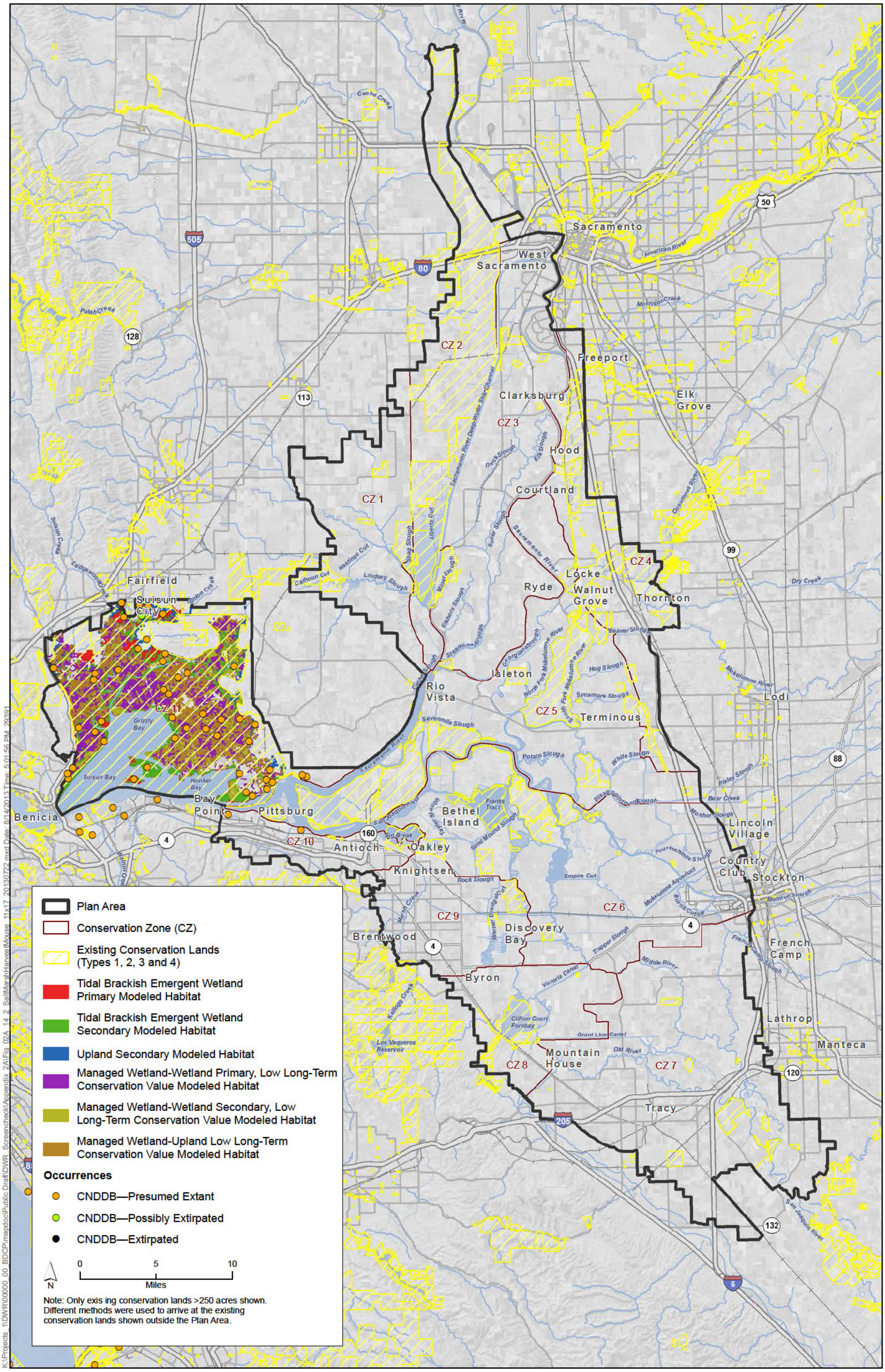
Shellhammer, Howard. Professor Emeritus, Department of Biological Sciences, San Jose State University. Written comments on earlier draft of species account.



K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix_2A\Fig_02A_14_1_SaltMarshHarvestMouse_Statewide_11x17_20130722.mxd Date: 8/14/2013 Time: 4:59:21 PM 29391

GIS Data Sources: Occurrences, CNDDB June 2013;
Range, DFG WHR 2008.

Figure 2A.14-1
Salt Marsh Harvest Mouse Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013.

Figure 2A.14-2
Salt Marsh Harvest Mouse Habitat Model and Recorded Occurrences

K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix 2A\Fig 02A_14_2_SaltMarshHarvestMouse_11x17_20130722.mxd Date: 8/14/2013 Time: 5:01:56 PM 29391

Appendix 2A.15
San Joaquin Kit Fox (*Vulpes macrotis mutica*)

2A.15.1 Legal Status

The San Joaquin kit fox (*Vulpes macrotis mutica*) is listed under the state and federal endangered species acts. It was listed by the U.S. Fish and Wildlife Service (USFWS) as an endangered species under the federal Endangered Species Act in 1967 and as a threatened species under the California Endangered Species Act in 1971. No critical habitat rules have been published for the San Joaquin kit fox. The USFWS (1983) *San Joaquin Kit Fox Recovery Plan* was the initial recovery plan for the species. Subsequently, a recovery strategy for San Joaquin kit fox was included in the USFWS (1998) *Recovery Plan for the Upland Species of the San Joaquin Valley, California* (Upland Recovery Plan). More recently, USFWS (2010) completed a 5-year review for this species, and determined that the kit fox continues to meet the definition as endangered.

2A.15.2 Species Distribution and Status

2A.15.2.1 Range and Status

Grinnell et al. (1937) initially described the range of the San Joaquin kit fox prior to 1930 as extending from southern Kern County as far north as eastern Contra Costa County. Grinnell et al. (1937) note that by 1930 the range had been reduced by more than half, with the largest portion of the occupied range remaining in the western and southern parts of the valley. They considered the species largely absent from the eastern and central parts of the valley.

Although no complete surveys have been conducted of the historical range, kit foxes are currently thought to inhabit suitable habitat on the San Joaquin Valley floor and in the surrounding foothills of the coastal ranges, Sierra Nevada, and Tehachapi Mountains north to Contra Costa, Alameda, and San Joaquin Counties on the west side of the valley, and near La Grange, Stanislaus County, on the east side of the valley (U.S. Fish and Wildlife Service 1998) (Figure 2A.15-1). Kit foxes have been found on all the larger, scattered islands of natural habitat on the valley floor in Kern, Tulare, Kings, Fresno, Madera, San Benito, Merced, Stanislaus, San Joaquin, Alameda, and Contra Costa Counties. They also occur in the interior basins and ranges in Monterey, San Benito, San Luis Obispo, and possibly Santa Clara Counties. They also occur in the upper Cuyama River watershed in northern Ventura and Santa Barbara Counties, and southeastern San Luis Obispo County (Laughrin 1970; Jensen 1972; Swick 1973; Morrell 1975).

USFWS (1998) reports that the largest extant populations of kit foxes are in western Kern County in and around the Elk Hills and Buena Vista Valley in Kern County, and in the Carrizo Plain National Monument area in San Luis Obispo County. Other relatively large populations have been reported to occur in the Central Coast around Fort Hunter Liggett and Camp Roberts, in Monterey and San Luis Obispo Counties. Occurrences further north are fewer and less frequent and include several in the Los Vaqueros watershed and surrounding area in Contra Costa County in the early 1990s (U.S. Fish and Wildlife Service 1998; California Department of Fish and Game 2011). Close to 50% of the

California Native Diversity Database (CNDDB) occurrences have been recorded from Kern County, with 10% from Tulare County, 6% from Kings County, 8% from Fresno County, and 9% from San Luis Obispo County (California Department of Fish and Game 2008 in U.S. Fish and Wildlife Service 2010).

Habitat loss, particularly on the San Joaquin Valley floor, has constrained the distribution of San Joaquin kit fox. Morrell (1975) reported that approximately 85% of the fox population in 1975 was found in only six counties (Kern, Tulare, Kings, San Luis Obispo, Fresno, and Monterey), and over half of the population occurred in two of those counties: Kern (41%) and San Luis Obispo (10%).

The *San Joaquin Kit Fox Recovery Plan* (U.S. Fish and Wildlife Service 1983) estimated that the population of adult kit foxes over the entire range prior to 1930 may have been between 8,667 and 12,340. The estimate presented was 6,961 adult foxes, representing a possible population decline of 20 to 43%.

More recently, Constable et al. (2009) found persistent but low populations in Merced County south of Santa Nella, but also questioned the viability and presence of kit fox populations north of Santa Nella because of habitat loss and fragmentation, declining populations of preferred prey (particularly kangaroo rats), low densities, and lack of reported population persistence.

Within this constrained, fragmented, and largely disturbed landscape, Cypher et al. (2000) showed that (1) population growth rates vary positively with reproductive success, (2) population density is positively related to both the current and the previous year's prey availability, and (3) prey abundance is strongly related to the previous year's effective precipitation (October to May). White and Garrott (1999) noted that two density-dependent mechanisms may also regulate kit fox population patterns: (1) the rate of juvenile recruitment, which is inversely related to the density of adult foxes, because higher proportions of juveniles are killed by coyotes at high fox densities, and (2) kit fox populations are bounded by their territorial spacing behavior, which limits recruitment when kit fox densities are high.

2A.15.2.2 Distribution and Status in the Plan Area

CNDDB reports eight occurrences of San Joaquin kit fox in the Plan Area (California Department of Fish and Game 2011). All occurrences are within the grassland landscape along the extreme western edge of the Plan Area south of Brentwood (Figure 2A.15-2). This is considered the extreme northern end of the San Joaquin kit fox range (U.S. Fish and Wildlife Service 1998). The species has not been detected, nor is it expected to occur elsewhere within the Plan Area. Most of the reported occurrences are from the late 1980s to the mid-1990s. Very few occurrences of this species have been reported within this far northern portion of its range (Alameda, Contra Costa, and San Joaquin Counties) since the mid-1990s. Of the 53 recorded occurrences in Contra Costa County between 1967 and 1997, only 15 were documented since 1986 (Duke et al. 1997). A recent survey of Contra Costa and Alameda Counties within the known range of the kit fox found no evidence of recent occupancy (Clark et al. 2003). While recent survey results do not necessarily indicate absence of the species, they do indicate very low density of San Joaquin kit fox and suggest a declining population within the northern range of the species.

2A.15.3 Habitat Requirements and Special Considerations

In the northern part of the range, the San Joaquin kit fox is associated primarily with foothill annual grasslands (Swick 1973; Hall 1983; Bell 1994) and sometimes with valley oak savanna and alkali grasslands (Bell 1994). In the vicinity of the Plan Area, San Joaquin kit foxes inhabit grazed grasslands and grasslands with associated wind farms and sometimes occur adjacent to and forage in tilled and fallow fields and irrigated row crops (Bell 1994). In the central and southern portions of the range, kit foxes are also found in remnant patches of native valley floor scrubland (e.g., valley sink scrub, valley saltbush scrub, upper Sonoran subshrub, interior Coast Range saltbush scrub), as well as grazed grasslands, agricultural lands, petroleum fields, and some urban areas (U.S. Fish and Wildlife Service 1998). Remaining patches of northern hardpan vernal pool, northern claypan vernal pool, alkali meadow, and alkali playa types also provide foraging habitat when associated with grasslands or other suitable denning habitats.

Dens are typically in relatively flat terrain or in gently sloping hills, in washes, drainages, and roadside berms. Occupied habitats are usually associated with loose-textured soils to facilitate den construction (Grinnell et al. 1937; Egoscue 1962; Morrell 1972). Shallow soils with close proximity to bedrock, soils with high water tables, and impenetrable hardpan layers are generally avoided (Morrell 1972; O'Farrell and Gilbertson 1979; O'Farrell et al. 1980; McCue et al. 1981). However, kit foxes will also modify burrows dug by other animals, such as California ground squirrel (*Otospermophilus beecheyi,* formerly *Spermophilus beecheyi*). Frequently in the northern end of their range, dens may be found in soils with high clay content (Orloff et al. 1986).

2A.15.4 Life History

2A.15.4.1 Description

The San Joaquin kit fox is the largest of eight subspecies of kit foxes, the smallest canid species in North America. Kit foxes have a small, slim body; long, slender legs; large ears set close together; a narrow nose; and a long, bushy tail tapering slightly toward the tip, which is typically carried low and straight (U.S. Fish and Wildlife Service 1998). Males average 80.5 centimeters (2.64 feet) in total length and 29.5 centimeters (11.6 inches) in tail length; females average 76.9 centimeters (2.52 feet) in total length and 28.4 centimeters (11.2 inches) in tail length (Grinnell et al. 1937). The average weight of adult males is 2.3 kilograms (5.1 pounds); that of adult females is 2.1 kilograms (4.6 pounds) (Morrell 1972).

The color and texture of the coat of kit foxes vary geographically and seasonally. The most commonly described colorations are buff, tan, grizzled, or yellowish-gray dorsal coats (McGrew 1979). Two distinctive coats develop each year: a tan summer coat and a silver-gray winter coat (Morrell 1972). The undersides vary from light buff to white (Grinnell et al. 1937), with the shoulders, lower sides, flanks, and chest varying from buff to a rust color. The ear pinna (external ear flap) is dark on the back side, with a thick border of white hairs on the forward-inner edge and inner base. The tail is distinctly black-tipped (U.S. Fish and Wildlife Service 1998).

2A.15.4.2 Activity

San Joaquin kit foxes are primarily nocturnal and active throughout the year (Grinnell et al. 1937; Morrell 1972). Adults and pups are sometimes observed resting and playing near the den entrance in the afternoons, but most aboveground activities begin near sunset and continue sporadically throughout the night (U.S. Fish and Wildlife Service 1998). Morrell (1972) reports that hunting occurred only at night; however, this may not be true for populations that rely on diurnal ground squirrels as their principal prey, such as those in the northern range. This suggests that kit foxes are not entirely nocturnal and appear to adapt to the activities of available prey (Balestreri 1981; Hall 1983; Orloff et al. 1986; O'Farrell et al. 1987).

2A.15.4.3 Reproduction

Kit foxes are capable of breeding at age one, but may not breed until their first year of adulthood (Morrell 1972). Adult pairs remain together all year, sharing the home range but not necessarily the same den (U.S. Fish and Wildlife Service 1998). During September and October, adult females begin to clean and enlarge natal or pupping dens, usually selecting dens with multiple openings (Morrell 1972). Mating and conception take place between late December and early March (Egoscue 1956; Morrell 1972; Zoellick et al. 1987a). The median gestation period is estimated to range from 48 to 52 days (U.S. Fish and Wildlife Service 1998). The majority of litters, from two to six pups, are born sometime between mid-February and late March (Egoscue 1962; Morrell 1972; Zoellick et al. 1987a).

During the time the female is lactating, she rarely hunts and is provisioned by the male. The pups emerge above ground at slightly more than 1 month of age and may already be weaned. After 4 to 5 months, usually in August or September, the family bonds begin to dissolve and the young begin dispersing. Occasionally a juvenile female will remain with the adult female for several more months (O'Neal et al. 1992). Koopman et al. (2000) found that 33% of juveniles disperse from their natal territory, with more males (49%) than females (24%). Others remain in their natal area. Dispersal was associated with mean annual litter size in males and prey abundance in females.

2A.15.4.4 Home Range and Territory Size

Home ranges appear to be highly variable, and range from less than 2.6 square kilometers (1 square mile) up to approximately 31 square kilometers (12 square miles) (Morrell 1972; Knapp 1978; Zoellick et al. 1987b; Paveglio and Clifton 1988; Spiegel and Bradbury 1992; White and Ralls 1993). Morrell (1972) reported home ranges between 2.6 and 5.2 square kilometers (1 and 2 square miles). Differences in home range size among study sites tend to be related to prey abundance (White and Ralls 1993; White and Garrott 1999). USFWS (1999) mentions large kit fox home ranges in the northern range; however, little other data are available for home range size in these northern areas.

2A.15.4.5 Foraging Behavior and Diet

San Joaquin kit fox diet varies geographically, seasonally, and annually based on variation in abundance of potential prey (U.S. Fish and Wildlife Service 1998). In the southern and central portions of their range, kangaroo rats, pocket mice, white-footed mice (*Peromyscus* spp.), and other nocturnal rodents are key prey items. California ground squirrels, black-tailed hares (*Lepus californicus*), San Joaquin antelope squirrels (*Ammospermophilus nelsoni*), desert cottontails

(*Sylvilagus audubonii*), ground-nesting birds, and insects are also taken (Jensen 1972; Scrivner et al. 1987a; Archon 1992). In the northern part of their range, kit foxes most frequently consume California ground squirrels (Orloff et al. 1986). Cottontails, black-tailed hares, pocket mice, and kangaroo rats are also eaten (Hall 1983).

2A.15.5 Threats and Stressors

2A.15.5.1 Habitat Loss and Fragmentation

Habitat loss and fragmentation from urbanization and agricultural expansion are the principal factors in the decline of the San Joaquin kit fox in the San Joaquin Valley (Laughrin 1970; Jensen 1972; Morrell 1975; Knapp 1978). By 1979, an estimated 6.7% of the San Joaquin Valley floor's original native habitat south of Stanislaus County remained untilled and undeveloped (U.S. Fish and Wildlife Service 1983). In the northern range, continued urbanization, primarily in Contra Costa and Alameda Counties, water storage and conveyance projects, road construction, energy development, and other activities continue to reduce and fragment remaining grassland habitats. These land conversions contribute to kit fox declines through displacement, isolation of remaining populations, creation of barriers to movement, mortality, and a reduction of prey populations (U.S. Fish and Wildlife Service 1998).

2A.15.5.2 Grazing

While livestock grazing is not necessarily detrimental and, in fact, may be beneficial (Morrell 1975; Balestreri 1981; Orloff et al. 1986), intensive overgrazing that destroys shrub cover and reduces prey abundance may be detrimental (O'Farrell et al. 1980; O'Farrell and McCue 1981; U.S. Fish and Wildlife Service 1983; Kato 1986).

2A.15.5.3 Rodent Control

The use of pesticides and rodenticides also threatens kit foxes. Ground squirrel control programs in the 1970s severely reduced California ground squirrel populations in Contra Costa County and are thought to have contributed to kit fox declines in the northern range (Bell et al. 1994; U.S. Fish and Wildlife Service 1998). Kit fox is also susceptible to secondary poisoning from rodenticides (Berry et al. 1992; Standley et al. 1992).

2A.15.5.4 Predation

Human activities, including urbanization, agricultural expansion, and agricultural and grazing practices, may have increased some predator populations that are more adaptable to disturbed environments, including coyote and red fox, two primary predators of the San Joaquin kit fox. This, in turn, can result in increased competition for resources and additional human-induced predation affecting kit fox populations.

2A.15.6 Relevant Conservation Efforts

The USFWS (1983) *San Joaquin Kit Fox Recovery Plan* proposed interim objectives of halting the decline of the San Joaquin kit fox and increasing population sizes above 1981 levels. Subsequently, the most significant conservation efforts have included land acquisitions by federal, state, and private agencies and organizations, including the Bureau of Land Management, USFWS, and The Nature Conservancy. Key acquisitions include the Carrizo Plain National Monument, Ciervo-Panoche Natural Area, and the Lokern Natural Area in the species' southern range. Other lands have been protected as mitigation for land conversions.

Past and continuing research, particularly on the Elk Hills Naval Petroleum Reserves in Kern County, provides data on a variety of topics that assist with long-term management and conservation of kit fox. Such data cover dispersal, mortality, movements and home ranges, habitat enhancement, relocation, supplemental feeding, and coyote control (Berry et al. 1987a, 1987b; Scrivner et al. 1987b; Zoellick et al. 1987a; Cypher and Scrivner 1992; EG&G Energy Measurements 1992). Other studies include survey efforts and life-history studies (Hall 1983; Orloff et al. 1986; Archon 1992; Spiegel and Bradbury 1992; White and Ralls 1993; Bell et al. 1994; White et al. 1994).

The San Joaquin kit fox is a covered species in the *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan* (San Joaquin Council of Governments 2000) and the *East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan* (East Contra Costa County Habitat Conservancy 2006). These plans limit or prohibit removal of occupied habitat that could affect the species as a result of the implementation of covered activities. Modeled kit fox habitat in the Plan Area (Conservation Zone 8) is adjacent to and overlaps with kit fox habitat in the East Contra Costa County plan area. The conservation strategy targets this as an important habitat linkage to be protected in the Plan Area.

2A.15.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.15.7.1 GIS Model Data Sources

The San Joaquin kit fox model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta]; Boul and Keeler-Wolf 2008 [Suisun Marsh]; TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005), and land use survey of the Sacramento–San Joaquin River Delta (Delta) and Suisun Marsh area—Version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable San Joaquin kit fox habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.15.7.2 Habitat Model Description

A geographic information system (GIS) constraint layer was developed to limit the upland breeding, foraging, and dispersal habitat model to the grassland habitats in the area south and west of State

Route 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard), to Old River. Then south along Old River to Clifton Court Forebay, then along the western and southern sides of Clifton Court Forebay to Old River. From there, south along the county line to Byron Highway, and from west of Byron Highway to Interstate 205 and also from north of Interstate 205 to Interstate 580, and west of Interstate 580.

The following vegetation types in the BDCP composite vegetation layer were included in the boundaries of the upland breeding, foraging, and dispersal habitat model, as described above.

- Grassland
  - Ruderal herbaceous grasses and forbs
  - California annual grasslands–herbaceous
  - *Bromus diandrus–Bromus hordeaceus*
  - Degraded vernal pool complex–California annual grasslands–herbaceous
  - Degraded vernal pool complex–ruderal herbaceous grasses and forbs
- Vernal pool complex
  - Ruderal herbaceous grasses and forbs
  - California annual grasslands–herbaceous

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most newly mapped areas, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. Additional detail regarding crop types was available for cultivated lands and was incorporated. In the new analysis areas, the following natural communities were assumed to provide San Joaquin kit fox habitat.

- Alkali seasonal wetland complex (Conservation Zone 8 only)
- Grasslands (Conservation Zone 8 only)

2A.15.7.3 Assumptions

- **Assumption**: San Joaquin kit fox habitat in the Plan Area is geographically constrained to areas described in Section 2A.12.7.2, *Habitat Model Description*.

  Rationale: Within the Plan Area, the San Joaquin kit fox has been detected in grasslands along the extreme southwestern edge of the Plan Area from approximately Brentwood to Tracy. This area is the northernmost edge of the San Joaquin kit fox range. The species is not known or expected to occur elsewhere in the Plan Area. Therefore, a GIS constraint layer was developed to limit suitable habitat to areas south of this northernmost edge.

- **Assumption:** San Joaquin kit fox habitat is restricted to the vegetation types described in Section 2A.12.7.2, *Habitat Model Description*.

  Rationale: In the northern part of the range, the San Joaquin kit fox is associated primarily with foothill annual grasslands (Swick 1973; Hall 1983; Bell 1994) and sometimes with valley oak savanna and alkali grasslands (Bell 1994).

2A.15.8 Recovery Goals

The USFWS (1998) Upland Recovery Plan incorporates and expands on the strategy provided in the USFWS (1983) *San Joaquin Kit Fox Recovery Plan*. The goal of the Upland Recovery Plan is to establish and maintain a viable complex of kit fox populations (i.e., a viable metapopulation) on private and public lands throughout the species' geographic range. The plan hinges on the enhanced protection and management of three geographically distinct core populations and a number of smaller satellite populations. The three core populations inhabit the Carrizo Plain National Monument area in San Luis Obispo County, natural lands of western Kern County (i.e., Elk Hills, Buena Vista Hill, Buena Vista Valley, Lokern Natural Area, and adjacent natural lands), and the Ciervo-Panoche Natural Area of western Fresno and eastern San Benito Counties (U.S. Fish and Wildlife Service 1998). Protection of smaller satellite populations will connect isolated natural lands to core and other populations.

The plan also includes a series of recovery actions that focus on land protection and maintenance for, or reestablishment of, habitat corridors that link all occupied portions of the range. While no core populations have been identified in the northern range, the "habitat protection and population interchange recovery actions" (U.S. Fish and Wildlife Service 1998) include the following action.

> Protect existing kit fox habitat in the northern, northeastern, and northwestern segments of their geographic range and existing connections between habitat in those areas and habitat farther south.

Additional ecology and recovery actions include determining habitat restoration and management prescriptions, determining the current geographic range of the species, monitoring populations, investigating use of farmlands by the kit fox, measuring movements between populations, determining the effects of rodent control, and evaluating the interactions between kit foxes and other canids (U.S. Fish and Wildlife Service 1998).

2A.15.9 References Cited

2A.15.9.1 Literature Cited

Archon, M. 1992. *Ecology of the San Joaquin Kit Fox in Western Merced County, California*. Master's thesis. California State University, Fresno.

Balestreri, A. N. 1981. *Status of the San Joaquin Kit Fox at Camp Roberts, California, 1981*. Unpublished report, U.S. Department of Army, Engineering, Environmental, and Natural Resources Office. San Luis Obispo, CA: California Polytechnic State University.

Bell, H. M. 1994. *Analysis of Habitat Characteristics of San Joaquin Kit Fox in Its Northern Range*. Master of Science thesis. California State University, Hayward.

Bell, H. M., J. A. Alvarez, L. L. Eberhardt, and K. Ralls. 1994. *Distribution and Abundance of San Joaquin Kit Fox*. Unpublished report. Sacramento, CA: California Department of Fish and Game, Nongame Bird and Mammal Sector.

Berry, W. H., J. H. Scrivner, T. P. O'Farrell, C. E. Harris, T. T. Kato, and P. M. McCue. 1987a. *Sources and Rates of Mortality of the San Joaquin Kit Fox, Naval Petroleum Reserve #1, Kern County, CA, 1980-1986*. Rep. No. EGG 10282-2154 Goleta, CA: EG&G Energy Measurements.

Berry, W. H., T. P. O'Farrell, T. T. Kato, and P. M. McCue. 1987b. *Characteristics of Dens Used by Radiocollared San Joaquin Kit Fox,* Vulpes macrotis mutica*, Naval Petroleum Reserve #1, Kern County, California*. U.S. Department of Energy. Topical Rep. No. EGG 10282-2177. Goleta, CA: EG&G Energy Measurements.

Berry, W. H., W. G. Standley, T. P. O'Farrell, and T. T. Kato. 1992. *Effects of Military-Authorized Activities at Camp Roberts Army National Guard Training Site, California*. Rep. No. EGG 10617-2159. Goleta, CA: EG&G Energy Measurements Group.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

California Department of Fish and Game 2008. California Natural Diversity Data Base (CNDDB). Element occurrence reports for *Vulpes macrotis mutica*. Unpublished cumulative data current to December 1, 2008.

California Department of Fish and Game. 2010. Biogeographic Data Branch. RareFind Version 3.1.0. Government Version - December 1. In. U.S. Fish and Wildlife Service. 2010. *San Joaquin Kit Fox (*Vulpes macrotis mutica*) 5-Year Review: Summary and Evaluation*. Sacramento, CA: Fish and Wildlife Office.

California Department of Fish and Game. 2011. California Natural Diversity Database (CNDDB). Records search of quadrangles in the Plan Area.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area* - Version 3 GIS dataset. Sacramento, CA.

Clark, Jr., H. O., D. A. Smith, B. L. Cypher, and P. A. Kelly. 2003. *Detection Dog Surveys for San Joaquin Kit Foxes in the Northern Range*. San Ramon, CA: Pacific Gas & Electric Company Technical and Ecological Services.

Constable, J. L., B. L. Cypher, S. E. Phillips, and P. A. Kelly. 2009. *Conservation of San Joaquin Foxes in Merced County, California*. California State University, Stanislaus, Endangered Species Recovery Program. Fresno, CA: Bureau of Reclamation.

Cypher, B. L., and J. H. Scrivner. 1992. Coyote Control to Protect Endangered San Joaquin Kit Foxes at the Naval Petroleum Reserves, California. In: J. E. Borrecco and R. E. Marsh (eds.) *Proceedings of the 15th Vertebrate Pest Conference.* University of California, Davis. Pages 42–47.

Cypher, B. L., G. D. Warrick, M. R. M. Otten, T. P. O'Farrell, W. H. Berry, C. E. Harris, T. T. Kato, P. M. McCue, J. H. Scrivner, and B. W. Zoellick. 2000. Population Dynamics of San Joaquin Kit Foxes at the Naval Petroleum Reserves in California. *Wildlife Monographs* 145:1–43.

Duke, R., R. Hopkins, and S. E. Townsend. 1997. *Distribution of the San Joaquin Kit Fox in the North Part of its Range*. H.T. Harvey & Associates. March 13. Project 673.11.

East Contra Costa County Habitat Conservancy. 2006. *East Contra Costa County Habitat Conservation Plan and Natural Community Conservation Plan*. Available: <http://www.co.contra-costa.ca.us/depart/cd/water/HCP/archive/final-hcp-rev/pdfs/hcptitleverso_9-27-06.pdf>. Accessed: December 22, 2011.

EG&G Energy Measurements. 1992. *Endangered Species Program Naval Petroleum Reserves in California - Annual Report FY90*. EGG 10617-2118. Goleta, CA.

Egoscue, H. J. 1956. Preliminary Studies of the Kit Fox in Utah. *Journal of Mammalogy* 37:351–357.

Egoscue, H. J. 1962. Ecology and Life History of the Kit Fox in Tooele County, Utah. *Ecology* 43:481–497.

Grinnell, J., J. S. Dixon, and J. M. Linsdale. 1937. *Fur Bearing Mammals of California, Their Natural History, Systematic Status, and Relations to Man.* Volumes I and II. Berkeley, CA: University of California Press.

Hall, F. A. 1983. *Status of the San Joaquin Kit Fox,* Vulpes macrotis mutica*, at the Bethany Wind Turbine Generating Site, Alameda County, California*. Unpublished report. Sacramento, CA: California Department of Fish and Game.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Jensen, C. C. 1972. *San Joaquin Kit Fox Distribution*. Sacramento, CA: U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Division of Wildlife Services.

Kato, T. T. 1986. *Survey of Potential Habitat for the Endangered San Joaquin kit fox (*Vulpes macrotis mutica*), in the Carrizo Plain, San Luis Obispo County, California*. Report Number EGG 10282-2124 Goleta, CA: EG&G Energy Measurements.

Knapp, D. K. 1978. *Effects of Agricultural Development in Kern County, California, on the San Joaquin Kit Fox in 1977*. Nongame Wildlife Investigations. Unpublished report. Sacramento, CA: California Department of Fish and Game.

Koopman, M. E., B. L. Cypher, and J. H. Scrivner. 2000. Dispersal Patterns of San Joaquin Kit Foxes (*Vulpes macrotis mutica*). *Journal of Mammalogy* 81(1):213–222.

Laughrin, L. 1970. *San Joaquin Kit Fox: Its Distribution and Abundance*. Administrative Report No. 70-2. Sacramento, CA: California Department of Fish and Game, Wildlife Management Branch.

McCue, P. M., T. Kato, M. L. Sauls, and T. P. O'Farrell. 1981. *Inventory of San Joaquin Kit Fox on Land Proposed as Phase II, Kesterson Reservoir, Merced County, California*. Rep. No. EGG 1183-2426. Goleta, CA: EG&G Energy Measurements.

McGrew, J. C. 1979. *Vulpes macrotis*. *Mammalian Species* 123:1–6.

Morrell, S. H. 1972. Life History of the San Joaquin Kit Fox. *California Fish and Game* 58(3):162–174.

Morrell, S. H. 1975. *San Joaquin Kit Fox Distribution and Abundance in 1975*. Administrative Report No. 75-3. Sacramento, CA: Wildlife Management Branch, California Department of Fish and Game.

O'Farrell, T. P., W. H. Berry, and G. D. Warrick. 1987. *Distribution and Status of the Endangered San Joaquin Kit Fox,* Vulpes macrotis mutica*, on Fort Hunter Liggett and Camp Roberts, California*. Rep. No. EGG 10282-2194. Goleta, CA: EG&G Energy Measurements.

O'Farrell, T. P., and L. Gilbertson. 1979. Ecology of the Desert Kit Fox, *Vulpes macrotis arsipus*, in the Mojave Desert of Southern California. *Bulletin of the Southern California Academy of Sciences* 85:1–15.

O'Farrell, T. P., T. T. Kato, P. M. McCue, and M. L. Sauls. 1980. *Inventory of San Joaquin Kit Fox on USBLM Lands in Southern and Southwestern San Joaquin Valley—Final Report*. Rep. No. EGG 1183-2400. Goleta, CA: EG&G Energy Measurements.

O'Farrell, T. P., and P. M. McCue. 1981. *Inventory of San Joaquin Kit Fox on USBLM Lands in the Western San Joaquin Valley—Final Report*. Rep. No. EGG 1183-2416. Goleta, CA: EG&G Energy Measurements.

O'Neal, G. T., J. T. Flinders, and W. P. Clary. 1992. Behavioral Ecology of the Nevada Kit Fox (*Vulpes macrotis nevadensis*) on a Managed Desert Rangeland. *Current Mammalogy* 1:443–481.

Orloff, S. G., F. Hall, and L. Spiegel. 1986. Distribution and Habitat Requirements of the San Joaquin kit fox in the Northern Extreme of Their Range. *Transactions of the Western Section of The Wildlife Society* 22:60–70.

Paveglio, F. L., and S. D. Clifton. 1988. *Selenium Accumulation by San Joaquin Kit Foxes and Coyotes in the Kesterson National Wildlife Refuge Area—Draft*. Unpublished report. Los Banos, CA: U.S. Fish and Wildlife Service.

San Joaquin Council of Governments. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan.* Available: <http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm>. Accessed: December 22, 2011.

Scrivner, J. H., T. P. O'Farrell, and T. T. Kato. 1987b. *Dispersal of San Joaquin Kit Foxes,* Vulpes macrotis mutica*, on Naval Petroleum Reserve #1, Kern County, California*. Rep. No. EGG 10282-2190. Goleta, CA: EG&G Energy Measurements.

Scrivner, J. H., T. P. O'Farrell, T. T. Kato, and M. K. Johnson. 1987a. *Diet of the San Joaquin Kit Fox,* Vulpes macrotis mutica*, on Naval Petroleum Reserve #1, Kern County, California, 1980-1984*. Rep. No. EGG 10282-2168. Goleta, CA: EG&G Energy Measurements.

Spiegel, L. K. and M. Bradbury. 1992. Home Range Characteristics of the San Joaquin Kit Fox in Western Kern County, California. *Transactions of the Western Section of The Wildlife Society* 28:83–92.

Standley, W. G., W. J. Berry, T. P. O'Farrell, and T. T. Kato. 1992. *Mortality of San Joaquin Kit Fox (*Vulpes macrotis mutica*) at Camp Roberts Army National Guard Training Site, California*. Rep. No. EGG 10617-2157. Goleta, CA: EG&G Energy Measurements.

Swick, C.D. 1973. *Determination of San Joaquin Kit Fox Range in Contra Costa, Alameda, San Joaquin, and Tulare Counties, 1973*. California Department of Fish and Game, Sacramento, Special Wildlife Investigations.

TAIC. 2008. *Yolo County Regional Vegetation.* July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program.* Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

U.S. Fish and Wildlife Service. 1983. *San Joaquin Kit Fox Recovery Plan*. Portland, OR.

U.S. Fish and Wildlife Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Region 1, Portland, OR.

U.S. Fish and Wildlife Service. 1999. *San Joaquin Kit Fox Survey Protocol for the Northern Range*. Sacramento Fish and Wildlife Office, CA.

U.S. Fish and Wildlife Service. 2010. *San Joaquin Kit Fox (*Vulpes macrotis mutica*) 5-Year Review: Summary and Evaluation*. Sacramento Fish and Wildlife Office, CA.

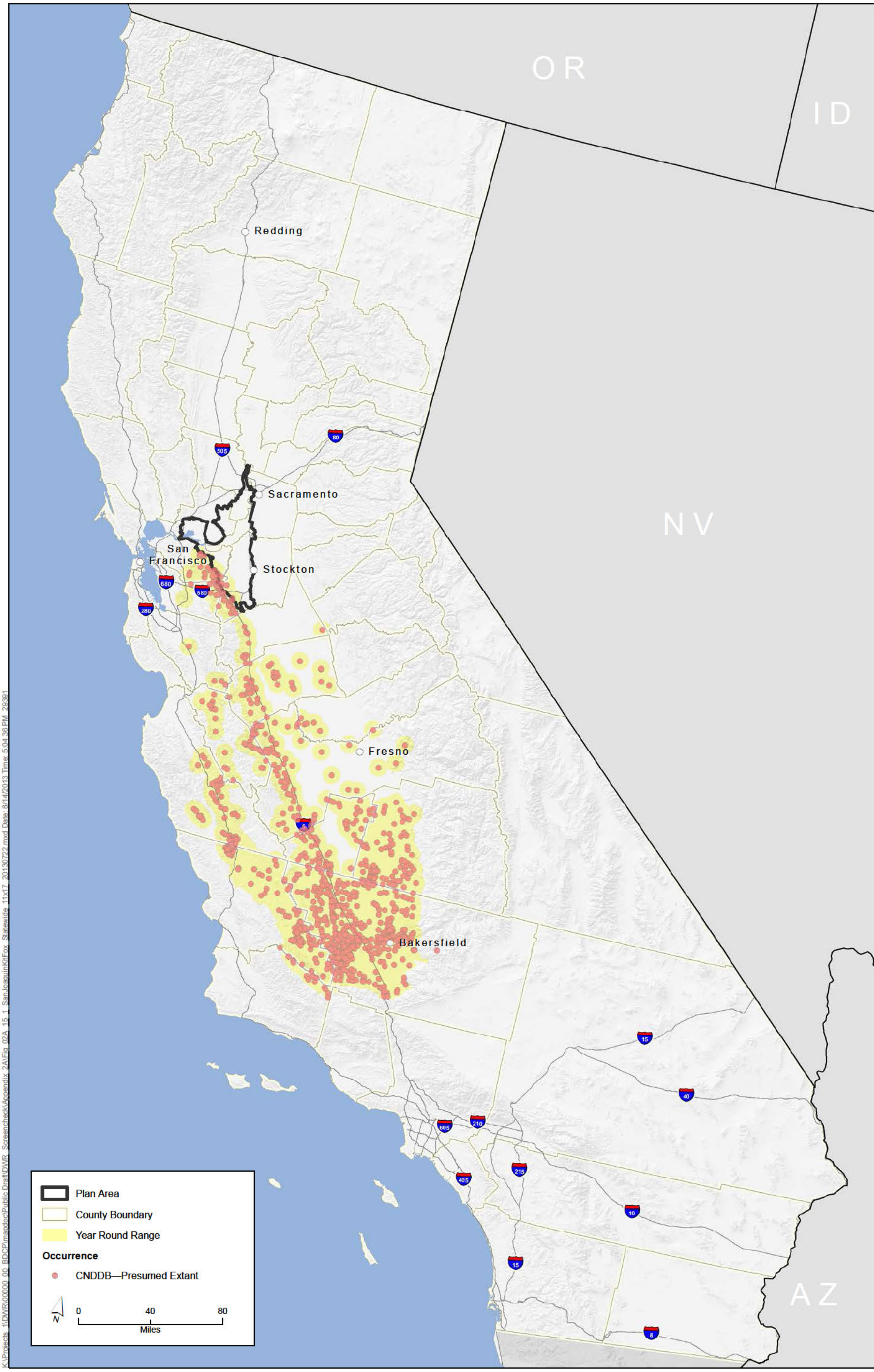
White, P. J., and R. A. Garrott. 1999. Population Dynamics of Kit Foxes. *Canadian Journal of Zoology* 77(3):486–493.

White, P. J., and K. Ralls. 1993. Reproduction and Spacing Patterns of Kit Foxes Relative to Changing Prey Availability. *Journal of Wildlife Management* 57:861–867.

White, P. J., K. Ralls, and R. A. Garrott. 1994. Coyote-Kit Fox Spatial Interactions based on Radio-Telemetry. *Canadian Journal of Zoology* 72:1831–1836.

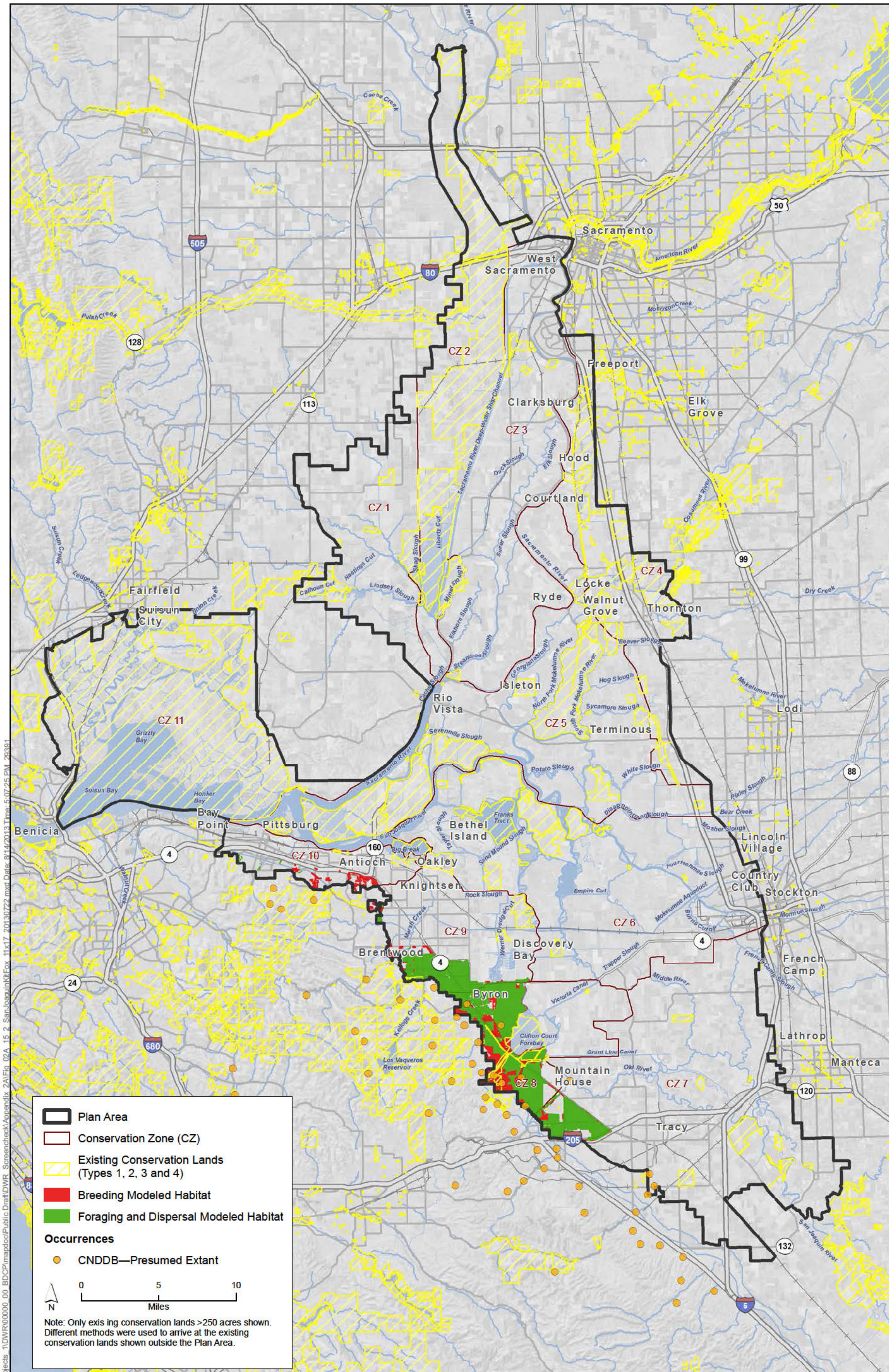
Zoellick, B. W., T. P. O'Farrell, and T. T. Kato. 1987b. *Movements and Home Range of San Joaquin Kit Foxes on the Naval Petroleum Reserves, Kern County, California*. EGG 10282-2184. Goleta, CA: EG&G Energy Measurements.

Zoellick, B. W., T. P. O'Farrell, P. M. McCue, C. E. Harris, and T. T. Kato. 1987a. *Reproduction of the San Joaquin Kit Fox on Naval Petroleum Reserve #1, Elk Hills, California, 1980–1985*. EGG 10282-2144. Goleta, CA: EG&G Energy Measurements.



GIS Data Sources: Occurrences, CNDDB June 2013;
Range, CDFG WHR 2008.

Figure 2A.15-1
San Joaquin Kit Fox Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013.

Figure 2A.15-2
San Joaquin Kit Fox Habitat Model and Recorded Occurrences

Appendix 2A.16
Suisun Shrew (*Sorex ornatus sinuosus*)

2A.16.1 Legal Status

The Suisun shrew (*Sorex ornatus sinuosus*) is a California Department of Fish and Wildlife (CDFW) Species of Special Concern (Williams 1986). The Suisun shrew has no federal regulatory status.

2A.16.2 Species Distribution and Status

2A.16.2.1 Range and Status

The Suisun shrew, one of several subspecies of the ornate shrew, is endemic to the tidal saline and brackish salt marshes of Solano, Napa, and eastern Sonoma Counties. While the historical range of the Suisun shrew is unknown, its current range was defined by Brown and Rudd (1981), who separated it from the ornate shrew (*S. o. californicus*), which is found west of Sonoma Creek and Tubbs Island. The species' current distribution is restricted to isolated remnants of natural tidal and brackish marshes along the northern borders of San Pablo and Suisun Bays, including a number of locations in Suisun Marsh, Southampton Marsh, and the Napa Marshes, and as far east as Grizzly Island, and as far west as Sonoma Creek and Tubbs Island (Figure 2A.16-1) (Brown and Rudd 1981; Western Ecological Services 1986).

Western Ecological Services (1986) identified nine additional sites with a high probability of supporting Suisun shrew populations, including Skaggs Island, Appleby Bay/Coon Island, Steamboat Slough, Vallejo, Morrow Island, Cordelia Slough (Rush Ranch, Peytonia Slough), Hammond Island, Simmons/Wheeler Islands, and Collinsville.

Limited information exists on population densities. Newman (1970) estimated densities of 111 shrews per hectare (2.5 acres) in high-value habitat. Hays (1990) estimated densities from 10 to 100 shrews per acre at Rush Ranch in Solano County, depending on the presence or absence of large aggregations (one male with several females) of shrews. Hays (1990) found that shrews often occur in aggregations consisting of one dominant male and several females. Individuals, mainly subdominant males, were dispersed between these aggregations and returned in early spring to compete with resident males during the breeding season. Dispersing males may also occupy the deeper tidal marsh areas that were not considered in Hays (1990) (LSA Associates 2007).

2A.16.2.2 Distribution and Status in the Plan Area

The only reported occurrences of Suisun shrew in the Plan Area are from the Suisun Marsh Restoration Opportunity Area (ROA) (Figure 2A.16-2), where there is a substantial amount of suitable habitat west of Sherman Island and throughout Suisun Marsh (Figure 2A.16-2). With the possible exception of portions of Kimball and Sherman Islands on the western edge of the Plan Area, there is little available tidal marsh habitat in the Sacramento–San Joaquin River (Delta) with potential to support the Suisun shrew.

2A.16.3 Habitat Requirements and Special Considerations

Suisun shrews inhabit tidal marshes characterized by pickleweed (*Salicornia pacifica,* formerly *S. virginica*), Pacific cordgrass (*Spartina foliosa*), and gumplant (*Grindelia* spp*.*). The species also occurs in brackish tidal marshes dominated by bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.) (Rudd 1955). Rudd (1955) also noted that plant community structure, rather than species composition, was the primary factor determining occupancy. The species appears to prefer dense, low-lying vegetation where invertebrates are abundant. However, suitability apparently decreases with increased inundation frequency. Williams (1983) suggests the importance of marsh habitat that is not regularly flooded and is 6 to 8 feet (2 to 2.5 meters) above sea level. Adjacent upland habitats are also important in providing cover and sources of food particularly during prolonged flooding of marshes and dikes (Williams 1983). Shellhammer (pers. comm.) stated that maintenance of an ungrazed upland band along the tidal wetland edge was vital. Driftwood and other litter above the mean high tide line may also be important for nesting and foraging sites (MacKay 2000).

Hays (1990) determined that shrews alter their microhabitat use seasonally. During the fall when the weather was hot and tides high, he noted that shrews were typically found under dense layers of matted plant material, beneath large clumps of succulents such as pickleweed and marsh jaumea (*Jaumea carnosa)*. During winter and early spring when tides were low and succulents above the line of frequent flooding died back, shrews were seen foraging mostly among arrowgrass (*Triglochin maritima*). Hays and Lidicker (2000) found shrew densities to be highest (at Rush Ranch) along the marsh/grassland ectone, and that subadult males largely overwintered below high tide levels.

Once abundant around San Pablo and Suisun Bays, the availability of suitable tidal marsh habitat for Suisun shrew and other tidal marsh species has declined dramatically. Western Ecological Services (1986) estimated that natural tidal marsh in this area has decreased from 100,000 acres (40,469 hectares) to around 12,000 acres (4,856 hectares). Most of the remaining tidal marsh habitat occurs in small, isolated units, the largest of these in Suisun Marsh.

2A.16.4 Life History

2A.16.4.1 Description

The Suisun shrew is a small (98 to 106 millimeters [3.9 to 4.2 inches]), dark mammal with a long, pointed nose, an elongate, fragile, and relatively narrow skull, and a 37- to 41-millimeter (1.5- to 1.6-inch) scaly tail (Engles 1965; Rudd 1955). It is distinguished from other shrews by its darker pelage (fur) and localization to tidal marshes in and near San Pablo and Suisun Bays.

2A.16.4.2 Activity

With their high metabolic rate, Suisun shrews spend much of their time foraging. Genoud and Vogel (1989) reported that between 60 and 200% of their body mass is eaten daily; during peak lactation, females can consume up to 300% of body mass. The also exhibit a Dehnel Effect whereby they lose 30 to 40% of their adult body mass after breeding (Hays and Lidicker 2000), possibly in response to some yet unidentified resource limitation.

They access their territories by constructing shallow subterranean tunnels (Hays 1990) or share burrows and runways with harvest mice (*Reithrodontomys* spp.) and meadow mice (*Microtus* spp.).

Males are apparently more subject to local movements than females. While young females typically remain in their natal area, subdominant males intersperse within the aggregations of single dominant males and several females. Hays and Lidicker (2000) found that subadult males overwintered in deeper tidal marsh areas rather than in upland habitats.

As with all other *Sorex* species, the life span of shrews is short, with 16 months being considered the maximum age (Rudd 1955); thus, most individuals do not live to breed in a second season. Most die shortly after the breeding season, with females generally living slightly longer than males.

2A.16.4.3 Reproduction

In early March, males reach sexual maturity and begin to migrate toward population foci. The harem-structured population foci are reestablished within a narrow band of preferred habitat. Breeding occurs from April through October, with the reproductive peak in May (Newman and Rudd 1978). After breeding occurs, each population focus is left with one dominant male, several breeding females, and several immature females (Hays 1990).

Shrews construct domed, cup-like nests composed usually of dead plant material. Nests are directly on the soil surface below driftwood or wooden planks and are situated above the high tide line (Western Ecological Services 1986). Gestation is approximately 3 weeks, and two to nine young are produced. Another 3 weeks of altricial dependency occurs prior to weaning. Suisun shrews are capable of producing two litters in 1 year, but this is apparently rare (Rudd 1955).

2A.16.4.4 Diet

The diet of Suisun shrews consists almost entirely of small animal prey that are the most common in the tidal marsh, including amphipods, isopods, and other invertebrate species (Hays 1990).

2A.16.5 Threats and Stressors

2A.16.5.1 Habitat Degradation and Fragmentation

Degradation of tidal marsh habitats continues to be the most significant threat to Suisun shrews and other tidal marsh species. Tidal marshes have been reduced by 84% since historical times (Dedrick 1989). The fragmentation of suitable habitats has isolated populations and reduced dispersal opportunities. While the loss of tidal marsh habitat through filling and diking has largely been curtailed, other current factors may be associated with declining populations, including the management of marshes in and around Suisun Marsh, which may favor the growth of bulrush (LSA Associates 2007). Contaminants accumulated in the food chain, such as polychlorinated biphenyls (PCBs), heavy metals, and pesticides may also degrade habitat conditions and threaten Suisun shrews (Western Ecological Services 1986). Once in the food chain, these pollutants can be consumed by the species. Depending on the concentration and degree of exposure, contaminants may be harmful as each contaminant has different characteristics that can affect wildlife in different ways.

2A.16.6 Relevant Conservation Efforts

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the Suisun shrew as a Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program has established a goal to recover the species. Successful recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to development and issues related to water quality within its boundaries. The Suisun Marsh Program (California Department of Water Resources 2012) summarizes the major agreements, management plans, and legislation that have directed management of Suisun Marsh since the mid-1970s. These efforts focus on the preservation of diked wetlands and restoration of tidal marsh habitats.

2A.16.6.1 The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974)

The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

2A.16.6.2 Suisun Marsh Protection Plan (1976)

This plan was developed by the Bay Conservation and Development Commission and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the State of California purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

2A.16.6.3 The Suisun Marsh Protection Act (1977)

This bill adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the Bay Conservation and Development Commission as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land in Suisun Marsh, when no longer managed for waterfowl, should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

2A.16.6.4 State Water Resources Control Board Water Rights Decision 1485 (1978)

The State Water Resources Control Board (State Water Board) adopted the Water Quality Control Plan for the Sacramento–San Joaquin Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the CDFW recommendations, which were based on the following elements:

- The relative value of marsh plants as food for ducks.
- The influence of soil salinity and other factors on distribution and growth of marsh plants.
- The relationships between channel water salinity and soil salinity.

CDFW concluded that improved management practices, improved drainage, water control facilities, and adequate water quality were needed to achieve desired soil salinity conditions for waterfowl food plants.

2A.16.6.5 Plan of Protection for Suisun Marsh (1984)

The California Department of Water Resources (DWR) and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) developed and began implementing the Plan of Protection in accordance with Water Rights Decision 1485. The implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant State Water Project (SWP)/Central Valley Project (CVP) storage releases estimated as much as 2 million acre-feet in dry or critical water years. The six-phase plan was the programmatic blue print (required by the State Water Board and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

2A.16.6.6 Suisun Marsh Preservation Agreement (1987)

This contractual agreement between DWR, Reclamation, CDFW, and Suisun Resource Conservation District contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP/CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and Reclamation to meet salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in Suisun Marsh.

2A.16.6.7 Bay-Delta Accord (1994)

On December 15, 1994, federal and state agencies, working with agricultural, environmental, and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow.
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life.
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon.
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

2A.16.6.8 State Water Resources Control Board Water Quality Control Plan (1995 to 1998)

In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May 1995, the State Water Board modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the Suisun Marsh Preservation Agreement agreed could be mitigated by more active water control by landowners.

2A.16.6.9 State Water Resources Control Board Water Rights Decision 1641 (1999)

The State Water Board issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to Suisun Marsh. DWR proposed that the State Water Board adopt the Amendment Three actions for Suisun Marsh in this decision. However, the State Water Board was unable to adopt Amendment Three actions because the Section 7 consultation with the U.S. Fish and Wildlife Service (USFWS) had not concluded. However, the State Water Board did relieve Reclamation and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

2A.16.6.10 CALFED Multi-Species Conservation Strategy and Record of Decision (2000)

In August 2000, the Programmatic Record of Decision for the CALFED Bay-Delta Program was signed by 13 federal and state agencies with management and regulatory responsibilities in the San Francisco Bay estuary. Based on the analysis in the multispecies conservation strategy and the final programmatic environmental impact statement/environmental impact report, the CALFED agencies fulfilled the regulatory requirement for programmatic evaluation of the CALFED program.

2A.16.6.11 Suisun Marsh Charter Implementation Plan (2001)

The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in Suisun Marsh.

2A.16.6.12 Habitat Management, Preservation, and Restoration Plan (2010)

The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that would balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement, and other management and restoration programs in Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based on voluntary participation by private landowners.

In addition, several facilities have been constructed in Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat.

- Roaring River Distribution System (1979 to 1980)
- Morrow Island Distribution System (1979 to 1980)
- Goodyear Slough Outfall (1979 to 1980)
- Suisun Marsh Salinity Control Gates (1988)
- Cygnus and Lower Joice Facilities (1991)

Several tidal marsh restoration projects are also planned or being implemented within the range of the Suisun shrew. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge, National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, CDFW, and the City of San Jose include the following.

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay.
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward, to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract, located just north of the west approach to the Dumbarton Bridge from the Port of Oakland.

The Suisun shrew is also proposed for coverage under the *Solano Multispecies Habitat Conservation Plan* (Solano County Water Agency 2009).

2A.16.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.16.7.1 GIS Model Data Sources

The Suisun shrew model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005), and land use survey of the Delta and Suisun Marsh area - version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable Suisun shrew habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.16.7.2 Habitat Model Description

Modeled Suisun shrew habitat consists of all *Salicornia*-dominated natural wetlands and certain *Schoenoplectus* and *Typha* communities found within Suisun Marsh only (Figure 2A.16-2). For purposes of this model, a geographic information system (GIS) constraint layer was developed to limit the potential range of the Suisun shrew to suitable habitats in Suisun Marsh, defined as Suisun Marsh and the western portion of the legal Delta toward the western tip of Sherman Island. Low marsh dominated by *Schoenoplectus acutus* and *S. californicus* and upland transitional zones within 150 feet of the tidal wetland edge were classified separately as secondary habitat because they are used seasonally (Hays and Lidicker 2000). All managed wetlands were excluded from the primary habitat model but were included in the secondary model for the below-listed vegetation types when within 150 feet of the primary habitat types. Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP GIS vegetation data layer. For selected vegetation to qualify as habitat, the habitat polygons were required to meet a minimum mapping unit of 1 acre.

Suisun shrew habitat in Suisun Marsh consists of the following vegetation types when they do not occur in the managed wetland natural community from the BDCP composite vegetation layer.

- Primary habitat
    - *Schoenoplectus americanus* (generic)
    - *Schoenoplectus americanus/Lepidium*
    - *Schoenoplectus americanus/Potentilla*
    - *Schoenoplectus maritimus*
    - *Schoenoplectus maritimus/Salicornia*
    - *Typha angustifolia/Distichlis*
    - *Typha angustifolia/S. americanus*
    - *Typha* species (generic)
    - *Schoenoplectus americanus/S. californicus–S. acutus*
    - *Schoenoplectus maritimus/Sesuvium*
    - *Typha angustifolia*/Phragmites
    - *Typha angustifolia/Polygonum–Xanthium–Echinochloa*
    - *Distichlis/Salicornia*

- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia*/*Atriplex*
- *Salicornia*/*Cotula*
- *Salicornia*/annual grasses
- *Salicornia*/*Crypsis*
- *Salicornia*/*Polygonum*–*Xanthium*–*Echinochloa*
- *Salicornia*/*Sesuvium*

Secondary habitat consists of secondary wetland and upland transitional zones with the following vegetation types from the BDCP composite vegetation layer. Secondary wetland types can occur within managed wetland or tidal brackish emergent wetland communities while the secondary upland transitional zones must be within 150 feet of primary habitat.

- Secondary wetland
  - *Schoenoplectus* (*californicus* or *acutus*)–*Typha* spp.
  - *Schoenoplectus californicus*/*S. acutus*
- Upland
  - Annual grassland (generic)
  - Annual grasses/weeds (generic)
  - *Atriplex lentiformis*
  - *Atriplex triangularis*
  - *Atriplex*/annual grasses
  - *Atriplex*/*Distichlis*
  - *Atriplex*/*Schoenoplectus maritimus*
  - *Atriplex*/*Sesuvium*
  - *Baccharis*/annual grasses
  - *Bromus* spp./*Hordeum*
  - *Hordeum*/*Lolium*
  - Perennial grasses

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. In the new analysis areas, the following natural communities (and vegetation alliances, where the information was available) were assumed to provide Suisun shrew habitat.

- Primary habitat: tidal brackish emergent wetland

- Upland transitional zones within 150 feet of primary habitat: grasslands

2A.16.7.3 Assumptions

- **Assumption**: Suisun shrew habitat in the Plan Area is geographically constrained to Suisun Marsh.

  Rationale: Historical and current records of this species indicate that its known distribution includes Suisun Marsh and extends eastward to approximately Grizzly Island.

- **Assumption:** Suisun shrew habitat is restricted to the vegetation types described in Section 2A.16.7.2, *Habitat Model Description*.

  Rationale: Suisun shrews are restricted to pickleweed and cordgrass (*Spartina foliosa*)-dominated saline tidal marshes and *Schoenoplectus*/*Typha*-dominated brackish marshes (Rudd 1955; Williams 1986). Low marsh dominated by *Schoenoplectus acutus* and *S. californicus* and upland transitional zones within 150 feet of the tidal wetland edge are classified separately as secondary habitat because they are used seasonally (Hays and Lidicker 2000). Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, data regarding the effects of these factors on potential occupancy for the Suisun shrew are insufficient. Thus, potential habitat for the Suisun shrew is not further restricted in this habitat model on the basis of these factors. Therefore, the model likely overestimates the extent of potentially occupied tidal marsh habitat.

2A.16.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species, and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the Suisun shrew as a Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program has established a goal to recover the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

2A.16.9 References Cited

2A.16.9.1 Literature Cited

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

Brown, R. J. and R. L. Rudd. 1981. Chromosomal Comparisons with the *Sorex ornatus-S. vagrans* Complex. *Wassman Journal of Biology* 39:30–35.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area.* Version 3 GIS dataset. California Department of Water Resources, Sacramento, CA.

California Department of Water Resources. 2012. *Suisun Marsh Program.* Last revised: December 22, 2009. Available: <http://www.water.ca.gov/suisun/program/>. Accessed: June 12, 2012.

Dedrick, K. G. 1989. San Francisco Bay Tidal Marshland Acreages: Recent and Historic Values. In: *Proceedings of the 6th Symposium in Coastal and Ocean Management (Coastal Zone 1989).* American Society of Engineers. Pages 383–398.

Engles, L. G. 1965. *Mammals of the Pacific States.* Stanford, CA: Stanford University Press.

Genoud, M. and P. Vogel. 1989. Energy Requirements during Reproduction and Reproductive Effort in Shrews (*Soricidae*). *Journal of Zoology* 220:41–60.

Hays, W. S. 1990. *Population Ecology of Ornate Shrews,* Sorex ornatus*.* MA dissertation. University of California, Berkeley.

Hays, W. S. and W. S. Lidicker, Jr. 2000. Winter Aggregations, Dehnel Effect, and Habitat Relations in the Suisun Shrew, *Sorex ornatus sinuosus*. *Acta Theriologica* 45:433–442.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

LSA Associates. 2007. Suisun Shrew. Working draft 2.2, *Solano County Habitat Conservation Plan, Natural Community and Species Accounts.* Elmira, CA: Solano County Water Agency.

MacKay, K. 2000. Suisun Shrew. In: P.R. Olofson (ed.). Goals Project 2000. *Baylands Ecosystem and Community Profiles: Life Histories and Environmental Requirements of Key Plants, Fish, and Wildlife.* Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. Oakland, CA: San Francisco Bay Regional Water Quality Control Board. Pages 233–236.

Newman, J. R. 1970. *Energy Flow of a Secondary Consumer (*Sorex sinuosus*) in a Salt Marsh Community*. Dissertation Abstract, 32B: 883.

Newman, J. R. and R. L. Rudd. 1978. Minimum and Maximum Metabolic Rates of *Sorex sinuosus*. A*cta Theriologica.* 23 (23):371–380.

Rudd, R.L. 1955. Age, Sex and Weight Comparisons in Three Species of Shrews. *Journal of Mammology* 36:323–338.

Solano County Water Agency. 2009. *Solano Multispecies Habitat Conservation Plan.* Final Administrative Draft. June 15. Available: <http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx>. Accessed: December 22, 2011.

TAIC. 2008. Yolo County Regional Vegetation. July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program.* USDA Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

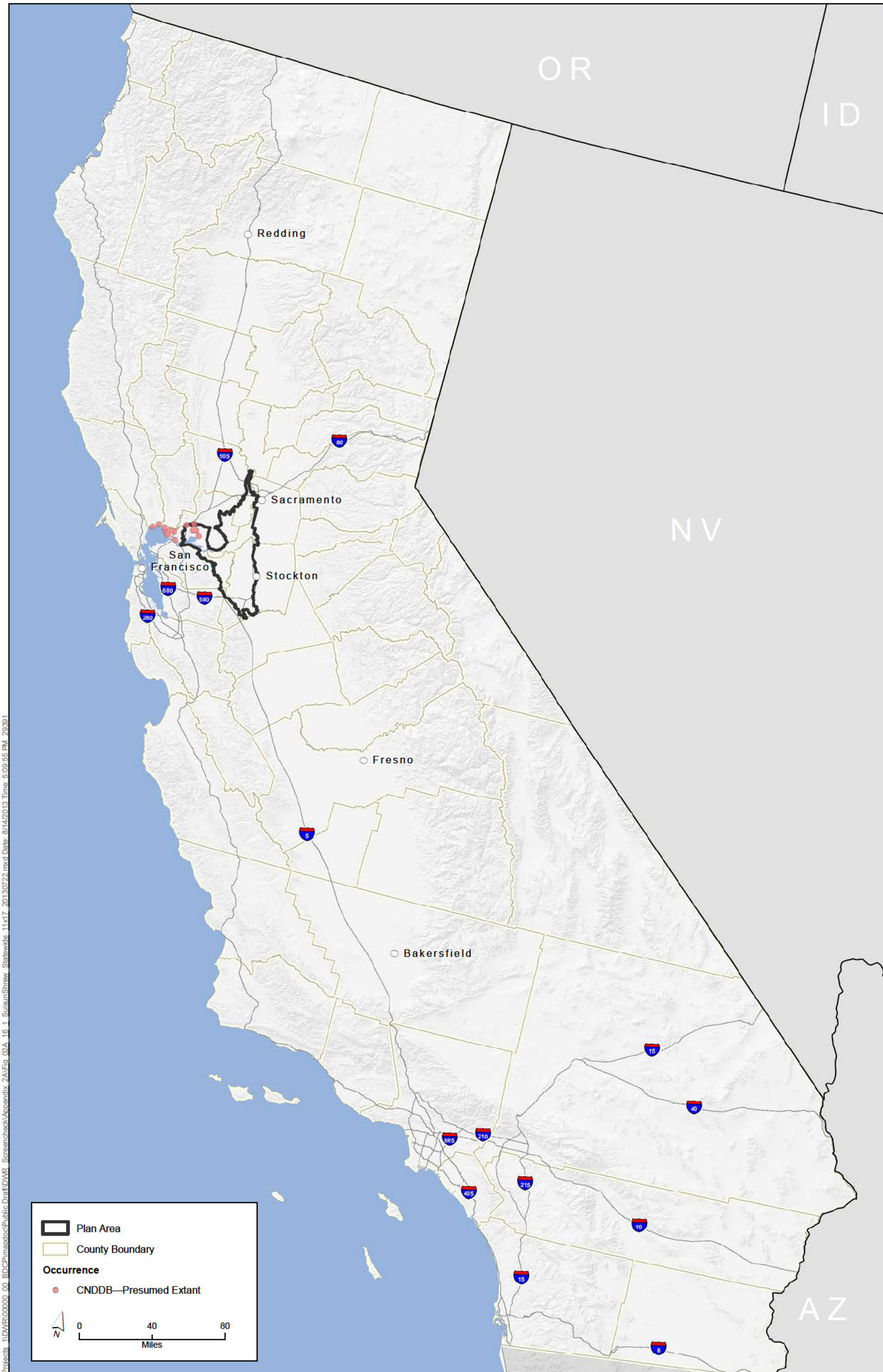
Western Ecological Services. 1986. *A Review of the Population Status of the Suisun Shrew* (Sorex ornatus sinuosus). Final report. Sacramento, CA: U.S. Fish and Wildlife Service.

Williams, D. F. 1983. *Population Surveys of the Santa Catalina, San Bernardino, and Suisun Shrews.* Sacramento, CA: U.S. Fish and Wildlife Service, Endangered Species Office.

Williams, D. F. 1986. *Mammalian Species of Special Concern in California*. Administrative Report 86-1:1-112. Wildlife Management Division, California Department of Fish and Game.

2A.16.9.2 Personal Communications

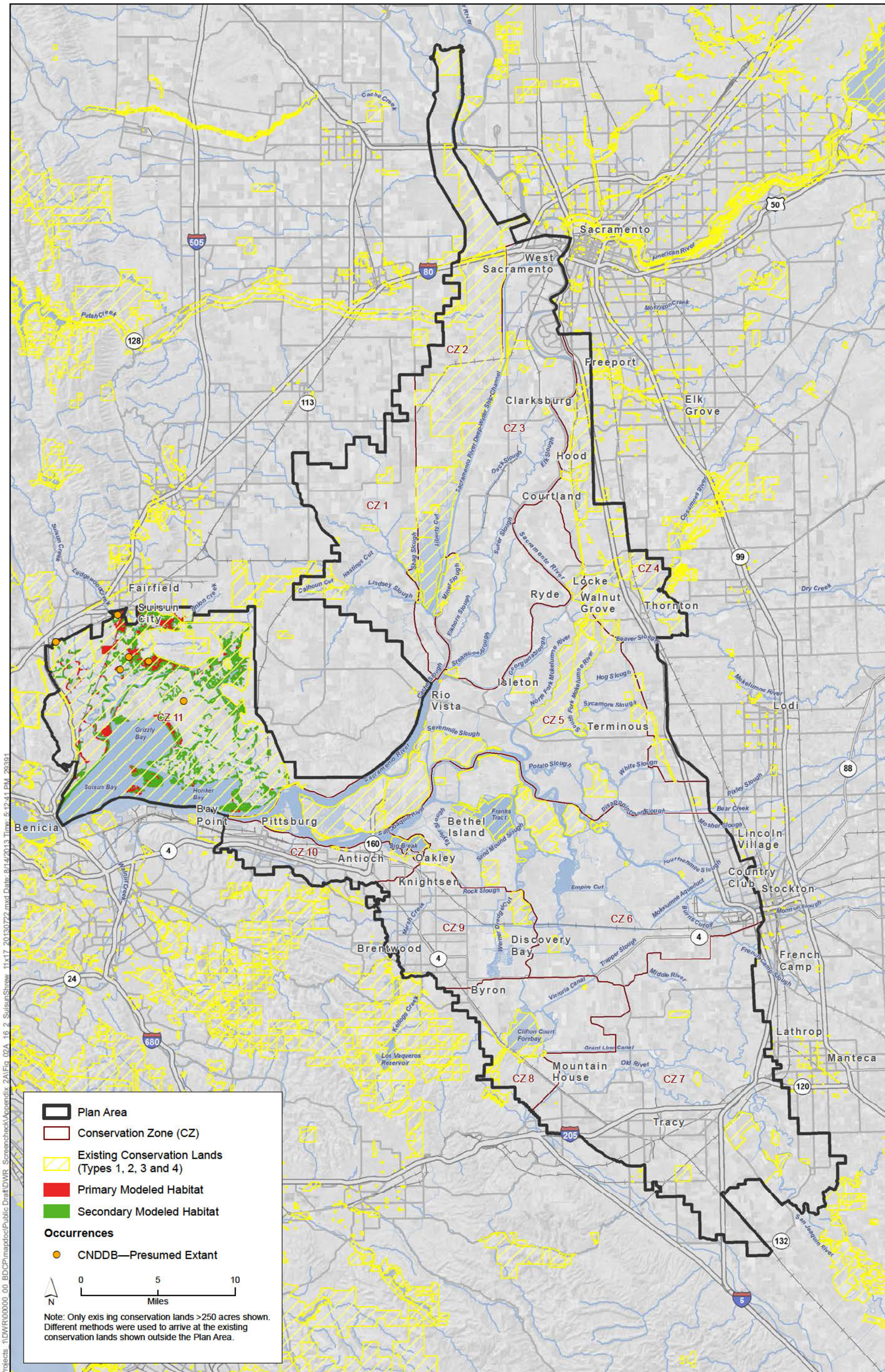
Shellhammer, Howard. Professor Emeritus, Department of Biological Sciences, San Jose State University. Written comments on earlier draft.



K:\Projects 1\DWR\00000 00 BDCP\mapdoc\Public Draft\DWR Screencheck\Appendix 2A\Fig 02A 16 1 SuisunShrew Statewide 11x17 20130722.mxd Date: 8/14/2013 Time: 5:09:55 PM 29391

GIS Data Sources: Occurrences, CNDDB June 2013.

Figure 2A.16-1
Suisun Shrew Statewide Range and Recorded Occurrences



K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix_2A\Fig_02A_16_2_SuisunShrew_11x17_20130722.mxd Date: 8/14/2013 Time: 5:12:41 PM 29391

GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013.

Figure 2A.16-2
Suisun Shrew Habitat Model and Recorded Occurrences

Appendix 2A.17
California Black Rail
(*Laterallus jamaicensis coturniculus*)

2A.17.1 Legal Status

The California black rail (*Laterallus jamaicensis coturniculus*) is listed as a threatened species under the California Endangered Species Act. It was listed by the California Fish and Game Commission in 1971. It is also designated as a Fully Protected species in California.

Black rail has no federal regulatory status; however, it is on the U.S. Fish and Wildlife Service (USFWS) Region 1 list of Birds of Conservation Concern, species that USFWS considers potential candidates for federal listing.

2A.17.2 Species Distribution and Status

2A.17.2.1 Range and Status

The California black rail is one of two subspecies of black rail that inhabit North America. The range of the California black rail extends throughout portions of California and Arizona. The eastern black rail (*Laterallus jamaicensis jamaicensis*) is found along the eastern seaboard, along the Gulf Coast, and rarely at inland sites in the Midwest (Eddleman et al. 1994).

The historical range of the California black rail extended from the San Francisco Bay, throughout the Sacramento–San Joaquin River Delta (Delta), along the coast to northern Baja California, and at other southern California locales such as the Salton Sea and the lower Colorado River. Early 20th century breeding records indicate that black rail populations existed on coastal marshes in San Diego, Los Angeles, and Santa Barbara Counties. Loss of tidal marsh habitat has resulted in the extirpation of populations from much of its coastal range, particularly in Southern California and much of the San Francisco Bay since the 1950s (Manolis 1978; Garrett and Dunn 1981 in California Department of Water Resources 2001).

Figure 2A.17-1 illustrates documented occurrences of California black rail in California. The species persists in remaining tidal marshes in the northern San Francisco Bay estuary, Tomales Bay, Bolinas Lagoon, the Delta, Morro Bay, the Salton Sea, and the lower Colorado River (Manolis 1978; Evens et al. 1991; Eddleman et al. 1994). Several small, isolated populations also still exist in southeastern California and western Arizona (Evens et al. 1991). The species has also been found more recently at several inland freshwater sites in the Sierra Nevada foothills in Butte, Yuba, and Nevada Counties (Aigner et al. 1995; Tecklin 1999), and most recently in Clover Valley (City of Rocklin) in southern Placer County (California Black Rail Project 2006). Additional detections have been made recently at the Cosumnes River Preserve in South Sacramento County and Bidwell Park in Chico, Butte County (Trochet 1999; Kemper and Manolis 1999).

Additional recent unconfirmed sightings from rice fields in the Butte Sink and Sutter County suggest that there may be downslope movement from the foothill breeding population.

Until 1994, the black rail was unknown from the Sacramento Valley except for a single winter record at the California Department of Fish and Wildlife (CDFW) Gray Lodge Wildlife Area in Butte County. In 1994, a population of the rail was found occupying a freshwater marsh at the University of California's Sierra Field Station in Yuba County (Aigner et al. 1995). Further examination revealed that the species could be breeding at four separate freshwater marsh ponds within approximately 3.7 miles (6 kilometers) of each other. As a result, CDFW provided funding for a more regional survey effort that resulted in additional occurrences in Butte, Yuba, and Nevada Counties (Tecklin 1999). Since then, the University of California has continued with the California Black Rail Project, which strives to locate additional subpopulations in their Sierra Nevada foothill study area and examines how each of these isolated subpopulations is functioning as a metapopulation.

Since 2002, this ongoing study annually samples approximately 200 wetlands (California Black Rail Project 2005). Wetland occupancy has shown a downward trend since 2005 when greater than 60% of wetlands were occupied to less than 40% occupied by 2010 (California Black Rail Project 2011). These populations, and presumably others that remain undetected in the region, are considered to be year-round residents. Given the geographic extent of this metapopulation and the consistently high occupancy rate detected over the last 5 years, it is likely that additional subpopulations occur elsewhere in the Sacramento Valley and Sierra Nevada foothills.

Declines in populations of the black rail in California are a result of habitat loss and degradation along with an increase in exotic predators such as black rats and red foxes (Evens et al. 1991). However, because there were no estimates of historical population levels, the extent of population declines is not fully understood. Evens et al. (1991) examined relative abundance of rails at various locations within the species' range and determined that more than 80% of the remaining population is confined to the northern reaches of the San Francisco Bay estuary. They also determined that the species was subject to continuing and ongoing population decline resulting from habitat loss and/or degradation.

2A.17.2.2 Distribution and Status in the Plan Area

Within the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) region, California black rail populations are restricted primarily to the remaining tidal marshlands of the northern San Francisco Bay estuary, the vicinity of Suisun and Napa Marshes, and the midchannel islands in the Delta. In Suisun Marsh, a high abundance of black rails has been found at east Mallard Island and moderate abundances at South Joice Island, Pacheco Creek, East Peyton Slough, Cutoff Island, Peytonia Slough, and Southampton Bay (Spautz et al. 2005). California black rails have also been recorded in Nurse Slough and on Ryer and Row islands in Suisun Bay (California Department of Fish and Game 2011). CDFW conducted surveys in Suisun Marsh in 2009 and 2010. In 2009 they found California black rails at Peytonia and Cutoff Sloughs (and Point Edith Marsh immediately south of the Plan Area boundary) (Estrella 2009). No black rails were recorded in 2010 (Estrella pers. comm.)

Surveys conducted by CDFW in the early 1990s found small numbers of black rails at several locations in the central Delta, including White, Little Potato, Disappointment, and Whiskey Sloughs; midchannel islands in Middle and San Joaquin Rivers; Holland and Palm Tracts; and Mildred, Bacon, and Mandeville Islands (California Department of Fish and Game 2011). They have also been recorded on Sherman and Browns islands at the lower reach of the Sacramento River (California Department of Fish and Game 2011). The California Department of Water Resources (DWR) conducted surveys in Delta 2009 and 2010 and found nesting pairs at White Slough and on several midchannel islands (*Delta Habitat Conservation and Conveyance Program* 2011).

Overall, habitat availability in the Delta is restricted to remnant wetland sites that are generally unavailable for agricultural uses. Insufficient data have been collected to estimate black rail populations in the Plan Area; however, the small populations found in the central Delta portion of the Plan Area likely represent a relatively small proportion of the population in the Bay-Delta region. Regardless, these small populations that persist east of Suisun Marsh are important relative to the overall range and dispersal capabilities of the species.

2A.17.3 Habitat Requirements and Special Considerations

California black rails inhabit saltwater, brackish, and freshwater marshes (Grinnell and Miller 1944; Manolis 1978; Spautz et al. 2005). A highly secretive and rarely observed bird, it appears to have a preference in coastal areas for tidal salt marshes dominated by dense pickleweed (*Salicornia pacifica*) with an open structure below. This provides a dense canopy for protective cover while providing nesting habitat and accessibility below the canopy (Evens and Page 1983). Rails are susceptible to predation by herons, egrets, northern harriers, short-eared owls, and several mammalian predators. A dense canopy that provides optimal cover is essential for survival.

Black rails tend to be associated with areas where *Schoenoplectus* (formerly *Scirpus*) spp. and *Salicornia* border each other. Evens et al. (1991) found rails in areas with a mosaic of *Juncus* (40%), *Schoenoplectus* (30%), *Triglochin* (10%), *Grindelia* (<10%), *Distichlis* (less than 10%), and *Typha* (less than 10%). In Suisun Marsh, presence of black rails occurs in conjunction with a pickleweed-alkali heath-American bulrush plant association in the high marsh zone. Data from Spautz et al. (2005) indicate that black rails prefer marshes that are close to water (bay or river), large, away from urban areas, and saline to brackish with a high proportion of *Salicornia*, *Grindelia*, *Bolboschoenus maritimus* ssp*. paludosus* (formerly *Scirpus maritimus*), *Juncus*, and *Typha*. Escape cover is critical to these birds. Rail nests consist of loosely made, deep cups either at ground level or slightly elevated. Nests are concealed in dense marsh vegetation near the upper limits of tidal flooding (California Department of Water Resources 2001).

At Suisun Marsh, low marsh habitats dominated by *Schoenoplectus acutus* and *S. californicus* do not provide breeding habitat, but they are used by black rails for foraging. In addition, upland transition zones provide both foraging habitat and refuge during extreme high tide events. Finally, managed wetlands that are intensively managed (e.g., by mowing and discing) for waterfowl generally provide only marginal habitat for this species, while less intensively managed shallow-water areas may provide more suitable habitat. Collectively, managed wetlands are considered secondary habitat compared to tidal middle and high marsh wetlands.

CDFW and DWR surveyors recorded black rails at instream islands in the central Delta and at one managed marsh on the eastern edge of the Delta during the 2009 and 2010 breeding seasons (California Department of Water Resources et al. 2012). The instream islands consisted of mixed tule (*Schoenoplectus* spp.) wetland and willow-dogwood scrub. The managed marsh consisted of two tule-dominated wetlands in the White Slough Wildlife Area northwest of Stockton.

Away from coastal estuaries and salt marshes, black rails are restricted to breeding in freshwater marshes with stands of tule, cattail, bulrush, and sedge (*Carex* spp.) (Eddleman et al. 1994). These sites are very shallow (usually less than 3 centimeters), but require a perennial water source. A relatively narrow range of conditions is required for occupancy and successful breeding. Water depth is an important parameter for successful nest sites, because rising water levels can prevent nesting or flood nests and reduce access to foraging habitat (Eddleman et al. 1994). Too little water will lead to abandonment of the site until the water source is reestablished. Primary factors determining their presence are annual fluctuations in water levels and shallow water depth (less than 3 centimeters) (Rosenberg et al. 1991; Eddleman et al. 1994; Conway et al. 2002). No information is available on minimum patch size for the California black rail in the Central Valley and Delta Region; however, in the foothills of the central Sierra Nevada, rails are in marshes ranging from 0.5 to 25 acres (0.2 to 10.1 hectares) in size, with 32% of occupied sites in wetlands less than 0.75 acre (0.3 hectare) (Tecklin 1999). The discovery of these Sierra Nevada populations suggests that the species is able to colonize isolated habitat patches (Aigner et al. 1995; Trulio and Evens 2000).

Black rails occur in marshland only, a habitat mostly destroyed or modified in the western United States since the mid-1800s (Atwater et al. 1979; Zedler 1982; Josselyn 1983; Nichols et al. 1986 in California Department of Water Resources 2001). Populations and numbers have and will continue to decline as loss and alteration of habitat continues. Currently, the species is confined to mostly pristine remnants of historical tidal marshlands, mainly along the large tributaries and shoreline of northern San Pablo Bay, along the Carquinez Strait, and throughout parts of Suisun Bay (Evens et al. 1991; Spautz et al. 2005). The marshes of San Pablo and Suisun Bays are important in that they are currently the last large refuge areas for a viable population. However, recent observations of California black rails using restored wetlands in the Bay area (Herzog et al. 2004; Liu et al. 2006) provide hope that for future population expansion, and success for restoration opportunities in Suisun Marsh and the Delta.

2A.17.4 Life History

2A.17.4.1 Description

The California black rail is a small (12 to 15 centimeters [4.7 to 5.9 inches] long), secretive, marsh-associated bird (Eddleman et al. 1994). They are black to gray in color with a small black bill, white speckled sides and back, and a deep chestnut brown nape (California Department of Fish and Game 1999). Difficult to observe, rails are usually identified by their call.

2A.17.4.2 Seasonal Patterns

Very little information is available on seasonal patterns, timing of reproduction, dispersal, or other activities. The breeding season begins as early as February with pair formation and extends through approximately early to mid-June. Egg laying peaks around May 1 (Eddleman et al. 1994). The species is generally known as a medium-distance migrant that winters in Mexico and Central America, although San Francisco Bay black rails are considered year-round residents, as are those from inland populations in central California. At these locations, seasonal movements, including juvenile dispersal and adult relocation to other wetland breeding sites, occur each year sometime during the nonbreeding season between approximately August and February (Tecklin 1999).

2A.17.4.3 Reproduction

Black rails are monogamous birds. They build cup nests with a woven canopy in dead or new emergent vegetation over shallow water less than 3 centimeters (1.2 inches) in depth (Eddleman et al. 1994). They initiate egg laying within a few days after nest construction is complete. Rails in California usually lay one single brood with an average clutch size of six eggs (range equals three to eight eggs) (Eddleman et al. 1994). Occasionally there are multiple nesting attempts but there is no evidence of multiple broods being produced (Spautz pers. comm.). The incubation period ranges from 17 to 20 days and both adults apparently incubate the eggs (Flores and Eddleman 1993); however, there is very limited data on this period. After hatching, the semiprecocial young leave the nest within a day, but at least one parent continues to brood the young for several additional days (Eddleman et al. 1994). Limited information is available on length of brooding period, timing of fledging, parental care, or reproductive success.

2A.17.4.4 Home Range and Territory Size

California black rails have small home ranges in the breeding season. In north San Francisco Bay tidal marshes, fixed-kernel home ranges (representing 95% utilization distribution) averaged 1.5 acres (0.6 hectare) and core use areas (representing the 50% utilization distribution) averaged 0.3 acre (0.1 hectare) (Tsao et al. 2009a). For comparison, minimum convex polygon home ranges for San Francisco Bay black rails averaged 0.6 acre (0.2 hectare) (Tsao et al. 2009a). Studies of other rail species showed increased home range sizes outside of the breeding season (Bookhout and Stenzel 1987; Conway 1990); however, black rails in Arizona, where water levels remain steady throughout the year, showed no difference in home range size across seasons (Flores and Eddleman 1991).

2A.17.4.5 Foraging Behavior and Diet

Very little information is available on the foraging behavior of the black rail. The species is assumed to be an opportunistic daytime feeder that forages exclusively in wetland habitat, presumably on or near the ground at the edges of emergent vegetation. Its diet consists of insects, small mollusks, amphipods, and other invertebrates, and seeds from bulrushes (*Schoenoplectus* spp.) and cattails (*Typha* spp.) (Eddleman et al. 1994).

2A.17.5 Threats and Stressors

Throughout its range, the primary threat to California black rail is the loss and fragmentation of habitat from urbanization, flood control projects, agricultural practices, hydrologic changes that affect water regimes, and sea level rise. The most significant historical threat was the draining of tidal marshes, which may be responsible for over 90% of the population declines of this species, and which is still occurring in some areas, albeit at a slower rate.

At inland sites, agricultural practices, livestock grazing, and urbanization may threaten individual subpopulations. Use of pesticides, including those used for mosquito control programs may also have unintended consequences for black rails. These isolated subpopulations are also susceptible to metapopulation dynamics and stochastic variables (Evens et al. 1991), meaning they are more susceptible to localized extirpation from processes such as storm events or disease. Other potential threats include increased predation by domestic cats and by native predators as a result of hydrologic and vegetation changes that increase black rail susceptibility to predation, pollution and its effect on freshwater marshes, and collisions with automobiles and utility lines.

Data gaps relating to many aspects of the ecology of the black rail are significant, including minimum patch size for successful breeding colonies, parameters of population sinks, sources of mortality, site fidelity and movement in winter, winter diet, and foraging ecology.

Because black rails reside year-round in tidal marshes throughout the Bay-Delta region where sediment methylmercury production is high (Marvin-DiPasquale et al. 2003), they may be particularly vulnerable to methylmercury contamination. Black rails at north San Francisco Bay tidal marshes had lower methylmercury concentrations than other waterbirds at San Francisco Bay (Ackerman et al. 2007; Tsao et al. 2009b), likely due to their low-trophic-level invertebrate diet (Eddleman et al. 1994) However, 78% of black rail feather samples contained mercury at higher levels than those associated with adverse reproductive effects in mallards and ring-necked pheasants (Heinz 1979; Eisler 2000); and 9% of blood samples fell within the range for moderate risk of reproductive effects in common loons (Evers et al. 2008). Because methylmercury sensitivity varies widely among species, the effects of methylmercury contamination on the San Francisco Bay black rail population are unclear.

2A.17.6 Relevant Conservation Efforts

The California black rail is a covered species in several neighboring regional habitat conservation plans/natural communities conservation plans, including the *San Joaquin County Multi-species Habitat Conservation and Open Space Plan* (San Joaquin Council of Governments 2000) , the *Solano Multispecies Habitat Conservation Plan* (Solano County Water Agency 2009), the *Yolo Natural Heritage Program Plan Habitat Conservation Plan/Natural Community Conservation Plan* (Yolo County Habitat Conservation Plan/Natural Community Conservation Plan Joint Powers Agency 2011), and the *Butte Regional Conservation Plan* (Butte County Association of Governments 2011) Several management plans have outlined threats to California black rails and provided recommendations for conservation (Trulio and Evens 2000). Recommendations focus primarily on protection of high-value habitats; however, few actual habitat protection or species conservation efforts specific to the California black rail have been undertaken to date.

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the California black rail as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

2A.17.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.17.7.1 GIS Model Data Sources

The California black rail model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005 & 2010), and land use survey of the Delta and Suisun Marsh area-version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable California black rail habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

2A.17.7.2 Habitat Model Description

In the central Delta portion of the Plan Area, California black rail may be found in patches of tidal freshwater emergent wetland found along the perimeter of sloughs and on in-channel islands of larger watercourses (Figure 2A.17-2) (National Audubon Society 2008; Gifford pers. comm.). The habitat mapping region used in the California black rail model is Suisun Marsh, the Delta west of Sherman Island, and the central and northern Delta.

The model identifies suitable habitat as tidal and nontidal, brackish, and freshwater marsh with appropriate vegetation alliances, especially those dominated by pickleweed (*Salicornia* spp.), bulrush (*Scirpus americanus*), and cattail (*Typha* spp.). Because California black rail vegetation associations vary by location in the Plan Area, the primary and secondary habitat models have three geographically distinct types: Suisun Marsh, Delta, and midchannel islands in the Delta.

In Suisun Marsh, primary habitat includes all *Scirpus americanus*-, *Typha* spp.-, and *Salicornia* spp.-dominated patches in the tidal brackish emergent wetland natural community. When *Scirpus americanus*-, *Typha* spp.-, and *Salicornia* spp.-dominated vegetation types occur in the managed wetland natural community, they are secondary California black rail habitat. Vegetation communities dominated by *Scirpus acutus* and *Scirpus californicus* are secondary habitat only when adjacent to primary or secondary habitat types in Suisun Marsh. All secondary vegetation types in Suisun Marsh are restricted to within 750 meters of primary modeled habitat.

In the Delta, there are two California black rail habitat model types: Delta and midchannel islands. The vegetation types included as primary or secondary habitat in each model type varies; however, for both the Delta and midchannel island model types, primary and secondary vegetation patches must combine to meet a 4-acre minimum mapping unit requirement. The 4-acre patch can be composed of both primary and secondary vegetation types.

California black rail primary habitat in the Delta model type includes *Scirpus americanus*- and *Typha* spp.-dominated patches in the tidal and nontidal freshwater emergent wetland natural communities. Modeled secondary habitat in the Delta primarily includes vegetation communities dominated by other *Scirpus* species (see list below) in tidal and nontidal freshwater emergent wetland natural communities. In the Delta model type, *Scirpus actus* pure and *Scirpus acutus*-*Typha latifolia* are not included in the primary or secondary habitat model.

To capture unique habitat types on midchannel islands in the Delta, CDFW created a separate midchannel island GIS layer. Primary and secondary modeled habitat on the midchannel include riparian and tidal and nontidal freshwater emergent wetland vegetation communities. When the riparian vegetation community types are adjacent to the selected emergent wetland types, the habitat is considered primary. Secondary habitat consists of those emergent wetland types when not directly adjacent to riparian vegetation patches.

The black rail model in Suisun Marsh includes the below-listed types from the BDCP composite vegetation layer. The primary model includes these vegetation patches when mapped within the tidal brackish emergent wetland community, and the secondary habitat model includes these patches when mapped within the managed wetland natural community. No minimum patch size is applied to these areas. All secondary habitat in Suisun Marsh is constrained to occur within 750 meters of primary habitat.

- *Distichlis*/*Salicornia*
- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia*/*Cotula*
- *Salicornia*/*Atriplex*
- *Salicornia*/annual grass
- *Salicornia*/*Crypsis*
- *Salicornia*/*Polygonum*–*Xanthium*–*Echinochloa*
- *Salicornia*/*Sesuvium*
- Mixed Scirpus mapping unit
- *Typha angustifolia*–*Distichlis spicata*
- *Scirpus*(*californicus* or *acutus*)/*Rosa*
- *Schoenoplectus* (*californicus* or *acutus*)/wetland herb
- *Schoenoplectus* (*californicus* or *acutus*)–*Typha* spp.
- *Scirpus americanus* (generic)
- *Scirpus americanus*/*Lepidium*
- *Scirpus americanus*/*Potentilla*
- *Schoenoplectus californicus*/*S. acutus*
- Mixed *Scirpus*/floating aquatics (*Hydrocotyle*–*Eichhornia*)
- Mixed *Scirpus*/submerged aquatics (*Egeria*–*Cabomba*–*Myriophyllum* spp.)
- *Phragmites australis*
- *Scirpus acutus*–pure
- *Scirpus maritimus*
- *Scirpus maritimus*/*Salicornia*
- *Typha angustifolia*/*S. americanus*
- *Typha* species (generic)
- Bulrush–cattail freshwater marsh NFD super alliance

- *Scirpus americanus/S. californicus/S. acutus*
- *Scirpus maritimus/Sesuvium*
- *Typha angustifolia/Phragmites*
- *Typha angustifolia/Polygonum–Xanthium–Echinochloa*
- *Distichlis–Juncus–Triglochin–Glaux*
- *Distichlis–S. americanus*
- *Distichlis–Juncus*
- *Calystegia–Euthamia*
- *Distichlis/Salicornia*
- *Distichlis/S. americanus*
- *Distichlis/Juncus/Calystegia/Euthamia*
- *Lepidium* (generic)
- Narrow-leaf cattail (*Typha angustifolia*)
- American bulrush (*Scirpus americanus*)

The following vegetation types are selected as secondary black rail habitat in Suisun Marsh when adjacent to primary or secondary habitat. All secondary habitat in Suisun Marsh is constrained to occur within 750 meters of primary habitat.

- *Scirpus acutus–Typha angustifolia* (secondary)
- *Scirpus acutus–Typha latifolia* (secondary)
- *Scirpus acutus–Typha latifolia–Phragmites australis* (secondary)
- *Scirpus californicus–Eichhornia crassipes* (secondary)
- *Scirpus californicus–Scirpus acutus* (secondary)
- *Scirpus californicus/S. acutus* (secondary)

The following vegetation types are included in the Delta model type as primary habitat when mapped as tidal or nontidal freshwater emergent wetland. Primary and secondary model patches must combine to meet the 4-acre minimum mapping unit requirement. *Scirpus actus* pure and *Scirpus acutus*-*Typha latifolia* are not included in the primary or secondary habitat model.

- *Distichlis/Salicornia*
- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia/Cotula*
- *Salicornia/Atriplex*
- *Salicornia*/annual grass
- *Salicornia/Crypsis*

- *Salicornia*/*Polygonum–Xanthium–Echinochloa*
- *Salicornia*/*Sesuvium*
- Mixed *Scirpus* mapping unit
- *Scirpus americanus* (generic)
- *Typha angustifolia* (dead stalks)
- *Typha angustifolia–Distichlis spicata*
- American bulrush (*Scirpus americanus*)
- Broad-leaf cattail (*Typha latifolia*)
- Narrow-leaf cattail (*Typha angustifolia*)
- *Distichlis–Juncus–Triglochin–Glaux*
- *Distichlis/S. americanus*
- *Distichlis spicata–Juncus balticus*
- *Distichlis/Juncus*
- *Calystegia/Euthamia*
- *Lepidium latifolium–Salicornia virginica–Distichlis spicata*
- Pickleweed (*Salicornia pacifica*)
- Perennial pepperweed (*Lepidium latifolium*)
- *Phragmites australis*

The following vegetation types are included in the Delta model type as secondary habitat when mapped as tidal or nontidal freshwater emergent wetland. Primary and secondary model patches must combine to meet the 4-acre minimum mapping unit requirement. *Scirpus actus* pure and *Scirpus acutus–Typha latifolia* mapped within the tidal freshwater emergent wetland natural community are not included in the primary or secondary habitat model.

- Mixed *Scirpus*/floating aquatics (*Hydrocotyle–Eichhornia*) (secondary)
- Mixed *Scirpus*/submerged aquatics (*Egeria–Cabomba–Myriophyllum* spp.) (secondary)
- *Scirpus acutus–Typha angustifolia*
- *Scirpus acutus*–(*Typha latifolia*)–*Phragmites australis*
- *Scirpus californicus–Eichhornia crassipes*
- *Scirpus californicus–Scirpus acutus*
- *Scirpus californicus*/*S. acutus*
- California bulrush (*Scirpus californicus*)
- Hard-stem bulrush (*Scirpus acutus*)

The below-listed riparian vegetation types are included in the primary portion of the midchannel island model type. Primary and secondary model patches must combine to meet the 4-acre minimum mapping unit requirement to be included in the model.

- Arroyo willow (*Salix lasiolepis*)
- *Baccharis pilularis*/annual grasses & herbs
- Blackberry (*Rubus discolor*)
- Buttonbush (*Cephalanthus occidentalis*)
- California dogwood (*Cornus sericea*)
- California wild rose (*Rosa californica*)
- *Cornus sericea–Salix exigua*
- *Cornus sericea–Salix lasiolepis/Phragmites australis*
- Coyotebush (*Baccharis pilularis*)
- Intermittently or temporarily flooded deciduous shrublands
- Narrow-leaf willow (*Salix exigua*)
- *Blackberry* (*Rubus discolor*)
- *Salix exigua* (*Salix lasiolepis–Rubus discolor–Rosa californica*)
- *Salix gooddingii–Quercus lobata/*wetland herbs
- *Salix gooddingii/Rubus discolor*
- *Salix gooddingii/*wetland herbs
- *Salix lasiolepis* (*Cornus sericea*)*/Schoenoplectus* spp. –(*Phragmites australis–Typha* spp.) complex
- *Salix lasiolepis*-mixed brambles (*Rosa californica–Vitis californica–Rubus discolor*)
- *Distichlis*/*Salicornia*
- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia*/*Cotula*
- *Salicornia*/*Atriplex*
- *Salicornia*/annual grass
- *Salicornia*/*Crypsis*
- *Salicornia*/*Polygonum–Xanthium–Echinochloa*
- *Salicornia*/*Sesuvium*
- Mixed *Scirpus* mapping unit
- Mixed *Scirpus*/floating aquatics (*Hydrocotyle–Eichhornia*) complex (secondary)
- Mixed *Scirpus*/submerged aquatics (*Egeria–Cabomba–Myriophyllum* spp.) (secondary)
- *Scirpus acutus* pure

- *Scirpus acutus–Typha angustifolia*
- *Scirpus acutus*–(*Typha latifolia*)–*Phragmites australis*
- *Scirpus californicus–Eichhornia crassipes*
- *Scirpus californicus–Scirpus acutus*
- *Scirpus californicus/S. acutus*
- *Scirpus americanus* (generic)
- *Typha angustifolia* (dead stalks)
- *Typha angustifolia–Distichlis spicata*
- American bulrush (*Scirpus americanus*)
- Broad-leaf cattail (*Typha latifolia*)
- Narrow-leaf cattail (*Typha angustifolia*)
- *Distichlis–Juncus–Triglochin–Glaux*
- *Distichlis/S. americanus*
- *Distichlis spicata–Juncus balticus*
- *Distichlis/Juncus*
- *Calystegia/Euthamia*
- *Lepidium latifolium–Salicornia pacifica–Distichlis spicata*
- Pickleweed (*Salicornia pacifica*)
- Perennial pepperweed (*Lepidium latifolium*)
- *Distichlis spicata–Salicornia virginica*
- *Salicornia virginica–Cotula coronopifolia*
- *Salicornia virginica–Distichlis spicata*

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. In the new analysis areas, the following natural communities and alliances, where the information was available, were assumed to provide habitat for California black rail:

- Managed wetland
- Nontidal freshwater perennial emergent wetland
- Tidal brackish emergent wetland
- Tidal freshwater emergent wetland

2A.17.7.3 Assumptions

- **Assumption:** In the Delta model type, California black rail habitat must meet a 4-acre minimum mapping unit requirement. Four-acre patches can be composed of contiguous primary and secondary patches.

  Rationale: Limited information is available on minimum habitat patch size for black rail in the Delta region. Tsao et al. (2009a) calculated an average home range size of 1.5 acres and average core use areas (representing the 50% utilization distribution) of 0.3 acre for the San Francisco Bay estuary. For purposes of this model, a minimum patch size of 4 acres is used, relying on surveys conducted in the midchannel islands and size of the smallest island with black rail detection is 4 acres (Tsao pers. comm.).

- **Assumption:** Primary and secondary habitat types are *Scirpus*- and *Typha*-dominated emergent wetlands.

  Rationale: Factors that determine occupancy include water depth and a perennial water source. Very shallow water (usually less than 1.2 inches) is required. In general, a relatively narrow range of conditions is required for occupancy and successful breeding (Eddleman et al. 1994). For purposes of this model, it is assumed that these conditions are met in all *Scirpus*- and *Typha*-dominated tidal freshwater emergent wetlands. This also likely results in an overestimate of potentially occupied habitat for this species. To better define habitats of most value to this species, habitats unlikely to be used for breeding were classified as secondary habitat. These include low marsh dominated by *Scirpus acutus* and *Scirpus californicus* and emergent wetland types in managed wetlands.

- **Assumption:** California black rail habitat is constrained to 750 meters within flooded diked wetlands adjacent to tidal wetlands in the Suisun Marsh.

  Rationale: Black rails are occasionally observed by CDFW and DWR staff in flooded, diked wetlands adjacent to tidal wetlands in Suisun Marsh (California Department of Fish and Game 2012). It is not known if California black rails actually nest in these locations. The most common locations of these observations are diked ponds between Goodyear Slough and Suisun Bay (five observations between 2002 and 2012) and the western diked portion of Hill Slough Wildlife Area (three observations between 2002and 2010). Typically, these observations are within 100 meters of tidal marsh. At Hill Slough Wildlife Area, black rails have been observed up to 600 meters from tidal marsh. Therefore, a 750-meter buffer was applied to this model (Estrella pers. comm.).

- **Assumption:** Black rail habitat in the nonisland portions of the Delta does not include *Scirpus actus* pure and *Scirpus acutus–Typha latifolia*

  Rationale: Black rails are not known to inhabit large, dense patches of *Scrirpus* or *Typha* that are not proximate to some upland type, and these two alliances were used to represent dense, monotypic stands (Spautz and Clipperton pers. comm.).

2A.17.8 Recovery Goals

A USFWS recovery plan has not been prepared for this species and no recovery goals have been established; however, the CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species*

Conservation Strategy designates the California black rail as "Contribute to Recovery" (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

2A.17.9 References Cited

2A.17.9.1 Literature Cited

Ackerman, J. T., C. A. Eagles-Smith, J. Y. Takekawa, S. A. Demers, T. L. Adelsbach, J. D. Bluso, A. Keith Miles, N. Warnock, T. H. Suchanek, and S. E. Schwarzbach. 2007. Mercury Concentrations and Space Use of Pre-Breeding American Avocets and Black-Necked Stilts in San Francisco Bay. *Science of the Total Environment* 394:452–466.

Aigner, P., J. Tecklin, and C. Koehler. 1995. Probable Breeding Population of the Black Rail in Yuba County, California. *Western Birds* 26:157–160.

Atwater, B. F., S. C. Conard, I. N. Dowden, C. W. Hedel, R. L. MacDonald, and W. Savage. 1979. History, Landforms, and Vegetation of the Estuary's Tidal Marshes. In: T. J. Conomos (ed.), *San Francisco Bay: The Urbanized Estuary.* Proceedings of the 58th Annual Meeting of the Pacific Division of the American Association for the Advancement of Science, Golden Gate Park, San Francisco, CA. Pages 347–385.

Bookhout, T. A. and J. R. Stenzel. 1987. Habitat and Movements of Breeding Yellow Rails. *Wilson Bulletin* 99:441–447.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

Butte County Association of Governments. 2011. *Butte Regional Conservation Plan*. Available: <http://www.buttehcp.com/>. Accessed: July 12, 2012.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Black Rail Project. 2005. *The California Black Rail Report: a Newsletter for Landowners Cooperating with the California Black Rail Study Project*. Vol. 3, No. 1.

California Black Rail Project. 2006. *The California Black Rail Report: a Newsletter for Landowners Cooperating with the California Black Rail Study Project*. Vol. 4, No. 1.

California Black Rail Project. 2011. *The California Black Rail Report: a Newsletter for Landowners Cooperating with the California Black Rail Study Project*. Vol. 9, No. 1.

California Department of Fish and Game. 1999. *California Black Rail*. Habitat Conservation Planning Branch. Sacramento, CA.

California Department of Fish and Game. 2011. California Natural Diversity Database. Records search of plan area quadrangles. Sacramento, CA.

California Department of Fish and Game. 2012. *California Clapper Rail and Black Rail Survey Reports; Salt Marsh Harvest Mouse Survey Data 2001 to 2012*. Unpublished.

California Department of Water Resources. 2001. *Suisun Ecological Workgroup; Wildlife of the Suisun Marsh, California Black Rail Final Report to the State Water Resources Control Board*. Sacramento, CA. Available: <http://www.iep.ca.gov/suisun_eco_workgroup/workplan/report/wildlife/blackrail.html>.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area.* Version 3 GIS dataset. Sacramento, CA.

California Department of Water Resources, Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. 2012. *Environmental Impact Report/Environmental Impact Statement for the Bay Delta Conservation Plan.* Prepared by ICF International. Sacramento, CA. February.

Conway, C. J. 1990. *Seasonal Changes in Movements and Habitat Use by Three Sympatric Species of Rails*. MS thesis. University of Wyoming, Laramie.

Conway, C., C. Sulzman, and B. Raulston. 2002. *Population Trends, Distribution, and Monitoring Protocols for the California Black Rail*. Final report. Tucson, AZ: Arizona Fish and Wildlife Research Unit, University of Arizona; and Boulder City, NV: Bureau of Reclamation,

Delta Habitat Conservation and Conveyance Program. 2011. *2009 to 2011 Bay Delta Conservation Plan EIR/EIS Environmental Data Report*. Review Draft 1. December. Prepared for consideration by the lead agencies. Published by California Department of Water Resources, Bureau of Reclamation, National Marine Fisheries Service, and U.S. Fish and Wildlife Service.

Eddleman, W. R., R. E. Flores, and M. L. Legare. 1994. Black Rail (*Laterallus jamaicensis*). In: A. Poole and F. Gill (eds.) *The Birds of North America 123.* Philadelphia, PA: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Eisler, R. 2000. *Handbook of Chemical Risk Assessment: Health Hazards to Humans, Plants, and Animals.* Volume 1–3. Boca Raton, FL: Lewis Publishers.

Estrella, S. 2009. *California Clapper Rail Survey Report 2009.* Prepared for the California Department of Water Resources.

Evens, J. and G. W. Page. 1983. *The Ecology of Rail Populations at Corte Madera Ecological Preserve*. Final report to Main Audubon Society at Point Reyes Bird Observatory.

Evens, J. G., G. W. Page, S. A. Laymon, and R. W. Stallcup. 1991. Distribution, Relative Abundance and Status of the California Black Rail in Western North America. *Condor* 93:952–966.

Evers, D. C., L. J. Savoy, C. R. DeSorbo, D. E. Yates, W. Hanson, K. M. Taylor, L. S. Siegel, J. H.Cooley Jr., M. S. Bank, A. Major, K. Munney, B. F. Mower, H. S. Vogel, N. Schoch, M. Pokras, M. W. Goodale, and J. Fair. 2008. Adverse Effects from Environmental Mercury Loads on Breeding Common Loons. *Ecotoxicology* 17:69–81.

Flores, R. E., and W. R. Eddleman. 1991. *Ecology of the California Black Rail in Southwestern Arizona*. Final Report, Intra-Agency Agreement 7-AA-30-05910. Yuma, AZ: Bureau of Reclamation.

Flores, R. E., and W. R. Eddleman. 1993. Nesting Biology of the California Black Rail in Southwestern Arizona. *Western Birds* 24:81–88.

Garrett, K. and J. Dunn. 1981. *Birds of Southern California.* Los Angeles, CA: Los Angeles Audubon Society. In: California Department of Water Resources. 2001. *Suisun Ecological Workgroup; Wildlife of the Suisun Marsh, California Black Rail.* Final report. Sacramento, CA: State Water Resources Control Board.

Grinnell, J. and A. H. Miller. 1944. *The Distribution of the Birds of California*. Berkeley, CA: Museum of Vertebrate Zoology, University of California.

Heinz, G. H. 1979. Methylmercury: Reproductive and Behavioral Effects on Three Generations of Mallard Ducks. *Journal of Wildlife Management* 43:394–401.

Herzog, M., L. Liu, N. Nur, H. Spautz, and N. Warnock. 2004. *San Francisco Bay Tidal Marsh Project Annual Report 2004*. Distribution, Abundance, and Reproductive Success of Tidal Marsh Birds. Petaluma, CA: PRBO Conservation Science.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Josselyn, M. 1983. *The Ecology of the San Francisco Bay Tidal Marshes: A Community Profile*. FWS/OBS-83/23. Washington, DC: U.S. Fish and Wildlife Service Division of Biological Services.

Kemper, J. and T. Manolis. 1999. *Bidwell Park, Chico*. Site Guide Reprinted from the Central Valley Bird Club Bulletin. Available: < http://www.cvbirds.org/CVBirdsSites.htm>. Accessed: June 18, 2012.

Liu, L., P. Abbaspour, M. Herzog, N. Nur, and N. Warnock. 2006. *San Francisco Bay Tidal Marsh Project Annual Report 2006: Distribution, abundance, and Reproductive Success of Tidal Marsh Birds.* PRBO Conservation Science, Petaluma, CA. Available: <http://www.prbo.org/cms/docs/wetlands/PRBOTidalMarsh2006AnnualReport.pdf> .

Manolis, T. 1978. Status of the Black Rail in Central California. *Western Birds* 9:151–158.

Marvin-DiPasquale, M. C., J. L. Agee, R. M. Bouse, and B. E. Jaffe. 2003. Microbial Cycling of Mercury in Contaminated Pelagic and Wetland Sediments of San Pablo Bay, California. *Environmental Geology* 43:260–267.

National Audubon Society. 2008. *Important Bird Areas in the U.S*. Available: <http://www.audubon.org/bird/iba>.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The Modification of an Estuary. Science 231:567–573. As cited in California Department of Water Resources. 2001. Suisun Ecological Workgroup; Wildlife of the Suisun Marsh, California Black Rail. Final Report to the State Water Resources Control Board, Sacramento, CA.

Rosenberg, K. V., R. D. Ohmart, W. C. Hunter, and B. W. Anderson. 1991. *Birds of the Lower Colorado River*. Tucson, AZ: University of Arizona Press.

San Joaquin Council of Governments. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan.* Available: <http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm>. Accessed: December 22, 2011.

Solano County Water Agency. 2009. *Solano Multispecies Habitat Conservation Plan.* Final Administrative Draft. June 15. Available: <http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx>. Accessed: December 22, 2011.

Spautz, H. and N. Nur. 2002. *Distribution and Abundance in Relation to Habitat and Landscape Features and Nest Site Characteristics of California Black Rail in the San Francisco Bay Estuary.* Final Report. Prepared for U.S. Fish and Wildlife Service.

Spautz, H., N. Nur, and D. Stralberg. 2005. *California Black Rail* (Laterallus jamaicensis coturniculus) *Distribution and Abundance in Relation to Habitat and Landscape Features in the San Francisco Bay Estuary*. USDA Forest Service General Technical Report PWS-GTR-191.

TAIC. 2008. Yolo County Regional Vegetation, July 2008. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

Tecklin, J. 1999. *Distribution and Abundance of the California Black Rail (*Laterallus jamaicensis coturniculus*) in the Sacramento Valley Region with Accounts of Ecology and Call Behavior of the Subspecies*. Draft report for the California Department of Fish and Game, Contract Nos. FG6154WM and FG6154-1WM.

Trochet, J. 1999. *Cosumnes River Preserve*. Site Guide Reprinted from the Central Valley Bird Club Bulletin. Available: < http://www.cvbirds.org/CVBirdsSites.htm>. Accessed: June 18, 2012.

Trulio, L. A. and J. G. Evens. 2000. California Black Rail. In: Olofson, P. R. (ed.). *Goals Project. Baylands Ecosystem Species and Community Profiles: Life Histories and Environmental Requirements of Key Plants, Fish and Wildlife*. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. Oakland, CA: San Francisco Bay Regional Water Quality Control Board. Pages 341–345.

Tsao, D. C., A. K. Miles, J. Y. Takekawa, and I. Woo. 2009b. Potential Effects of Mercury on Threatened California Black Rails. *Archives of Environmental Contamination and Toxicology* 56:292–301.

Tsao, D. C., J. Y. Takekawa, I. Woo, J. Yee, and J. Evens. 2009a. Home Range, Habitat Selection and Movements of California Black Rails at Tidal Marshes at San Francisco Bay, California. *Condor* 111:599–610.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program.* USDA Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

Yolo County Habitat Conservation Plan/Natural Community Conservation Plan Joint Powers Agency. 2011. *Yolo Natural Heritage Program Plan Habitat Conservation Plan/Natural Community Conservation Plan.* Available: <http://www.yoloconservationplan.org/enviro-portal.html>. Accessed: December 22, 2011.

Zedler, J. B. 1982. *The Ecology of Southern California Coastal Salt Marshes: A Community Profile*. U.S. Department of Interior, Fish and Wildlife Service, FWS/OBS-81/54.

2A.17.9.2 Personal Communications

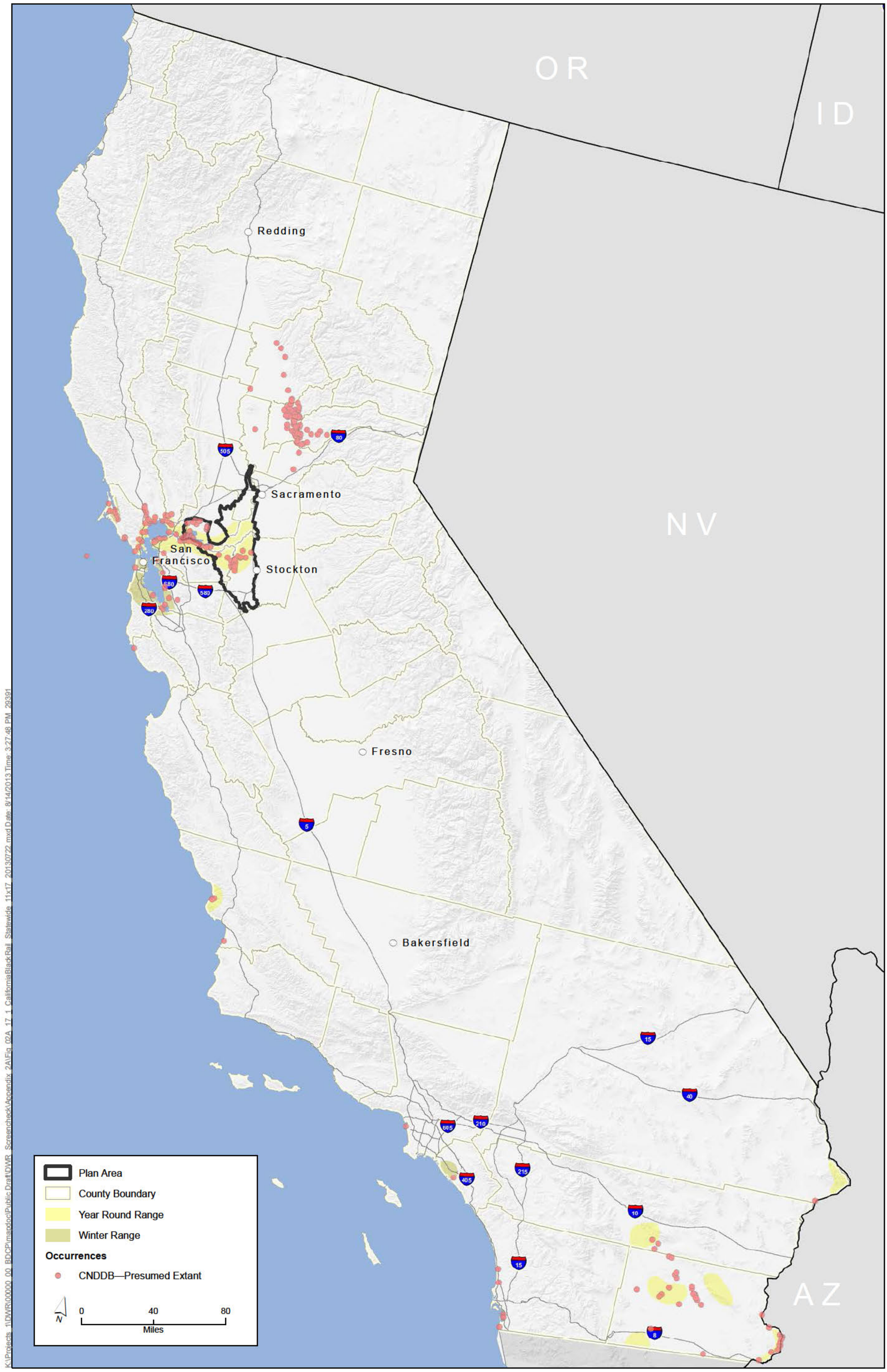
Gifford, Dan. Wildlife Biologist, California Department of Fish and Game. October 22, 2008—Telephone conversation with Jim Estep, Estep Environmental Consulting.

Estrella, Sarah. Associate Wildlife Biologist. California Department of Fish and Game. November 22, 2011—Email regarding black rail occurrence data.

Spautz, Hilde. California Department of Fish and Game. November 29, 2011—Comments on preliminary draft of this species account.

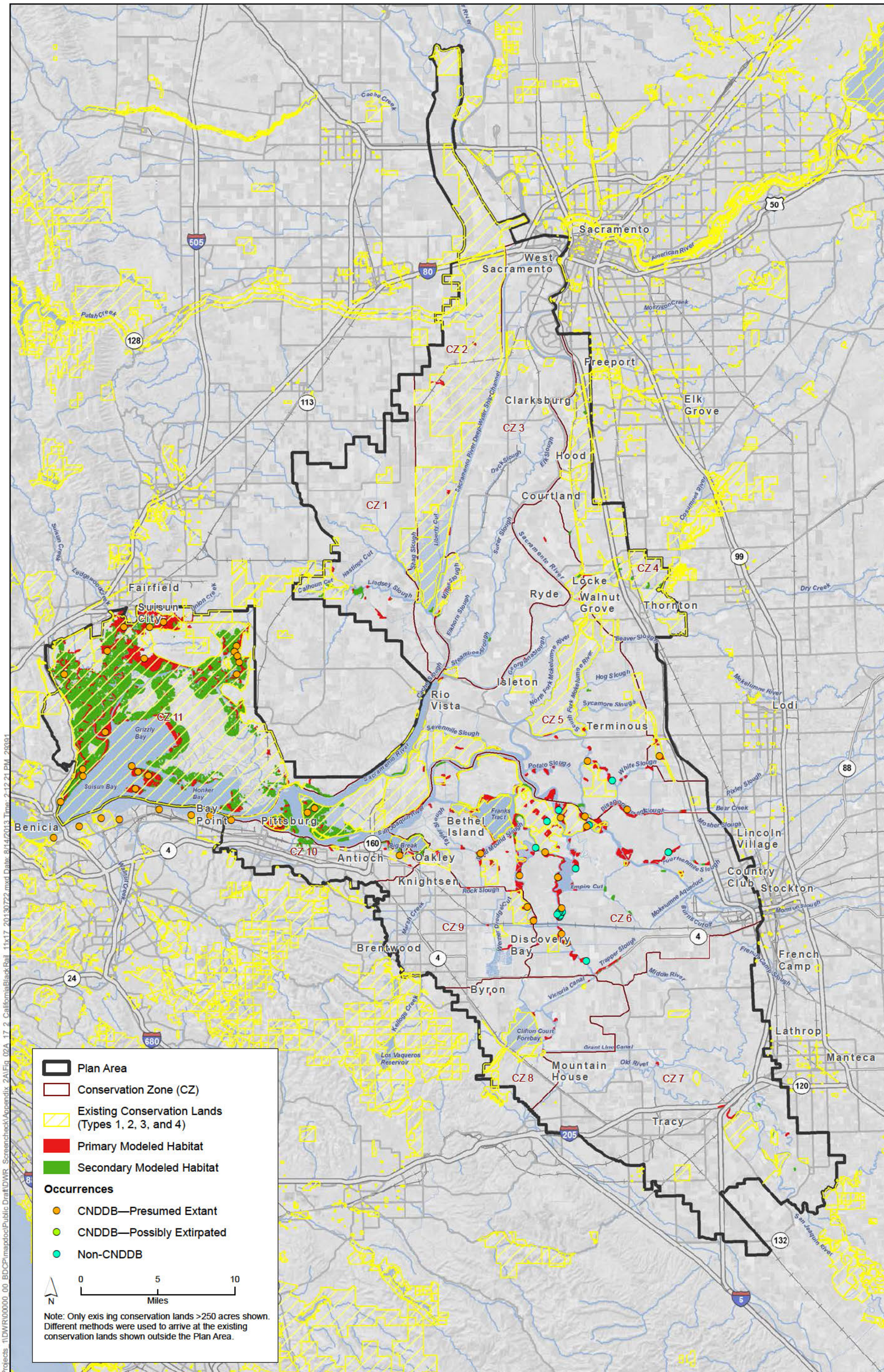
Spautz, Hilde. and Neil Clipperton. California Department of Fish and Game. May 15, 2013—Comments regarding revised black rail model.

Tsao, Danika. California Department of Water Resources. January 22, 2013—Email regarding black rail habitat model output.



GIS Data Sources: Occurrences, CNDDB June 2013;
Range, DFG WHR 2008.

Figure 2A.17-1
California Black Rail Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011;
Occurrences, CNDDB June 2013 and DHCCP 2009-2011

Figure 2A.17-2
California Black Rail Habitat Model and Recorded Occurrences

Appendix 2A.18
California Clapper Rail (*Rallus longirostris obsoletus*)

2A.18.1 Legal Status

The California clapper rail (*Rallus longirostris obsoletus*) is listed under the state and federal endangered species acts. The species was listed by the California Fish and Game Commission pursuant to the California Endangered Species Act (Fish and Game Code, Sections 2050 *et seq*.) on June 27, 1971, and by the U.S. Fish and Wildlife Service (USFWS) pursuant to the federal Endangered Species Act on October 13, 1970 (35 *Federal Register* [FR] 16047). The California clapper rail is also designated as a state Fully Protected species.

Critical habitat has not been designated for this species. Recovery is addressed under the USFWS (2010) *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (Draft Tidal Marsh Recovery Plan).

2A.18.2 Species Distribution and Status

2A.18.2.1 Range and Status

The California clapper rail is one of three subspecies of clapper rail (including light-footed clapper rail [*R. l. levipes*] and Yuma clapper rail [*R. l. yumanensis*]) listed as endangered under both state and federal endangered species acts.

The historical range of the California clapper rail extended in the coastal California tidal marshes from Humboldt Bay southward to Elkhorn Slough and Morro Bay, and in the estuarine marshes of San Francisco Bay and San Pablo Bay to the Carquinez Strait. Historically, the highest densities of California clapper rails existed in south San Francisco Bay (California Department of Water Resources 1994; U.S. Fish and Wildlife Service 1998; LSA Associates 2007).

The current distribution of the California clapper rail is limited to San Francisco Bay, San Pablo Bay, Suisun Bay, and tidal marshes associated with estuarine sloughs draining into these bays (Figure 2A.18-1) (U.S. Fish and Wildlife Service 1998; Albertson and Evens 2000; California Department of Fish and Game 2000). There are populations in all of the larger tidal marshes in south San Francisco Bay, and the distribution in the North Bay is patchy and discontinuous, primarily in small, isolated habitat fragments (U.S. Fish and Wildlife Service 1998). Small populations are widely distributed throughout San Pablo Bay and at various locations throughout the Suisun Marsh area (Carquinez Strait to Browns Island, including tidal marshes adjacent to Suisun, Honker, and Grizzly Bays) (U.S. Fish and Wildlife Service 1998).

California clapper rails were historically abundant throughout much of the San Francisco Bay estuary. Sport and market hunting significantly reduced populations in the late 19th and early 20th centuries. Population levels recovered following passage of the Migratory Bird Treaty Act in 1913; however, with increasing loss and fragmentation of tidal marshes for salt ponds, agricultural land, and bay fill, available habitat continued to be reduced.

Of the 193,800 acres of tidal marsh that bordered San Francisco Bay in 1850, about 30,100 acres currently remain (Dedrick 1989), representing an 84% reduction of available habitat.

In the early 1970s, California clapper rail populations were estimated at 4,200 to 6,000 individuals (Gill 1979). Loss and fragmentation of habitat continued over the following two decades, resulting in a total rail population of approximately 500 birds in 1991, 300 of which are estimated to occur in the south San Francisco Bay (Albertson and Evens 2000). Since then, management activities, including predator management, have resulted in population increases with the current estimate at approximately 450 to 600 pairs (Albertson and Evens 2000). Of these, 195 to 282 pairs are estimated to occur in the North San Francisco Bay population, which includes Suisun Marsh (Collins et al. 1994). However, population analysis from more recent surveys (2005 to 2008) (Liu et al. 2009) indicated a Suisun Marsh population of only about seven to thirteen individuals.

2A.18.2.2 Distribution and Status in the Plan Area

Reported occurrences of California clapper rail in the Plan Area are mapped in Figure 2A.18-2. Isolated patches of suitable habitat may occur in the Plan Area as far east as (but not including) Sherman Island.

Harvey (1980) reported the first California clapper rail in Suisun Marsh at Cutoff Slough in 1978, which extended their range east of the San Francisco Bay Area. A coordinated clapper rail survey was conducted by the San Francisco Bay Bird Observatory throughout the estuary between 1983 and 1986, resulting in two detections at the upper end of First Mallard Branch. Additional detections were made in 1986 at the Concord Naval Weapons Station (O'Neil 1988). Subsequent surveys, conducted by the California Department of Fish and Wildlife (CDFW) and the California Department of Water Resources (DWR), confirmed the presence of the species in several locations in Suisun Marsh including Hill Slough, Cutoff Slough, First and Second Mallard Branches, Suisun Slough from Goodyear Slough to Suisun Bay, Suisun Bay shoreline at the Suisun Marsh Reserve Fleet, Ryer Island, Point Edith Marsh, mouth of Boynton Slough, Union Creek, McCoy Creek and Suisun Slough at Morrow Island (California Department of Water Resources 1994) (Figure 2A.18-2). Liu et al. (2009) conducted additional surveys for California clapper rails in Suisun Marsh between 2005 and 2008 but found rails only at First Mallard Branch, Rush Ranch, and Goodyear Slough. They estimated the Carquinez Strait/Suisun Bay population at less than 13 individuals.

2A.18.3 Habitat Requirements and Special Considerations

Throughout their distribution, California clapper rails occur within a range of salt and brackish marshes. In south and central San Francisco Bay and along the perimeter of San Pablo Bay, rails typically inhabit salt marshes dominated by pickleweed (*Salicornia pacifica,* formerly *S. virginica*) and Pacific cordgrass (*Spartina foliosa*). Pacific cordgrass dominates the middle marsh zone throughout the south and central Bay (U.S. Fish and Wildlife Service 1998).

In the North Bay (Petaluma Marsh, Napa-Sonoma Marshes, Suisun Marsh), clapper rails also live in tidal brackish marshes that vary significantly in vegetation structure and composition. Use of brackish marshes by clapper rails is largely restricted to major sloughs and rivers of San Pablo Bay and Suisun Marsh, and along Coyote Creek in South San Francisco Bay. Clapper rails have rarely been recorded in nontidal marsh areas (U.S. Fish and Wildlife Service 1998).

Population density is higher in habitats that exceed 100 hectares (247 acres) in size. Other factors that affect density include proximity of suitable marsh habitats to each other, buffer areas between marsh and upland areas, marsh elevation, and hydrology (LSA Associates 2007). Rail densities are lower in more brackish habitats resulting from freshwater outflows, possibly due to the resulting change in vegetation (Collins et al. 1994).

2A.18.3.1 Nesting

In saline emergent wetlands, California clapper rails nest mostly in lower zones near tidal sloughs and where Pacific cordgrass is abundant (Harvey 1980; Zembal and Massey 1983; Eddleman and Conway 1998). In fresh or brackish water, clapper rails construct nests in dense cattail or bulrush (Harvey 1980; LSA Associates 2007). Clapper rails build a platform concealed by a canopy of woven cordgrass stems or pickleweed and gumweed (Harvey 1980). Nests are constructed only as high as necessary to prevent inundation while preserving a natural cover of vegetation. Clapper rail nests are described as a mass or heap of vegetation, deeply cupped and securely woven to the surrounding vegetation that allows for flotation during extreme tidal events. Zucca (1954) discovered that although the nests are somewhat buoyant, they do not remain intact through a series of high tides. Clapper rails also use dead drift vegetation as a platform (Harvey 1990). The vegetation used to construct clapper rail nests is partly determined by the time of the nesting and the tidal influence (Zucca 1954).

2A.18.3.2 Foraging

California clapper rails forage in higher marsh vegetation, along the vegetation and mudflat interface, and along tidal creeks.

2A.18.4 Life History

2A.18.4.1 Description

The clapper rail is a coot-sized bird that is generally gray-brown above and buff-cinnamon below with brownish-gray cheeks and black-and-white barred flanks. It has a short neck, slightly down-curved bill, and a short tail cocked upward, revealing a white patch. Overall length ranges from 33 to 48 centimeters (13 to 19 inches), and bill length is greater than 5 centimeters (2 inches) (Lewis and Garrison 1983). The sexes differ only in size with males slightly larger than females. Juveniles have a paler bill and darker plumage, with a gray body, black flanks and sides, and indistinct light streaking on flanks and undertail coverts. The California clapper rail is larger and of grayer plumage than the light-footed clapper rail and the Yuma clapper rail. Clapper rails are secretive, elusive, and difficult to observe in dense vegetation. Census data are usually taken by listening for vocal responses to recorded calls. When evading discovery, they typically freeze, hide in small sloughs or under overhangs, or run rapidly through vegetation or along slough bottoms. They prefer to walk or run over land rather than fly, and generally walk upright. When flushed, they normally fly only a short distance before landing. They can swim well, although only to cross sloughs or escape immediate threats at high tide (U.S. Fish and Wildlife Service 1998; LSA Associates 2007).

2A.18.4.2 Seasonal Patterns

The California clapper rail is apparently nonmigratory; however, some seasonal movements occur, probably in response to seasonal hydrologic changes and their effect on habitat availability and quality (Rozengurt et al. 1987; Collins et al. 1994). Dispersal after breeding has also been recorded in late fall and early winter (Orr 1939; Wilbur and Tomlinson 1976; Harvey unpublished data as cited in LSA Associates 2007). In general, these findings indicate that, while clapper rails tend to be more dispersed in the marsh following the nesting season, in general they appear to move very little between seasons and between nesting or core-use territories (Albertson 1995 as cited in LSA Associates 2007).

2A.18.4.3 Reproduction

The nesting season for California clapper rails begins mid-March and extends into August with peaks observed in early May and late June (Gill 1973; Harvey 1980). Clutch size ranges from six to ten eggs (Wilbur and Tomlinson 1976). Both the male and female incubate the eggs for approximately 18 to 29 days. Harvey (1980) reports hatching success of approximately 38% in the San Francisco Bay Area.

2A.18.4.4 Foraging Behavior and Diet

Clapper rails are most active in early morning and late evening, when they forage in marsh vegetation in and along creeks and mudflat edges. Most feeding is surface-gleaning and probing (Zembal and Fancher 1988), which occurs as the rail walks a few steps, probes with its beak into the mud up to eye level, walks a few more steps, then repeats the probing (Wilbur and Tomlinson 1976). Less frequent foraging behaviors include surface gleaning, fishing, and scavenging.

Moffitt (1941) examined the diet of California clapper rail by volumetric content of rail stomachs, finding ribbed horse mussels (*Ischadium demissum*, 56.5%), spiders (Lycosidae, 15%), seeds and hulls of cordgrass (14.6%), little macoma clam (*Macoma balthica*, 7.6%), mud crabs (3.2%), worn-out nassa (*Ilyanassa obsoletus*, 2%), insects, clam worms (*Nereis* spp.), and carrion (1.1%) (Eddleman and Conway 1998). Overall, the content included over 85% animal matter and 14.6% vegetable matter.

2A.18.5 Threats and Stressors

2A.18.5.1 Habitat Degradation

Loss and degradation of tidal marsh habitats continue to be the most significant threats to California clapper rail. Tidal marshes have been reduced by 84% since historical times (Dedrick 1989). While the loss of tidal marsh habitat through filling and diking has largely been curtailed, other current factors associated with declining populations include the conversion of salt marshes to brackish marshes as a result of freshwater discharges from sewage treatment plants, a progressive rise in sea level, invasion of runoff, industrial discharges, and sewage effluent (Williams 1985; Ohlendorf and Fleming 1988; Ohlendorf et al. 1989;Harvey 1990; Lonzarich et al. 1990; Foerster and Takekawa 1991; Leipsic-Baron 1992; California Department of Fish and Game 2000 as cited in LSA Associates 2007).

The suitability of many marshes for clapper rails is further limited, and in some cases precluded, by their small size, fragmentation, and lack of tidal channel systems and other microhabitat features. These limitations render much of the remaining tidal marsh acreage unsuitable or of low value for the species. In addition, tidal amplitudes are much greater in South San Francisco Bay than in San Pablo or Suisun Bays (Atwater et al. 1979). Consequently, many South Bay tidal marshes are completely submerged during high tides and lack sufficient escape habitat, likely resulting in nesting failures and high rates of predation. The reductions in carrying capacity in existing marshes necessitate the restoration of larger tracts of habitat throughout the current range of the species to maintain stable populations.

2A.18.5.2 Predation

California clapper rails are subject to heavy predation from nonnative species such as red fox (*Vulpes vulpes*), feral cat (*Felis catus*), and Norway rat (*Rattus norvegicus*), as well as various native mammals and raptors (Foerster et al. 1990; Albertson 1995 as cited in LSA Associates 2007; U.S. Fish and Wildlife Service 1998; California Department of Fish and Game 2000). The fragmentation of habitat through the construction of dikes and levees has increased and facilitated predation of clapper rails because terrestrial predators use these features as corridors to access clapper rail habitat (Foerster et al. 1990; Burkett and Lewis 1992). Urban development adjacent to marshland habitat has also increased predation by native predators such as raccoons, which thrive in urban areas, and raptors, which use electric power transmission lines as hunting perches (U.S. Fish and Wildlife Service 1998). Red foxes, the predator that may pose the most serious threat to California clapper rails, have not yet been detected in Suisun Marsh; however, river otters (*Lutra canadensis*) and mink (*Mustela vision*) are common in the Suisun Marsh area and could also prey on eggs or young of clapper rails (Albertson and Evens 2000; LSA Associates 2007).

2A.18.5.3 Mercury Contamination

Mercury contamination has been detected in eggs and embryos in the South San Francisco Bay (Schwarzbach et al. 2006). Mortality and embryonic developmental issues associated with mercury contamination could potentially have long-term effects on reproduction and recruitment.

2A.18.6 Relevant Conservation Efforts

Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to issues related to development and water quality. The Suisun Marsh Program (California Department of Water Resources 2012) summarizes the major agreements, management plans, and legislation that have directed management of Suisun Marsh since the mid-1970s. These efforts focus on the preservation of diked wetlands and restoration of tidal marsh habitats.

2A.18.6.1 The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974)

The California Legislature enacted the Suisun Marsh Preservation Act that protects the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

2A.18.6.2 Suisun Marsh Protection Plan (1976)

This plan was developed by the Bay Conservation and Development Commission and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the State of California purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

2A.18.6.3 The Suisun Marsh Protection Act (1977)

This act adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the Bay Conservation and Development Commission as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land in Suisun Marsh, when no longer managed for waterfowl, should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

2A.18.6.4 State Water Resources Control Board Water Rights Decision 1485 (1978)

The State Water Resources Control Board (State Water Board) adopted the Water Quality Control Plan for the Sacramento–San Joaquin Delta (Delta) and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from CDFW recommendations, which were based on the following elements:

- The relative value of marsh plants as food for ducks.
- The influence of soil salinity and other factors on distribution and growth of marsh plants.
- The relationships between channel water salinity and soil salinity.

CDFW concluded that improved management practices, improved drainage, water control facilities, and adequate water quality were needed to achieve desired soil salinity conditions for waterfowl food plants.

2A.18.6.5 Plan of Protection for Suisun Marsh (1984)

DWR and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) developed and began implementing the Plan of Protection in accordance with Water Rights Decision 1485. The implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant State Water Project (SWP)/ Central Valley Project (CVP) storage releases estimated as much as 2 million acre-feet in dry/critical water years. The six-phase plan was the programmatic blue print (required by the State Water Board and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

2A.18.6.6 Suisun Marsh Preservation Agreement (1987)

This contractual agreement between DWR, Reclamation, CDFW, and Suisun Resource Conservation District contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP/CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and Reclamation to meet salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in Suisun Marsh.

2A.18.6.7 Bay-Delta Accord (1994)

On December 15, 1994, state and federal agencies, working with agricultural, environmental and urban stakeholders, reached agreement on water quality standards and related provisions that would remain in effect for three years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include:

- Springtime export limits expressed as a percentage of Delta inflow.
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life.
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon.
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

2A.18.6.8 State Water Resources Control Board Water Quality Control Plan (1995 to 1998)

In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May 1995, the State Water Board modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the Suisun Marsh Preservation Agreement agreed could be mitigated by more active water control by landowners.

2A.18.6.9 State Water Resources Control Board Water Rights Decision 1641 (1999)

The State Water Board issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to Suisun Marsh. DWR proposed that the State Water Board adopt the Amendment Three actions for Suisun Marsh in this decision. However, the State Water Board was unable to adopt Amendment Three actions because the Section 7 consultation with USFWS had not concluded.

However, the State Water Board did relieve Reclamation and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

2A.18.6.10 Suisun Marsh Charter Implementation Plan (2001)

The Suisun Marsh Charter was completed in 2001 and commenced development of an Implementation Plan. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan including coordinated water quality, endangered species, and heritage value protection in Suisun Marsh.

2A.18.6.11 Habitat Management, Preservation, and Restoration Plan (2010)

The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that would balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement, and other management and restoration programs in Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based on voluntary participation by private landowners.

In addition, several facilities have been constructed in Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat.

- Roaring River Distribution System (1979 to 1980)
- Morrow Island Distribution System (1979 to 1980)
- Goodyear Slough Outfall (1979 to 1980)
- Suisun Marsh Salinity Control Gates (1988)
- Cygnus and Lower Joice Facilities (1991)

Several tidal marsh restoration projects are also planned or being implemented within the range of the California clapper rail. These projects, implemented through the direction or support of the San Francisco Bay National Wildlife Refuge, National Biological Service, East Bay Regional Park District, Regional Water Quality Control Board, CDFW, and the City of San Jose include the following.

- Restoration of the 1,500-acre Napa Marsh Unit in the Napa River in the north bay.
- Restoration of the Knapp Property, a 452-acre former salt pond in the Alviso area, on the edge of the bay, between Alviso and Guadalupe Sloughs.
- Enhancement of the 325-acre Oro Loma Marsh, an area of diked salt marsh and adjacent uplands located along the shore of Hayward. The area will be restored to tidal marsh and seasonal wetland habitat.
- Restoration of the Baumberg Tract, an 835-acre inactive salt evaporator in Hayward, to tidal marsh and seasonal wetlands.
- Restoration of the Moseley Tract, located just north of the west approach to the Dumbarton Bridge from the Port of Oakland.

The California clapper rail is also proposed for coverage under the *Solano Multispecies Habitat Conservation Plan* (Solano County Water Agency 2009).

2A.18.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.18.7.1 GIS Model Data Sources

The California clapper rail model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005), and land use survey of the Delta and Suisun Marsh area - version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable California clapper rail habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.18.7.2 Habitat Model Description

Modeled habitat includes all *Salicornia*-dominated natural seasonal wetlands and *Schoenoplectus (*formerly *Scirpus)*/*Typha*-dominated tidal freshwater emergent wetlands located west of Sherman Island. All *Salicornia*-dominated habitats were considered primary habitat, while *Schoenoplectus, Typha*, *Atriplex*, and upland transitional zones within 150 feet of the tidal wetland edge were classified separately as secondary habitat. All managed wetlands were excluded from the habitat model. Vegetation types designated as species habitat in this model correspond to the mapped vegetation associations in the BDCP geographic information systems (GIS) vegetation data layer. A 1.6-acre minimum mapping unit was applied to the primary and secondary model components. A GIS constraint layer was developed to limit suitable habitat to Suisun Marsh and areas west of the western edge of Sherman Island.

The California clapper rail primary habitat model includes the following vegetation types from the BDCP GIS composite vegetation layer only when those types are mapped within the tidal brackish emergent wetland and tidal perennial aquatic natural communities.

- *Distichlis*/*Salicornia*
- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia*/*Cotula*
- *Salicornia*/*Atriplex*
- *Salicornia*/annual grasses
- *Salicornia*/*Crypsis*
- *Salicornia*/*Polygonum–Xanthium–Echinochloa*
- *Salicornia*/*Sesuvium*

The California clapper rail secondary habitat model includes the following vegetation types from the BDCP GIS composite vegetation layer only when those types are mapped within the tidal brackish emergent wetland and tidal perennial aquatic natural communities.

- Narrow-leaf cattail (*Typha angustifolia*)
- *Typha angustifoli–Distichlis spicata*
- *Scirpus* (*californicus* or *acutus*)/*Rosa*
- *Scirpus* (*californicus* or *acutus*)/wetland
- *Scirpus* (*californicus* or *acutus*)–*Typha* sp.
- *Scirpus americanus* (generic)
- *Scirpus americanus*/*Lepidium*
- *Scirpus americanus*/*Potentilla*
- *Scirpus californicus*/*S. acutus*
- *Typha angustifolia*/*S. americanus*
- *Typha* sp. (generic)
- Bulrush–cattail fresh water marsh NFD super alliance
- *Scirpus americanus*/*S. Californicus–S. acutus*
- *Typha angustifolia*/*Phragmites*
- *Typha angustifolia*/*Polygonum–Xanthium–Echinochloa*

For those areas in the Delta but west of Sherman Island, the California clapper rail secondary habitat includes the following types from the BDCP GIS composite vegetation layer.

- Mixed *Schoenoplectus* (formerly *Scirpus*) mapping unit
- Mixed *Scirpus*/floating aquatics complex
- Mixed *Scirpus*/submerged aquatics complex
- Hardstem bulrush (*Scirpus acutus*)
- *Scirpus acutus* pure
- *Scirpus acutus–Typha angustifolia*
- *Scirpus acutus –Typha latifolia*
- *Scirpus acutus* –(*Typha latifolia*)–*Phragmites australis*
- California bulrush (*Scirpus californicus*)
- *Scirpus californicus–Eichhornia crassipes*
- *Scirpus californicus–Scirpus acutus*
- American bulrush (*Scirpus americanus*)
- Narrow-leaf cattail (*Typha angustifolia*)
- *Typha angustifolia–Distichlis spicata*

And the following upland types (secondary habitat) that occur within 150 feet of the tidal wetland edge.

- Annual grasses ,generic
- Annual grasses/weeds
- Ruderal herbaceous grasses and forbs
- California annual grasslands–herbaceous
- Vernal pools
- *Atriplex lentiformis* (generic)
- *Atriplex triangularis*
- *Atriplex triangularis* (generic)
- *Atriplex*/annual grasses
- *Atriplex*/*Distichlis*
- *Atriplex*/*S. maritimus*
- *Atriplex*/*Sesuvium*
- *Baccharis*/annual grasses
- *Bromus diandrus*–*Bromus hordeaceus*
- *Bromus* spp./*Hordeum*
- *Hordeum*/*Lolium*
- Perennial grass
- Degraded vernal pool complex–California annual grasslands– herbaceous
- Degraded vernal pool complex–Italian ryegrass (*Lolium multiflorum*)
- Degraded vernal pool complex–rabbitsfoot grass (*Polygpogon maritimus*)
- Degraded vernal pool complex–ruderal herbaceous grasses and forbs
- Degraded vernal pool complex–vernal pools

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. In the new analysis areas, the following natural communities are assumed to provide California clapper rail habitat west of Sherman Island.

- Nontidal freshwater perennial emergent wetland
- Tidal brackish emergent wetland
- Tidal freshwater emergent wetland

2A.18.7.3 Assumptions

- **Assumption**: California clapper rail habitat in the Plan Area is geographically constrained to west of Sherman Island.

  Rationale: Historical and current records of this species indicate that its known distribution includes Suisun Marsh and extends eastward to west of Sherman Island (Figure 2A.18-2). Patches of suitable habitat extend into the Plan Area in the vicinity of Collinsville and Antioch, though no occurrences have been recorded there.

- **Assumption:** California clapper rail habitat is restricted to the vegetation types described in Section 2A.18.7.2, *Habitat Model Description*.

  Rationale: California clapper rails are found in a range of salt and brackish marshes. Typical habitat consists of dense pickleweed and Pacific cordgrass (*Spartina foliosa*)-dominated saline tidal marshes (Zucca 1954; Harvey 1980). There is also reported use of *Schoenoplectus*/*Typha*-dominated brackish marshes in the North Bay (Petaluma Marsh, Napa-Sonoma Marshes, Suisun Marsh) (U.S. Fish and Wildlife Service 1998). Based on current understanding of California clapper rail ecology, low marsh (dominated by *Schoenoplectus, Typha,* and *Atriplex*) and upland transitional zones (within 150 feet of the tidal wetland edge) are considered to be secondary habitat. Suitability of habitat may also be dependent on other factors, such as patch size, tidal connectivity (diked marshes), and proximity to other land uses. However, there is insufficient data on the effects of these issues on potential occupancy particularly with respect to determining minimum requirements. Thus, potential habitat for the California clapper rail is not further restricted in this model based on these factors. As a result, this model likely overestimates the extent of suitable habitat for California clapper rail in the Plan Area.

2A.18.8 Recovery Goals

The *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* was finalized in 1984 but has since been replaced by the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010). Critical habitat has not been designated for this species. Critical habitat has not been designated for this species.

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the California clapper rail as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to recover the species. Recovery goals are addressed under the Draft Tidal Marsh Recovery Plan (U.S. Fish and Wildlife Service 2010).

2A.18.9 References Cited

2A.18.9.1 Literature Cited

Albertson, J. D. 1995. *Ecology of the California Clapper Rail in South San Francisco Bay.* M.S. Thesis, San Francisco State University, San Francisco, CA. In: LSA Associates. 2007. California Clapper Rail. Working Draft 2.2, *Natural Community and Species Accounts, Solano Multispecies Habitat Conservation Plan.* Solano County Water Agency.

Albertson, J. D. and J. G. Evens. 2000. California Clapper Rail. In: P.R. Olofson (ed.). *Baylands Ecosystem Species and Community Profiles: Life Histories and Environmental Requirements of Key Plants, Fish and Wildlife*. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. Oakland, CA: San Francisco Bay Regional Water Quality Control Board. Pages 332–341.

Atwater, B. F., S. C. Conard, I. N. Dowden, C. W. Hedel, R. L. MacDonald, and W. Savage. 1979. History, Landforms, and Vegetation of the Estuary's Tidal Marshes. In: T. J. Conomos (ed.), *San Francisco Bay: The Urbanized Estuary.* Proceedings of the 58th Annual Meeting of the Pacific Division of the American Association for the Advancement of Science, Golden Gate Park, San Francisco, CA. Pages 347–385.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

Burkett, E. E. and J. C. Lewis. 1992. The Spread of the Red Fox. *Outdoor California* 53(2):1–6.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2000. *The Status of Rare, Threatened, and Endangered Animals and Plants in California, California Clapper Rail*. Sacramento, CA.

California Department of Water Resources. 1994. *Summary of Sensitive Plant and Wildlife Resources in Suisun Marsh during Water Years 1984–1994*. Sacramento, CA: Environmental Services Office.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area -* Version 3 GIS dataset. Sacramento, CA.

California Department of Water Resources. 2012. *Suisun Marsh Program*. Last revised: December 22, 2009. Available: <http://www.water.ca.gov/suisun/program/>. Accessed: June 12, 2012.

Collins, J., J. G. Evens, and B. Grewell. 1994. *A Synoptic Survey of the Distribution and Abundance of the California Clapper Rail,* Rallus Longirostris Obsoletus, *in the Northern Reaches of the San Francisco Estuary during the 1992 and 1993 Breeding Seasons.* Technical Report to California Department of Fish and Game.

Dedrick, K. G. 1989. San Francisco Bay Tidal Marshland Acreages: Recent and Historic Values. *Proceedings of the 6th Symposium in Coastal and Ocean Management (Coastal Zone 1989).* American Society of Engineers. Pages 383–398.

Eddleman, W. R. and C. J. Conway. 1998. *Clapper Rail (*Rallus longirostris*).* In: A. Poole and F. Gill, (eds.). *The Birds of North America 340*. Philadelphia, PA: The Birds of North America, Inc.,

Foerster, K. S. and J. E. Takekawa. 1991. *San Francisco Bay National Wildlife Refuge Predator Management Plan and Environmental Assessment*. Fremont, CA: San Francisco Bay National Wildlife Refuge.

Foerster, K. S., J. E. Takekawa, and J. D. Albertson. 1990. *Breeding Density, Nesting Habitat, and Predators of the California Clapper Rail.* Unpublished Report Number SFBNWR-116400-90-1, Fremont, CA: San Francisco Bay National Wildlife Refuge.

Gill, R. Jr. 1973. *The Breeding Birds of the South San Francisco Bay Estuary*. MA thesis. San Jose State University, CA.

Gill, R. Jr. 1979. *Status and Distribution of the California Clapper Rail (*Rallus Longirostris Obsoletus*)*. California Fish and Game. 65:36–49.

Harvey, T. E. 1980. *California Clapper Rail Survey, 1978–1979*. Special Wildland Investment. Final report E-W-3, Job V-1-8. Sacramento, CA: California Department of Fish and Game.

Harvey, T. E. 1990. *California's Wildlife, Birds, Clapper Rail*. California Wildlife Habitat Relationships System. Sacramento, CA: California Department of Fish and Game, California Interagency Wildlife Task Group.

Harvey, T. E. Unpublished data . In: LSA Associates. 2007. California Clapper Rail. Working Draft 2.2, *Natural Community and Species Accounts, Solano Multispecies Habitat Conservation Plan*. Solano County Water Agency.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Leipsic-Baron, T. 1992. *Anthropogenic Influences on the Biogeography of Clapper Rails in California*. MS thesis. University of California, Los Angeles.

Lewis, J. C. and R. L. Garrison. 1983. *Habitat Suitability Index Models: Clapper Rail.* Washington, DC: U.S. Fish and Wildlife Service.

Liu, L., J. Wood, N. Nur, D. Stralberg, and M. Herzog. 2009. *California Clapper Rail* (Rallus longirostris obsoletus) *Population Monitoring: 2005–2008*. Prepared by PRBO Conservation Science, Petaluma, CA. Prepared for California Department of Fish and Game. Available: <http://www.prbo.org/cms/docs/wetlands/clra_dfg_report_p0630020_final.pdf>.

Lonzarich, D. G., T. E. Harvey, and J. E. Takekawa. 1990. Trace Element and Organochlorine Concentrations in California Clapper Rail (*Rallus longirostris obsoletus*) Eggs. *Archives of Environment Contamination Toxicology* 23:47–153.

LSA Associates. 2007. California Clapper Rail. Working Draft 2.2, Natural Community and Species Accounts. *Solano Multispecies Habitat Conservation Plan.* Vacaville, CA: Solano County Water Agency.

Moffitt, J. 1941. Notes on the Food of the California Clapper Rail. *Condor* 43:270–273.

O'Neil, L. J. 1988. *Feasibility Study of Contamination Remediation at Naval Weapons Station, Concord, California, Vol. II: Biological Assessment.* Misc. Paper EL-86–3. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Ohlendorf, H. M. and W. J. Fleming. 1988. Birds and Environmental Contaminants in San Francisco and Chesapeake Bays. *Marine Pollution Bulletin* 19:487–495.

Ohlendorf, H. M., K. C. Marois, R. W. Lowe, T. E. Harvey, and P. R. Kelly. 1989. Environmental Contaminants and Diving Ducks in San Francisco Bay. In: *Selenium and Agricultural Drainage: Proceedings of the Fourth Selenium Symposium*. Berkeley, CA. March 21. Sausalito, CA: The Bay Institute of San Francisco. Pages 60–69.

Orr, R. T. 1939. Fall Wanderings of Clapper Rails. *Condor* 41:151–152.

Rozengurt, M. A., M. J. Herz, and S. Feld. 1987. *Analysis of the Difference of Water Withdrawals on Runoff to the Delta, San Francisco Bay (1921–1983).* Tiburon, CA: Tiburon Center for Environmental Studies.

Schwarzbach, S. E., J. D. Albertson, and C. M. Thomas. 2006. Effects of Predation, Flooding, and Contamination on Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. *Auk* 123:45–60.

Solano County Water Agency. 2009. *Solano Multispecies Habitat Conservation Plan.* Final Administrative Draft. June 15. Available: <http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx>. Accessed: December 22, 2011.

TAIC. 2008. *Yolo County Regional Vegetation*. July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program*. Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

U.S. Fish and Wildlife Service. 1998. *California Clapper Rail* (Rallus longirostris obsoletus). Available: <http://www.fws.gov/sacramento/es/animal_spp_acct/ca_clapper_rail.pdf>.

U.S. Fish and Wildlife Service. 2010. *Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California*. Sacramento, CA. Available: <http://www.fws.gov/ecos/ajax/docs/recovery_plan/TMRP_Intro_1.pdf>. Accessed: August 3, 2012.

Wilbur, S. R. and R. E. Tomlinson.1976. *The Literature of Western Clapper Rails.* Wildlife Research Report Number 194. Washington, D.C.: U.S. Fish and Wildlife Service.

Williams, P. B. 1985. *An Overview of the Impact of Accelerated Sea Level Rise on San Francisco Bay.* Report to the Bay Conservation and Development Commission, San Francisco, CA.

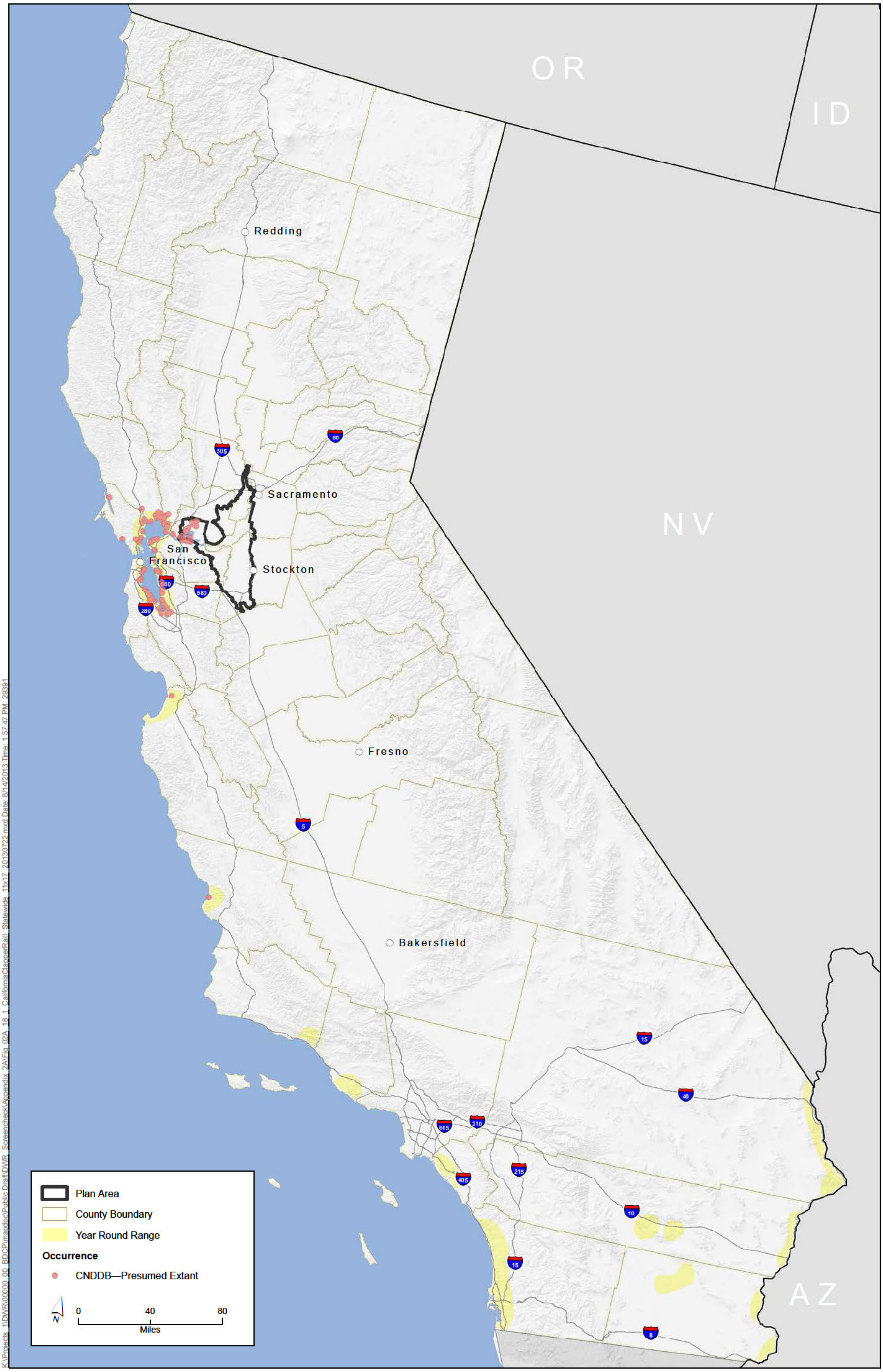
Zembal, R. and B. W. Massey. 1983. The Light-Footed Clapper Rail: Distribution, Nesting Strategies, and Management. *Cal-Neva Wildlife Transactions*. 1983:97–103.

Zembal, R. and J. M. Fancher. 1988. Foraging Behavior and Foods of the Light-footed Clapper Rail. *Condor* 90:959–962.

Zucca, J. J. 1954. A Study of the California Clapper Rail. *Wasmann Journal of Biology* 12:135–153.

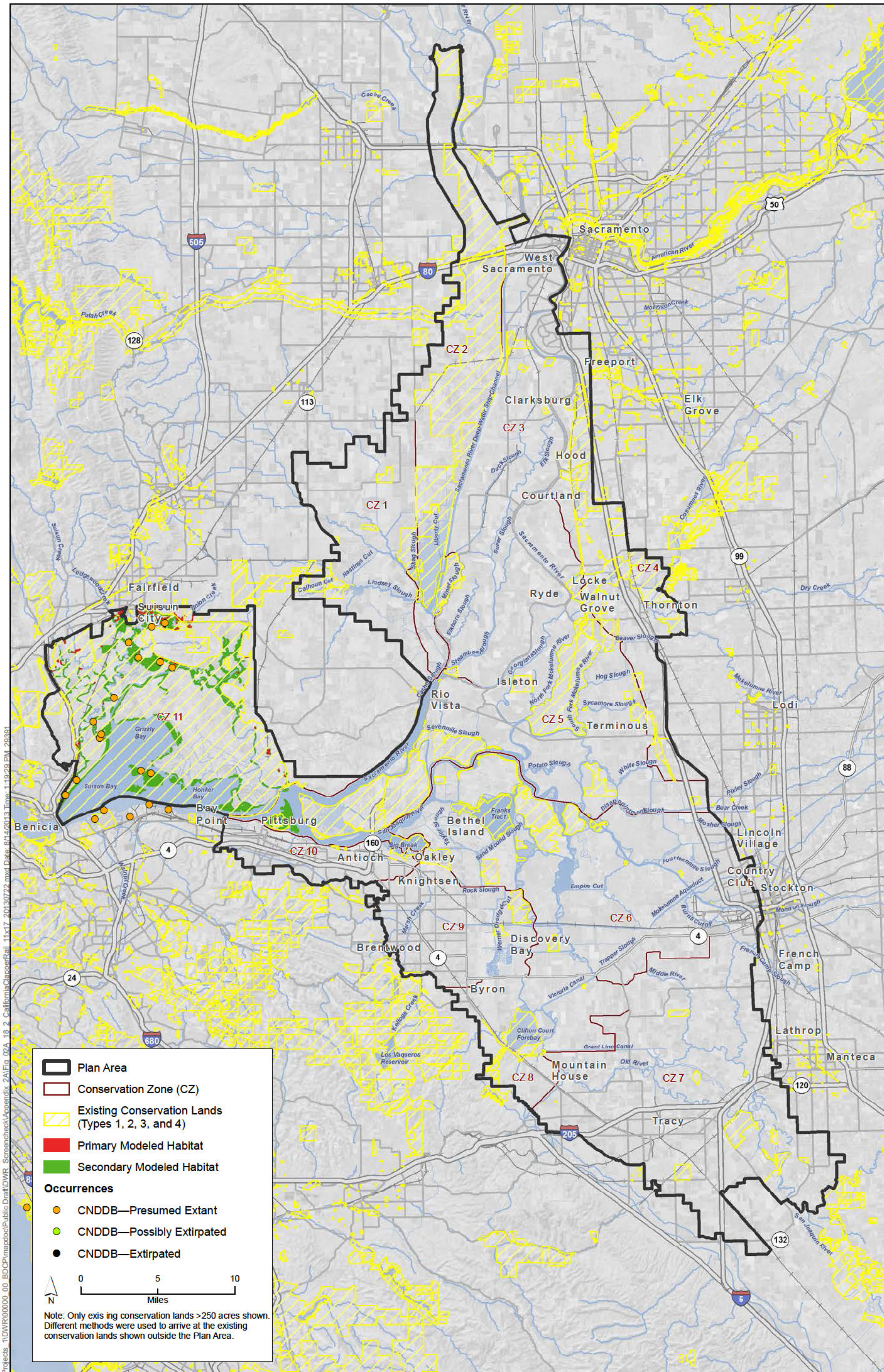
2A.18.9.2 Federal Register Notices Cited

35 FR 16047. 1970. United States List of Endangered Native Fish and Wildlife. *Federal Register* 35:16047.



GIS Data Sources: Occurrences, CNDDB June 2013;
Range, DFG WHR 2008

Figure 2A.18-1
California Clapper Rail Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013.

Figure 2A.18-2
California Clapper Rail Habitat Model and Recorded Occurrences

Appendix 2A.19
Greater Sandhill Crane (*Grus canadensis tabida*)

2A.19.1 Legal Status

The greater sandhill crane (*Grus canadensis tabida*) is listed as a state-threatened species under the California Endangered Species Act (Fish and Game Code, Sections 2050 et seq.). The species was listed by the California Fish and Game Commission in 1983. The greater sandhill crane is also designated as a state Fully Protected species. The greater sandhill crane has no federal regulatory status. Critical habitat has not been designated for this species.

2A.19.2 Species Distribution and Status

2A.19.2.1 Range and Status

The greater sandhill crane is one of six subspecies of sandhill crane in North America; three of which are nonmigratory and occupy ranges in the southeastern United States and Cuba (Littlefield and Ivey 2000). The remaining three are migratory and include the lesser and greater subspecies, both of which are further divided into distinct populations. The greater sandhill crane is divided into five migratory populations, all of which return to the same breeding territory and wintering sites each year. These include the Eastern Population, the Prairie Population, the Rocky Mountain Population, the Lower Colorado River Population, and the Central Valley Population. The Central Valley Population breeds in northeastern California (Figure 2A.19-1), central and eastern Oregon, southwestern Washington, and southern British Columbia; and winters in the Central Valley of California (Littlefield and Ivey 2000).

2A.19.2.1.1 Breeding Range

There are an estimated 500,000 sandhill cranes in North America, of which an estimated 62,600 are greater sandhill cranes. An estimated 8,500 of these belong to the Central Valley Population (Littlefield and Ivey 2000). The most recent breeding surveys have recorded 1,151 breeding pairs in Oregon, 465 breeding pairs in California, 20 pairs in Washington, and 11 pairs in Nevada (Engler and Brady 2000 as cited in Ivey and Herziger 2001; Ivey and Herziger 2000). The exact number of breeding pairs in British Columbia remains unknown; however, Littlefield and Ivey (2000) estimate approximately 2,500 individuals.

In California, the breeding distribution is restricted to a six-county area in the northeastern corner of the state, including Siskiyou, Modoc, Shasta, Lassen, Plumas, and Sierra Counties (Figure 2A.19-1) (Littlefield 1982, 1989; Ivey and Herziger 2001). Ivey and Herziger (2001) conducted the most recent surveys and found that the greatest number of breeding pairs are in Modoc County (54%) followed by Lassen County (26%). A total of 91% of the breeding pairs were found in Modoc, Lassen, and Siskiyou Counties (Ivey and Herziger 2001).

Prior to the early 1970s, surveys were insufficient to accurately estimate the breeding population of greater sandhill crane; however, major population declines have been noted and attributed to the widespread destruction of essential wetland habitats between 1870 and 1915 (Walkinshaw 1949). The first comprehensive surveys were conducted in 1971 (112 pairs), followed by surveys in 1981 (129 pairs) and 1988 (170 pairs), indicating a positive trend in the breeding population during that period (Littlefield 1982, 1989). The next subsequent, and most recent, survey was conducted in 2000 (Ivey and Herziger 2001) when 465 pairs were reported, an increase of 68% since the 1988 survey. Much of this increase may be attributable to protection of traditional nesting areas on state and national wildlife refuges, lack of hunting, and a variety of management practices.

2A.19.2.1.2 Wintering Range

Pogson and Lindstedt (1991) identified eight distinct wintering locations in the Central Valley from Chico/Butte Sink in the north to Pixley National Wildlife Refuge near Delano in the south, with over 95% in the Sacramento Valley between Butte Sink and the Sacramento–San Joaquin River Delta (Delta) (Figure 2A.19-1). Use varies seasonally within this area probably as a function of the winter flooding regime and food resources. The Butte Sink has been reported to support a large segment of the population (more than 50%) during October and November. Use then shifts to the Delta and the Cosumnes River floodplain during December and January, where an estimated two-thirds of the population resides the remainder of the winter (Pogson and Lindstedt 1988; Littlefield and Ivey 2000).

The first exhaustive winter survey was conducted in the mid-1980s (Pogson and Lindstedt 1988), which estimated a wintering population of 6,000 birds. This was adjusted in the early 1990s to 8,500 birds as a result of additional follow-up survey work in the Sacramento Valley (Littlefield 1993). Although portions of the wintering population have been monitored periodically prior to and since the mid-1980s, no other comprehensive survey has been conducted and information has been insufficient to reliably detect trends.

2A.19.2.2 Distribution and Status in the Plan Area

Figure 2A.19-2 illustrates the current winter distribution of the of the greater sandhill crane in the Plan Area as defined by Ivey (pers. comm.). The entire Delta winter range of the species (defined here as including the Delta and Cosumnes River floodplain), as defined by Pogson and Lindstedt (1988), Littlefield and Ivey (2000), and most recently by Ivey (pers. comm.) occurs within the Plan Area with the exception of the eastern portion of the Cosumnes River floodplain area. Greater sandhill cranes begin arriving in the Delta in October and from 3,000 to 4,000 cranes are in the Delta region in October and November. As noted above, the population peaks in December and January as cranes move into the Delta from the Butte Basin. An estimated two-thirds (from 5,000 to 6,000 cranes) of the population resides in the Delta the remainder of the winter (Pogson and Lindstedt 1988; Littlefield and Ivey 2000).

The current Delta greater sandhill crane winter distribution, as illustrated in Figure 2A.19-2 is a subset of the Crane Use Area, which supports wintering greater and lesser sandhill cranes (Littlefield and Ivey 2000). The greater sandhill crane winter distribution is based on the proximity to known greater sandhill crane nighttime roosting sites. Ivey (pers. comm.) provided recent information on active roost sites, and on the basis of radiotelemetry information has determined that greater sandhill cranes restrict their daytime movements to within approximately 4 miles of roost sites. Therefore, the current winter distribution of the greater sandhill crane in the Delta is defined as a 4-mile radius surrounding known current roosting sites. The distribution incorporates lands in Conservation Zones 3, 4, 5, and 6.

While populations have shifted over the years in response to changing agricultural patterns, particularly the increase of vineyards, the islands and tracts traditionally receiving the highest crane use include Staten Island, Terminous Island, Canal Ranch, and New Hope Tract. Other areas receive less and from occasional to regular use, including Bouldin Island, Empire Tract, King Island, Grand Island, Tyler Island, Ryer Island, Brannan Island, Twitchell Island, Bradford Island, Venice Island, Manderville Island, and Webb, Holland, and Palm Tracts (Pogson 1990; Littlefield and Ivey 2000). More recently, greater sandhill cranes have also been found occasionally using Ridge, Bacon, and Roberts Islands (Bradbury pers. comm.); and on lands west of the Sacramento River, in the west Delta in the vicinity of Sherman Island, and in the vicinity of the Stone Lakes National Wildlife Refuge (Ivey pers. comm.). As noted above, areas receiving the highest use are generally associated with the location of active roost sites. Highest levels of use are typically within approximately 2 miles of known roosts, and use (measured as a function of observed crane density) decreases beyond approximately 2 miles from roosts (Ivey pers. comm.).

The Cosumnes River floodplain, much of it protected within The Nature Conservancy's Cosumnes River Preserve, also supports significant winter crane use. Use may have increased in this area as continued conversion to vineyards on Delta Islands has reduced habitat availability in that area (Littlefield and Ivey 2000).

As noted, crane use is entirely dependent on agricultural crop patterns. Conversion to unsuitable crop types effectively eliminates crane habitat. Over the last two decades, a substantial amount of conversion to vineyards has occurred on Delta islands and is considered among the most important conservation issues for the greater sandhill crane (Littlefield and Ivey 2000). Several important traditionally used areas, such as portions of the Thompson-Folger Ranch along Peltier Road, have been converted to vineyards. Habitat loss from agricultural conversion, urbanization, and disturbances from increasing recreation activities in some areas threaten the long-term sustainability of key wintering areas for this species.

2A.19.3 Habitat Requirements and Special Considerations

Greater sandhill cranes are primarily birds of open freshwater wetlands. In California, nesting typically occurs in open grazed meadows. Most of these are bulrush or sedge meadows adjacent to grasslands or short vegetation uplands (Littlefield and Ryder 1968; Littlefield 1982). While breeding sites occur on state and federal refuges or U.S. Forest Service lands, more than 60% occur on private lands (Ivey and Herziger 2001).

Wintering habitat is found almost entirely in cultivated lands, and to a lesser extent in managed wetlands and grasslands. Greater sandhill cranes, like many birds, exhibit a high degree of fidelity to their wintering grounds and to specific roosting and foraging habitat areas (Littlefield and Ivey 2000). Wintering habitat consists of three primary elements: foraging habitat, loafing habitat, and roosting habitat. There are two principal foraging habitat types used during winter. In the Delta, harvested corn fields are the most commonly used foraging habitat along with winter wheat, alfalfa, pasture, and fallow fields (Pogson and Lindstedt 1988). Ivey (pers. comm. in Sacramento County 2008) rated foraging habitat cover types in the Delta region in the following order of importance to greater sandhill cranes: harvested corn, winter wheat, irrigated pasture, and alfalfa fields. In the Butte Basin, harvested rice fields are the most commonly used foraging habitat along with winter wheat, harvested and unharvested corn, fallow fields, and grasslands (Pogson and Lindstedt 1988; Littlefield 2002).

Loafing generally occurs midday when birds loosely congregate along agricultural field borders, levees, rice-checks, ditches, managed wetlands, or in alfalfa fields or pastures. Cranes will often loaf in rocky uplands or along gravel roads where they collect grit, which is important in the digestion of grain seeds. During the late afternoon and evening, cranes begin to congregate into large, dense communal groups where they remain until the following morning. Providing protection from predators during the night, roost sites are typically within 2 to 4 miles of foraging and loafing areas (Ivey pers. comm.) and thus available roosting sites are an essential component of winter habitat. Roosting habitat typically consists of shallowly flooded open fields of variable size (1 to 300 acres) or wetlands interspersed with uplands. Water depth is important and averages 4.5 inches. Littlefield (1993) reported cranes abandoning roosting sites when water depth reached 8 to 11 inches. He recommended roost sites be a minimum of 20 acres in size with water maintained from early September to mid-March. If properly managed, roost sites are often used for many years.

Greater sandhill cranes are considered intolerant of excessive human disturbances and the level of disturbance may play a role in habitat selection (Lovvorn and Kirkpatrick 1981). Excessive disturbances have caused cranes to abandon foraging and roosting sites; and repeated disturbance may affect their ability to feed and store the energy needed for survival. Ivey and Herziger (2003) documented disturbances of greater sandhill cranes on Staten Island, a high-use area, and found that aircraft, vehicles, hunting, and recreational activities (e.g., birding, walking, horseback riding, bicycling, boating) can cause cranes to run or fly away. Ivey (pers. comm. in Sacramento County 2008) found that cranes generally avoid suitable agricultural foraging habitat near occupied dwellings, and foraging areas within 100 yards of occupied dwellings should not be considered suitable (Sacramento County 2008).

2A.19.4 Life History

2A.19.4.1 Description

The greater sandhill crane is the largest of the six sandhill crane subspecies. It stands up to 4.9 feet tall and has a wing span from 5.9 to 6.9 feet. Adult males and females are similar in appearance with gray plumage, whitish face, chin, and upper throat, and a bare red forehead and crown. Greater sandhill cranes sometimes preen iron-rich mud into their feathers leaving a rusty-brown hue that can last throughout the summer months and sometimes remains detectable during the early winter. Juveniles are easily detectable through their first winter by their smaller size and cinnamon-brown plumage, which changes to gray during their first year (Tacha et al. 1992).

2A.19.4.2 Seasonal Patterns

Nesting generally begins in April and May and extends from July through August. By September, the Central Valley population begins their migration and arrives onto the wintering grounds by late September, where the cranes remain until approximately late February to early March, when they begin their northward migration back to the breeding grounds (Pogson 1990; Tacha et al. 1992). Local winter movements continue throughout the winter season in response to changes in flooded habitat and available food resources. For example, Pogson and Lindstedt (1988) and Littlefield

(2002) report extensive use of the Butte Basin during the early part of the winter season in October and November and movement of a large segment of the population into the Delta during December and January.

2A.19.4.3 Nest Site Selection

Nesting areas are selected on the basis of meadow size, flooding regime, condition of meadow and presence of cattle, vegetation composition, available food resources, and proximity to human disturbances (Armbruster 1987). Nests are usually constructed as mounds in shallow water (generally less than 12 inches deep), typically in wetland vegetation. The nest is constructed by plucking and stacking the dominant vegetation in the nesting area to form a mound. These are often very large, 2 to 3 feet high and up to 6 feet in diameter. They often use all of the vegetation from several feet around the nest creating a distinctive circular unvegetated ring around the nest mound (Smith 1999). Nests are also constructed on dry ground.

2A.19.4.4 Reproduction

Females usually lay two eggs. Both the male and female incubate the eggs; incubation lasts from 29 to 32 days. One or two young fledge from successful nests. Young fledge at 67 to 75 days. Juveniles remain with the adults during the first year in family groups and do not disperse until they return to the breeding areas the following year (Tacha et al. 1992).

2A.19.4.5 Foraging Behavior and Diet

Sandhill cranes are omnivorous and primarily search for subsurface food items by probing soil with their bill. They also glean seeds and other foods on the surface (Walkinshaw 1973; Tacha 1987). Sandhill crane diet consists of tubers, seeds, grains (particularly corn and rice), small vertebrates (e.g., mice and snakes) and a variety of invertebrates.

2A.19.4.6 Home Range and Territory Size

Ivey and Herziger (2003) estimated average winter home range sizes of greater sandhill cranes in the Delta to be 0.66 square mile, varying from 0.07 to 2.12 square miles. Average distance between roost sites and feeding areas was estimated by Pogson (1990) to be 1.74 miles and by Ivey and Herziger (2003) to be 0.88 miles (range 0.17 to 1.89 miles).

2A.19.5 Threats and Stressors

On the breeding grounds, threats include changes in water regime that lowers the water table and eliminates nesting areas; cattle grazing that can degrade habitat, destroy nests, and disturb nesting birds; and mowing and haying operations that can kill young cranes.

Threats on the wintering grounds include changes in water availability; flooding fields for waterfowl, which reduces foraging habitat for cranes; conversion of cereal cropland to vineyards or other incompatible crop types; human disturbances; collision with power lines and other structures; disease; and urban encroachment (Littlefield and Ivey 2000).

2A.19.5.1 Habitat Loss and Alteration

The most significant threat to wintering greater sandhill cranes is the loss of traditional winter habitat from urbanization and agricultural conversion. While relatively limited urbanization has occurred to date within key crane areas, surrounding development and increased levels of human disturbances may threaten the long-term sustainability of important wintering lands. In the Delta region, the conversion of suitable agricultural foraging and roosting habitats to unsuitable cover types, particularly orchards and vineyards, has removed key habitats and altered the distribution and behavior of wintering greater sandhill cranes.

2A.19.5.2 Disturbance of Foraging and Roosting Areas

Greater sandhill cranes are sensitive to human presence and do not tolerate regular disturbances, including low-level recreational disturbances. Types of disturbances include hunting, birding, photography, operating equipment for habitat management, boating, and aircraft. Disturbances cause birds to abandon otherwise suitable habitats, and may cause birds to deplete important energy stores needed for survival during wintering and migration. Only a single predawn disruption can cause cranes to abandon a site (Littlefield and Ivey 2000). Disturbance from hunting also poses a threat to cranes. Hunters accessing hunt areas during predawn hours flush cranes from their roosts and hunter presence can keep cranes from roosting or foraging in an area (Ivey and Herziger 2003). Flooding of agricultural fields for waterfowl hunting also reduces available foraging habitat for wintering cranes.

2A.19.6 Relevant Conservation Efforts

Several significant efforts have been made to protect and enhance wintering habitat for greater sandhill cranes. In 1985, the California Department of Fish and Wildlife (CDFW) acquired and continues to manage the Woodbridge Ecological Reserve. Purchased specifically to manage as a crane roosting area, this site has been a traditional crane roost for decades and continues to be one of the most important crane roosts for this wintering population.

Management of Staten Island has also provided substantial benefit to greater sandhill cranes. The island has been managed for several decades to provide benefit to wildlife in conjunction with agricultural production. Crane use of the island has increased particularly since the 1980s and 1990s under the successful management of the private landowners and the island continues to be among the most significant crane use areas in the Delta (Littlefield and Ivey 2000). In 2002, The Nature Conservancy established the Conservation Farms and Ranches program to provide oversight management of Staten Island and to ensure long-term conservation of crane habitat on the island.

Beginning in 1984, a cooperative effort between The Nature Conservancy, the Bureau of Land Management, CDFW, the Wildlife Conservation Board, and Ducks Unlimited began acquiring lands that today encompass approximately 40,000 acres on the Cosumnes River Preserve. Portions of the preserve are managed specifically for winter crane use and have attracted up to 20% of the greater sandhill crane wintering population at certain times of the wintering season (Littlefield and Ivey 2000).

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the greater sandhill crane as a Contribute to Recovery species (CALFED Bay-Delta

Program 2000). This means that the program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts. To maintain the population of cranes in the Plan Area, the conservation strategy focuses on maintaining and enhancing suitable foraging habitats on cultivated lands and maintaining and expanding the distribution of managed roosting habitat in the Winter Use Area.

The greater sandhill crane is a covered species under the approved *San Joaquin County Multi-species Habitat Conservation and Open Space Plan* (San Joaquin Council of Governments 2000). It is also proposed for coverage under the *South Sacramento County Habitat Conservation Plan* (Sacramento County 2010) and the *Butte Regional Conservation Plan* (Butte County Association of Governments 2011).

2A.19.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, Species *Habitat Suitability Model Methods.*

2A.19.7.1 GIS Model Data Sources

The greater sandhill crane model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005, 2010), and land use survey of the Delta and Suisun Marsh area-version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable winter roosting and foraging greater sandhill crane habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

2A.19.7.2 Habitat Model Description

The greater sandhill crane wintering habitat model includes four types of habitat: roosting and foraging-permanent; roosting and foraging-temporary; foraging; and the winter use area. For modeling purposes, roosting and foraging habitat are combined because many foraging habitats, particularly agricultural lands, can also function as roosting habitat under appropriate inundation conditions. The roosting and foraging type and the foraging type are described below. The winter use area is used as a model boundary to confine the three habitat model components. The winter use area layer (Ivey pers. comm. 2013) is based on the greater sandhill crane range in the Plan Area.

The permanent and temporary roosting and foraging model types (Ivey pers. comm. 2013) are based on years of greater sandhill crane surveys in the Plan Area. Permanent roosting and foraging sites are those used regularly, year after year, while temporary roosting and foraging sites are those used in some years. Roosting and foraging habitat is primarily composed of managed seasonal wetlands and flooded cultivated lands such as corn and rice. Additional land cover types in the roosting and foraging layer include pasturelands, hay crops, grasslands, natural seasonal wetlands, and other annually rotated agricultural crops that occur within the defined winter range.

The model for foraging habitat includes appropriate crop and vegetation types within a 4-mile radius of both the permanent and temporary roosting and foraging types (i.e., lands in the winter use area as described above). Below is a list of crop and natural community vegetation types known to provide suitable greater sandhill crane foraging habitat.

- Grain and hay crops
  - Barley
  - Wheat
  - Oats
  - Rice
  - Miscellaneous grain and hay
  - Mixed grain and hay
- Field crops
  - Safflower
  - Sugar beets
  - Corn
  - Grain sorghum
  - Sudan
  - Beans
  - Miscellaneous field
  - Sunflowers
- Pasture
  - Alfalfa and alfalfa mixtures
  - Clover
  - Mixed pasture
  - Native pasture
  - Induced high-water-table native pasture
  - Miscellaneous grasses
  - Non-irrigated mixed pasture
  - Non-irrigated native pasture
  - Other pasture
- Truck, nursery and berry crops
  - Asparagus
  - Beans
  - Onions and garlic

    - Tomatoes
    - Peppers
    - Potatoes
    - Green beans
- Rice
    - Rice
    - Wild rice
- Idle
    - Land not cropped the current or previous crop season, but cropped within the past 3 years
    - New lands being prepared for crop production
- Citrus and subtropical
- Deciduous fruits and nuts
- Flowers, nursery, Christmas trees
- Vineyards

2A.19.7.3 Assumptions

- **Assumption**: Greater sandhill crane distribution in the Plan Area includes all current known roosting sites indicated on Figure 2A.19-2 (Ivey pers. comm.) and lands within a 4-mile radius of these roosting sites but within the boundary of the greater sandhill crane winter use area established by Ivey (2010).

  Rationale: The current Delta greater sandhill crane winter distribution, as illustrated in Figure 2A.19-2 is a subset of the greater sandhill crane winter use area established by Ivey (2010) based on observational data of greater sandhill cranes. The greater sandhill crane winter distribution is based on the proximity to known greater sandhill crane nighttime roosting sites. Ivey (pers. comm.) provided recent information on active roost sites, and on the basis of radiotelemetry information has determined that greater sandhill cranes restrict their daytime movements to within approximately 4 miles of roost sites. Therefore, the current winter distribution of the greater sandhill crane in the Delta is defined as a 4-mile radius surrounding known current roosting sites but within the boundary of the winter use area. The 4-mile radius area defines the area where cranes are most likely to occur based on telemetry studies by Ivey (2010).

- **Assumption:** Greater sandhill crane habitat is restricted to the vegetation types described in Section 2A.19.7.2, *Habitat Model Description*.

  Rationale: Throughout their wintering range in the Delta, cranes roost in shallowly flooding seasonal wetlands and forage primarily in harvested corn fields, winter wheat fields, alfalfa fields, seasonal wetlands, irrigated pastures, and grasslands (Pogson and Lindstedt 1988, 1991; Littlefield and Ivey 2000). Suitable foraging habitat is likely also a function of patch size. However, because there is insufficient data on winter habitat patch size and because, in general, field sizes within the Delta winter range are probably sufficiently large to support foraging cranes, all suitable cover types are considered suitable irrespective of patch size. Because annually rotated crop types could convert to a more suitable or less suitable cover type in any given year, all crop types that are or could potentially rotate into a suitable cover type (grain and hay; field; and truck, nursery and berry crop types listed above) are included here as potentially suitable habitat. Therefore, these crop types are not differentiated based on their seasonal value and are instead combined into a category of seasonally rotated croplands. As a result, this model may overestimate the extent of available agricultural roosting/foraging habitat in any given year.

2A.19.7.4 Habitat Value Categories

As described, greater sandhill cranes are closely associated with agricultural lands in the Plan Area. Most of the land in the Delta Crane Use Area consists of agricultural land, and much is considered to have some value as foraging habitat for greater sandhill cranes. While the species is traditional to winter use areas, the agricultural landscape throughout the crane's use area is dynamic and subject to seasonal and annual changes in crop types. Because the greater sandhill crane is closely associated with specific agricultural crop types and patterns, use areas are also subject to change as crop patterns change. Because of the dynamic nature of the agricultural landscape and the variability of crop patterns and conditions seasonally and annually, only a portion of the agricultural landscape is suitable or available for foraging in any given season.

Sufficient information is available on the use of different agricultural crops to generally categorize crops based on their value as foraging habitat. Table 2A.19-1 categorizes modeled cover types according to four relative value classes: very high, high, moderate, and low. These value classes correspond to the conservation objectives for the greater sandhill crane with regard to sustaining maintaining high- and very high-value types on protected conservation lands. Table 2A.19-1 provides the rationale for assigning crop types and other agricultural land uses to habitat value categories. Figure 2A.19-3 displays the distribution of habitat and the assigned habitat values within the Plan Area.

Table 2A.19-1. Greater Sandhill Crane Foraging Habitat Value Class Assignments

Foraging Habitat Value Class	Agricultural Crops/ Habitats	Rationale for Assignment of Value Class	Information Sources[1]
Very High	Corn, rice	The primary food of sandhill cranes in agricultural areas is waste grain. Within the Delta wintering area, waste corn from harvested fields is generally regarded as the highest value forage for cranes. Fields traditionally planted to corn in the central Delta and therefore considered to have the highest value ranking relative to other agricultural cover types. Rice is also considered a very high-value foraging cover type; however, it has a very limited distribution within the crane use area.	Reinecke and Krapu 1979; Pogson and Lindstedt 1991; Ivey pers. comm.; Littlefield and Ivey 2000
High	Alfalfa and alfalfa mixtures, mixed pasture, native pasture, wheat, other pasture, irrigated pasture, managed wetlands, native vegetation[a]	Alfalfa, irrigated pasture, and winter wheat also provide high-value foraging habitat for cranes. However, these types are generally used on a more temporary basis based on crop growth, harvesting, irrigation, and grazing regimes. For example, use of alfalfa fields increases following cutting and during flood irrigation events. Wheat, while available during November and December following initial planting, decreases in value during January and February as the vegetation height increases. Managed wetlands also provide high-value invertebrate prey and potential roosting sites if they meet crane roosting habitat needs (e.g., appropriate water depth, vegetation type, availability of berms and other adjacent uplands, and proximity to agricultural foraging habitats) and are thus also regarded as having high value.	Pogson and Lindstedt 1991; Ivey pers. comm.; Littlefield and Ivey 2000
Medium	Grain and hay crops, miscellaneous grain and hay, mixed grain and hay, nonirrigated mixed grain and hay, other grain crops, miscellaneous grasses, grassland, alkali seasonal wetlands, vernal pool complex	Other grain crops including oats and barley also provide foraging value but are traditionally less abundant in the Delta or the growth/harvest regime is not optimal for crane foraging use. Grasslands provide more sustained value throughout the winter, but generally provide less foraging value than grain crops, pastures, and managed wetlands. Alkali seasonal wetland and vernal pool complex natural communities may also provide suitable foraging habitat for cranes. Suitability, however, is dependent on flooding regimes, vegetation type and structure, and food availability. While under appropriate conditions, this type may provide high value to cranes, it is considered less predictable than managed wetlands, which are typically managed for waterfowl and other water birds and thus have a greater likelihood of providing suitable habitat conditions for cranes.	Pogson and Lindstedt 1991; Ivey pers. comm.; Littlefield and Ivey 2000

Foraging Habitat Value Class	**Agricultural Crops/ Habitats**	**Rationale for Assignment of Value Class**	**Information Sources**[1]
Low	Other irrigated crops, idle cropland, blueberries, asparagus, clover, cropped within the last 3 years, grain sorghum, green beans, miscellaneous truck, miscellaneous field, new lands being prepped for crop production, nonirrigated mixed pasture, nonirrigated native pasture, onions, garlic, peppers, potatoes, safflower, sudan, sugar beets, tomatoes (processing), melons squash and cucumbers all types, artichokes, beans (dry)	A variety of other irrigated crops may receive occasional use by cranes during the winter if fields have been left idle following harvest or immediately following planting.	Pogson and Lindstedt 1991; Ivey pers. comm.; Littlefield and Ivey 2000
[a] Native vegetation is a land use designation within the DWR crop type dataset (2007). For the purposes of incorporating native vegetation classes into the correct species models, and, when applicable, assigning habitat foraging values, the management of these lands most resembles that of native pasture, an irrigated pasture type.			

2A.19.8 Recovery Goals

In 1997, the California Endangered Species Act was amended, explicitly requiring CDFW to develop a recovery strategy pilot program for the greater sandhill crane (California Department of Fish and Game 2001). A recovery strategy team was assembled with representatives from state and federal agencies, local landowners, environmental groups, and species experts; and it produced a draft recovery strategy. The strategy included long-term recovery goals, and a range of alternative management goals and activities. The overall goal was to improve the status of the species through a variety of specific habitat protections and other actions so the protections of the California Endangered Species Act are no longer necessary, and delisting could be proposed (California Department of Fish and Game 2005). The draft recovery strategy has not been finalized or implemented.

2A.19.9 References Cited

2A.19.9.1 Literature Cited

Armbruster, M. J. 1987. *Habitat Suitability Index Models: Greater Sandhill Crane*. U.S. Fish and Wildlife Service Biological Report. 82(10.140).

Boul, P., and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

Butte County Association of Governments. 2011. *Butte Regional Conservation Plan*. Available: <http://www.buttehcp.com/>. Accessed: July 12, 2012.

CALFED Bay-Delta Program. 2000. *Bay–Delta Program. Multi-Species Conservation Strategy, Final Programmatic EIR/EIS Technical Appendix.* July. Available: <http://www.calwater.ca.gov/Programs/EcosystemRestoration/EcosystemMultiSpeciesConservationStrategy.shtml>.

California Department of Fish and Game. 2001. *The Status of Rare, Threatened, and Endangered Animals and Plants of California.* Annual Report for 2000.

California Department of Fish and Game. 2005. *The Status of Rare, Threatened, and Endangered Animals and Plants of California*. Annual Report for 2004.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area* - Version 3 GIS dataset. Sacramento, CA.

Engler, J. D. and J. E. Brady. 2000. *Final Report 2000 Greater Sandhill Crane Nesting Season at Conboy Lake National Wildlife Refuge*. Ridgefield, WA: U.S. Fish and Wildlife Service, Ridgefield National Wildlife Refuge.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Ivey, G. L., and C. P. Herziger. 2000. *Distribution of Greater Sandhill Crane Pairs in Oregon 1999/2000.* Nongame Technical Report #03-01-00. Portland, OR: Oregon Department of Fish and Wildlife.

Ivey, G. L., and C. P. Herziger. 2001. *Distribution of Greater Sandhill Crane Pairs in California 2000.* Sacramento, CA: California Department of Fish and Game.

Ivey, G. L., and C. P. Herziger. 2003. *Sandhill Crane Monitoring at Staten Island, San Joaquin County, California 2002-03*. Galt, CA: The Nature Conservancy.

Littlefield, C. D. 1982. *The Status And Distribution of Greater Sandhill Cranes in California, 1981.* California Department of Fish and Game Admin. Report 82-1.

Littlefield, C. D. 1989. *Status of Greater Sandhill Crane Breeding Populations in California, 1988.* Nongame Bird and Mammal Section Report, California Department of Fish and Game, Sacramento, CA.

Littlefield, C. D. 1993. *Greater Sandhill Crane Assessment in the Upper Butte Basin, California 1991-1993*. Report to California Department of Fish & Game, Rancho Cordova, CA .

Littlefield, C. D. 2002. Winter Foraging Habitat of Greater Sandhill Cranes in Northern California. *Western Birds* 33:51–60.

Littlefield, C. D. and G. L. Ivey. 2000. *Conservation Assessment for Greater Sandhill Cranes Wintering on the Cosumnes River Floodplain and Delta Regions of California*. Galt, CA: The Nature Conservancy.

Littlefield, C. D. and R. A. Ryder 1968. Breeding Biology of the Greater Sandhill Crane on Malheur National Wildlife Refuge, Oregon. *Transactions of the North American Wildlife Natural Resources Conference.* 33:444–454.

Lovvorn, J. R. and C. M. Kirkpatrick. 1981. Roosting Behavior and Habitat of Migrant Greater Sandhill Cranes. *The Journal of Wildlife Management* 45(4):842–857.

Pogson, T. H. 1990. *Distribution, Abundance and Behavior of Greater Sandhill Cranes (*Grus canadensis tabida*) Wintering in California's Central Valley*. MA thesis. University of Alaska.

Pogson, T. H. and S. M. Lindstedt. 1988. *Abundance, Distribution, and Habitat of Central Valley Population Greater Sandhill Cranes during Winter*. Portland, OR: U.S. Fish and Wildlife Service

Pogson, T. H. and S. M. Lindstedt. 1991. Distribution and Abundance of Large Sandhill Cranes, *Grus Canadensis*, Wintering in California's Central Valley. *Condor* 93:266–278.

Reinecke, K. J. and G. L. Krapu. 1979. Spring Food Habits of Sandhill Cranes in Nebraska. In: Lewis, J. C. (ed.). *Proceedings 1978 Crane Workshop.* Fort Collins, CO. Pages 7–12.

Sacramento County. 2008. *South Sacramento County Habitat Conservation Plan: Species Analysis: Greater Sandhill Crane.* Available: <http://www.planning.saccounty.net/habitat-conservation/docs/species/Greater-Sandhill-Crane.pdf>.

Sacramento County. 2010. *South Sacramento Habitat Conservation Plan.* Appendix A. Available: <http://www.southsachcp.com/Documents.aspx>. Accessed: December 22, 2011.

San Joaquin Council of Governments. 2000. *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan.* Available: <http://www.sjcog.org/programs-projects/Habitat_files/The-Plan.htm>. Accessed: December 22, 2011.

Smith, R. 1999. The Greater Sandhill Cranes of Shasta Valley. *Outdoor California.* March-April.

Tacha, T. C. 1987. Foraging and Maintenance Behavior of Sandhill Cranes . In: Lewis, J. C. (ed.). *Proceedings 1985 Crane Workshop.* Grand Island, NE: U.S. Fish and Wildlife Service, Grand Island, NE. Pages 93–106.

Tacha, T. C., S. A. Nesbit, and P. A. Vohs. 1992. Sandhill Crane (*Grus canadensis*). In: A. Poole, F. Gill (eds.). *The Birds of North America 31*. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologist's Union.

TAIC. 2008. *Yolo County Regional Vegetation.* July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program.* Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

U.S. Department of Agriculture. 2010. *National Agricultural Imaging Program.* Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

Walkinshaw, L. H. 1949. *The Sandhill Cranes.* Cranbrook Institute of Science Bulletin. 29. Bloomfield Hills, MI.

Walkinshaw, L. H. 1973. *Cranes of the World.* New York: Winchester Press.

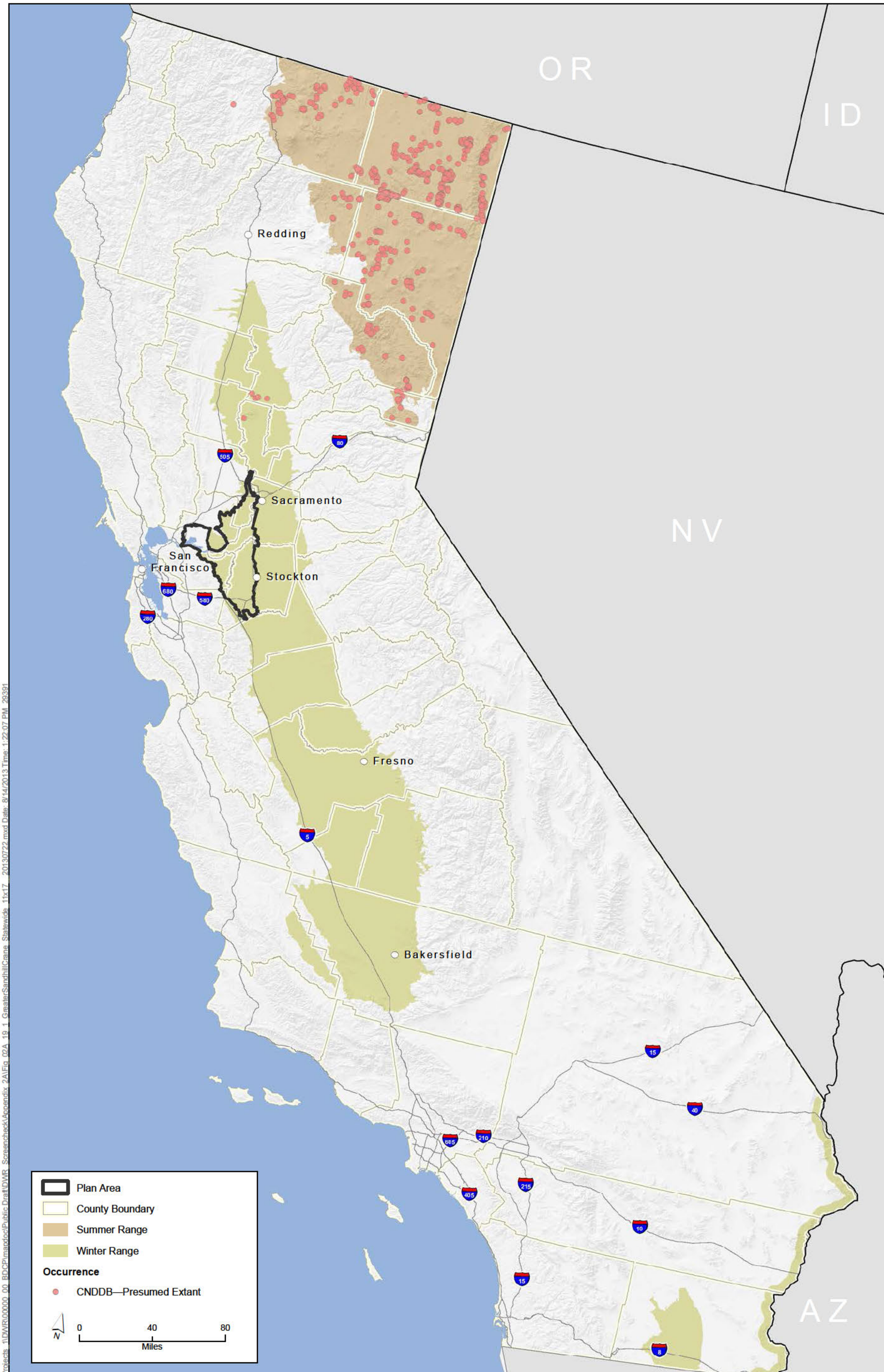
2A.19.9.2 Personal Communications

Bradbury, M. Wildlife Biologist, California Department of Water Resources. Delta Habitat Conservation and Conveyance Program written comments on draft account.

Ivey, G.L. Wildlife Biologist. Greater Sandhill Crane Specialist. Personal communication reference in the South Sacramento Habitat Conservation Plan (Sacramento County 2008) regarding habitat preferences of greater sandhill crane.

Ivey, G.L. Wildlife Biologist. Greater Sandhill Crane Specialist. 2010. GIS layer transmitted to SAIC for the assessment of greater sandhill crane use areas in the Sacramento-San Joaquin Delta.

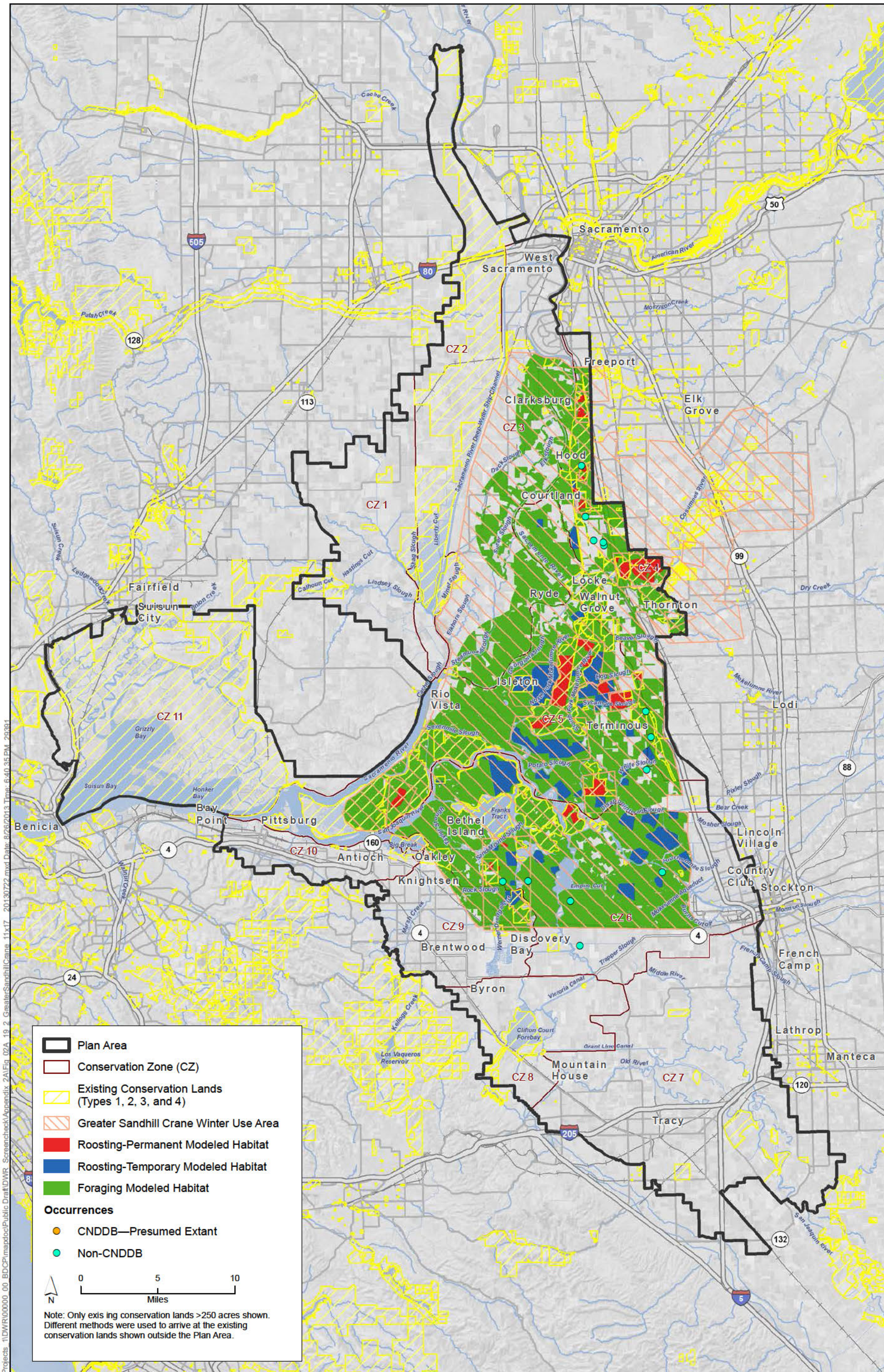
Ivey, G.L. Wildlife Biologist. Greater Sandhill Crane Specialist. 2013. Email transmittal of a GIS layer for the assessment of greater sandhill crane roost locations in the Sacramento-San Joaquin Delta.



K:\Projects_1\DWR\00000_00_BDCP\mapdoc\Public Draft\DWR_Screencheck\Appendix 2A\Fig_02A_19_1_GreaterSandhillCrane_Statewide_11x17_20130722.mxd Date: 8/14/2013 Time: 1:22:07 PM 29391

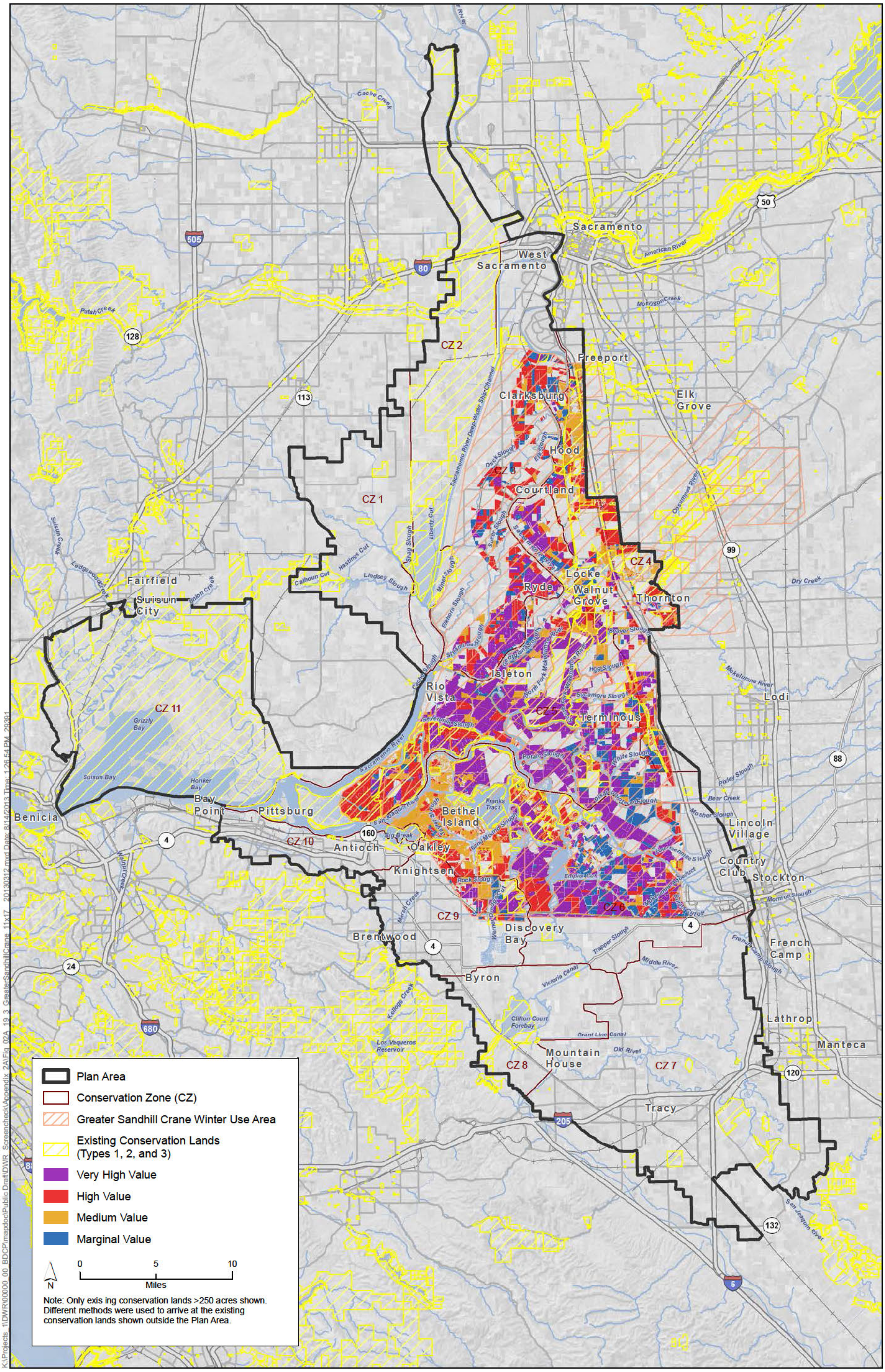
GIS Data Sources: Occurrences, CNDDB June 2013; Range, DFG WHR 2008.

Figure 2A.19-1
Greater Sandhill Crane Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013 and DHCCP 2009-2011; Crane Roosting Habitat, Ivey 2013.

Figure 2A.19-2
Greater Sandhill Crane Habitat Model and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011.

Figure 2A.19-3
Greater Sandhill Crane Foraging Habitat and Associated Value Rankings

Appendix 2A.20
Least Bell's Vireo (*Vireo bellii pusillus*)

2A.20.1 Legal Status

The least Bell's vireo (*Vireo bellii pusillus*) is state and federally listed as endangered. The species was listed by the California Fish and Game Commission pursuant to the California Endangered Species Act (Fish and Game Code, Sections 2050 *et seq.*) on October 2, 1989, and by the U.S. Fish and Wildlife Service (USFWS) pursuant to the federal Endangered Species Act on May 2, 1986 (51 *Federal Register* [FR] 16474). Critical habitat was designated for this species pursuant to the federal Endangered Species Act on February 2, 1994 (59 FR 4845).

2A.20.2 Species Distribution and Status

2A.20.2.1 Range and Status

The least Bell's vireo is one of four subspecies of Bell's vireo and is the only subspecies that breeds entirely in California and northern Baja California. Arizona Bell's vireo (*V. bellii arizonae*) is found along the Colorado River and may occur on the California side, but otherwise occurs throughout Arizona, Utah, Nevada, and Sonora, Mexico (Kus 2002a).

The least Bell's vireo, a riparian obligate, had a historical distribution that extended from coastal southern California through the San Joaquin and Sacramento Valleys as far north as Tehama County near Red Bluff (Kus 2002a) (Figure 2A.20-1). The Sacramento and San Joaquin Valleys were the center of the species' historical breeding range supporting 60 to 80% of the historical population (51 FR 16474). The species also occurred along western Sierra Nevada foothill streams and in riparian habitats of the Owens Valley, Death Valley, and Mojave Desert (Cooper 1861 and Belding 1878 in Kus 2002a; Grinnell and Miller 1944). The species was reported in Grinnell and Miller (1944) from elevations ranging from -175 feet in Death Valley to 4,100 feet in Bishop, Inyo County. These and other historical accounts described the species as common to abundant (Kus 2002a), but no reliable population estimates are available prior to the species' federal listing in 1986.

Coinciding with widespread loss of riparian vegetation throughout California (Katibah 1983), Grinnell and Miller (1944) began to detect population declines in the Sacramento and San Joaquin Valleys by the 1930s. Surveys conducted in late 1970s (Goldwasser et al. 1980) detected no least Bell's vireos in the Sacramento and San Joaquin Valleys, and the species was considered extirpated from the region. By 1986, USFWS determined that least Bell's vireo had been extirpated from most of its historical range and numbered approximately 300 pairs statewide (51 FR 16474).

The historical range was reduced to six California counties south of Santa Barbara, with the majority of breeding pairs in San Diego County (77%), Riverside County (10%), and Santa Barbara County (9%) (51 FR 16474).

Since federal listing in 1986, populations have gradually increased and the species has recolonized portions of its historical range. Increases are attributed primarily to riparian restoration and efforts to control the brood parasite brown-headed cowbird (Kus 1998 and Kus and Whitfield 2005 in Howell et al. 2010). By 1998, the total population was estimated at 2,000 pairs and recolonization was reported along the Santa Clara River in Ventura County, the Mojave River in San Bernardino County, and sites in Monterey and Inyo Counties (Kus and Beck 1998; Kus 2002a; U.S. Fish and Wildlife Service 2006). A single nest was reported from Santa Clara County near Gilroy in 1997 (Roberson et al. 1997). Still, the distribution remained largely restricted to San Diego County (76%) and Riverside County (16%) (U.S. Fish and Wildlife Service 2006).

By 2005, the population had reached an estimated 2,968 breeding pairs (U.S. Fish and Wildlife Service 2006) with increases in most southern California Counties and San Diego County (primarily Camp Pendleton Marine Corps Base) supporting roughly half of the current population (U.S. Fish and Wildlife Service 2006). Recent occurrences have suggested a range expansion to the northern extent of the species' historical breeding range.

Two singing least Bell's vireo males were detected, positively identified, and photographed in the southern portion of the Yolo Bypass Wildlife Area in Yolo County from April 17 to August 4, 2010 (California Department of Fish and Game 2012). The presumed same least Bell's vireo males were heard singing at the same sites the following year from May 7 to June 18, 2011 (California Department of Fish and Game 2012). The next closest sighting occurred in June 2005, when least Bell's vireos were detected nesting at the San Joaquin River National Wildlife Refuge, west of Modesto in Stanislaus County, the first nesting record of the species in the Central Valley in over 50 years (Howell et al. 2010). A single breeding pair nested successfully at the refuge in 2005 and 2006. The nest was depredated in 2007. No least Bell's vireos were detected in 2008 or 2009 (Howell et al. 2010).

2A.20.2.2 Distribution and Status in the Plan Area

There are no records of least Bell's vireos breeding in the Plan Area since at least the 1970s (Figure 2A.20-2). Two singing males were detected in the Yolo Bypass Wildlife Area in mid-April 2010, and again in 2011 (California Department of Fish and Game 2012). However, no least Bell's vireos were detected in the Yolo Bypass Wildlife Area in 2012. The next-nearest most recent record (noted above) is approximately 7 miles south of the Plan Area at the San Joaquin River National Wildlife Refuge in the San Joaquin and Tuolumne River floodplain (Howell et al. 2010). Because of the recent sighting of least Bell's vireo in the Plan Area and because the Plan Area may support suitable riparian habitat for a breeding pair, the species may potentially recolonize the Plan Area.

2A.20.3 Habitat Requirements and Special Considerations

The least Bell's vireo is an obligate riparian breeder that typically inhabits structurally diverse woodlands, including cottonwood-willow woodlands/forests, oak woodlands, and mule fat scrub (U.S. Fish and Wildlife Service 1998). Two features appear to be essential for breeding habitat: the presence of dense cover within 3 to 6 feet (1 to 2 meters) of the ground, where nests are typically placed; and a dense, stratified canopy for foraging (Goldwasser 1981; Gray and Greaves 1981; Salata 1981, 1983; Regional Environmental Consultants 1989). While least Bell's vireo typically nests in willow-dominated areas, plant species composition does not seem to be as important a factor as habitat structure.

Early successional riparian habitat typically supports the dense shrub cover required for nesting and a diverse canopy for foraging. While least Bell's vireo tends to prefer early successional habitat, breeding site selection does not appear to be limited to riparian stands of a specific age. If willows and other species are not managed, within 5 to 10 years they form dense thickets and become suitable nesting habitat (Goldwasser 1981; Kus 1998). Tall canopy tends to shade out the shrub layer in mature stands, but least Bell's vireo will continue to use such areas if patches of understory exist. In mature habitat, understory vegetation consists of species such as California wild rose (*Rosa californica*), poison oak (*Toxicodendron diversilobum*), California blackberry (*Rubus ursinus*), grape (*Vitis californica*), and perennials that can conceal nests. Nest site characteristics are highly variable and no features have been identified that distinguish nest sites from the remainder of the territory (Hendricks and Rieger 1989; Olson and Gray 1989; Regional Environmental Consultants 1989).

Least Bell's vireos use upland habitat, in many cases coastal sage scrub, adjacent to riparian habitat. These areas provide migratory stopover grounds, foraging habitat, and dispersal corridors for nonbreeding adults and juveniles (Kus and Miner 1989; Riparian Habitat Joint Venture 2004). Vireos along the edges of riparian corridors maintain territories that incorporate both habitat types, and a significant proportion of pairs with territories encompassing upland habitat place at least one nest there (Kus and Miner 1989).

Little is known about least Bell's vireo wintering habitat requirements. They are not exclusively associated with riparian habitat during winter, and can occur in mesquite scrub vegetation to a greater degree than riparian areas in winter (Kus unpublished data in U.S. Fish and Wildlife Service 2006). Least Bell's vireo may also occur in palm groves or along hedgerows associated with agriculture and rural residential areas (Kus 2002a).

2A.20.4 Life History

2A.20.4.1 Description

The least Bell's vireo is the smallest subspecies of the Bell's vireo (*Vireo bellii*). The Bell's vireo can range from 4.3 to 4.7 inches (11 to 12 centimeters) in length and has a wingcord length of 2.0 to 2.2 inches (5.1 to 5.8 centimeters). It weighs approximately 0.2 to 0.4 ounce (7 to 10 grams) (Kus et al. 2010). It is drably colored and indistinctly marked. The least Bell's vireo is the grayest subspecies of Bell's vireo and has very little yellow or green in its plumage.

2A.20.4.2 Seasonal Patterns

Least Bell's vireos are migratory and usually depart from their wintering grounds in Mexico to arrive at their California breeding grounds from mid-March to early April (Kus 2002a). Observations of banded birds suggest that returning adult breeders may arrive earlier than first-year birds by a few weeks (Kus unpublished data in U.S. Fish and Wildlife Service 2006). Least Bell's vireos begin departing for their wintering grounds by late July but are generally present on their breeding grounds until late September (Garrett and Dunn 1981; Salata 1983).

2A.20.4.3 Nest Site Selection

Nests are typically placed in the fork of a tree or shrub branch in dense cover within 3 to 6 feet (1 to 2 meters) of the ground. Both members of the pair construct the cup-shaped nest from leaves, bark, willow catkins, spider webs, and other material, in about 4 to 5 days. The female selects the nest site (Bent 1950; Barlow 1962). Nests are placed in a wide variety of plant species, but the majority are placed in willows (*Salix* spp.) and mule fat (*Baccharis salicifolia* ssp. *salicifolia*) (U.S. Fish and Wildlife Service 1998). Nests tend to be placed in openings along the riparian edge, where exposure to sunlight allows the development of shrubs.

2A.20.4.4 Reproduction

Egg laying begins 1 to 2 days after nest completion. Typically, 3 to 4 eggs are laid. Average clutch sizes of nonparasitized nests observed with complete clutches have ranged from 3.1 to 3.9 (U.S. Fish and Wildlife Service 1998). Both males and females share in incubation, which takes approximately 14 days (Bent 1950; Kus 2002a). After hatching, nestlings are fed by both parents for 10 to 12 days until fledging (U.S. Fish and Wildlife Service 1998). Adults continue to care for the young at least 2 weeks after fledging, when territorial boundaries may be relaxed as family groups range over larger areas. Fledglings usually remain in the territory or its vicinity for most of the season (U.S. Fish and Wildlife Service 1998). Least Bell's vireo pairs may attempt up to five nests in a breeding season, although most fledge young from only one or two. Few nests are initiated after mid-July. Long-term annual rates of hatching success (the percentage of eggs laid that hatch) have ranged from 53 to 83% percent in the major study populations at the San Luis Rey, Santa Margarita, and Tijuana Rivers. The annual average number of fledglings produced per pair has ranged from 0.9 to 4.5, with long-term averages ranging between 1.8 and 3.2 (U.S. Fish and Wildlife Service 1998).

2A.20.4.5 Home Range and Territory Size

Territory size ranges from 0.5 to 7.5 acres (0.2 to 3 hectares), but on average are between 1.5 and 2.5 acres (0.6 and 1 hectare) in southern California (U.S. Fish and Wildlife Service 1998). Newman (1992) investigated the relationship between territory size, vegetation characteristics, and reproductive success for populations in San Diego County, but found no significant factors that could account for the variability in territory size found at his sites. Spatial differences in riparian habitat structure, patch size, and numerous other factors result in differences in the density of territories within and between drainages (U.S. Fish and Wildlife Service 1998). Embree (1992) concluded that patch size and crowding did not influence least Bell's vireo reproductive success, at least not through the mechanisms of singing rates and attraction of predators.

2A.20.4.6 Foraging Behavior and Diet

Least Bell's vireos are insectivorous and prey on a wide variety of insects, including bugs, beetles, grasshoppers, moths, and especially caterpillars (Chapin 1925; Bent 1950). They obtain prey primarily by foliage gleaning (picking prey from leaf or bark substrates) and hovering (removing prey from vegetation surfaces while fluttering in the air). Foraging occurs at all levels of the canopy but appears to be concentrated in the lower to middle level strata, particularly when pairs have active nests (Grinnell and Miller 1944; Goldwasser 1981; Gray and Greaves 1981; Salata 1983; Miner 1989). Miner (1989) determined that least Bell's vireo foraging time across heights was not simply a function of the availability of vegetation at those heights, but rather represented an actual preference for the 3- to 6-meter zone. Foraging occurs most frequently in willows (Salata 1983; Miner 1989), but occurs on a wide range of riparian species and even some nonriparian plants that may host relatively large proportions of large prey (Miner 1989).

2A.20.5 Threats and Stressors

2A.20.5.1 Habitat Loss and Fragmentation

A major factor leading to declines in populations of least Bell's vireo is the loss and degradation of riparian woodland habitat throughout the species' range. Habitat loss and degradation can occur through clearing of vegetation for agriculture, timber harvest, development, or flood control.

Flood control and river channelization eliminates early successional riparian habitat that least Bell's vireo (and many other riparian focal species) use for breeding. Dams, levees and other flood control structures hinder riparian re-establishment, creating more old-growth conditions (dense canopy and open understory) that are unfavorable to breeding vireos. Finally, habitat degradation encourages nest predation and parasitism. Agricultural land uses and water projects not only directly destroy habitat, but may also reduce water tables to levels that inhibit the growth of the dense vegetation least Bell's vireo prefer (Riparian Habitat Joint Venture 2004).

Grazing can also have a significant effect on riparian vegetation (Sedgwick and Knopf 1987). Cattle and other livestock can trample vegetation and eat seedlings, saplings, shrubs, and herbaceous plants. This can lead to a reduction in cover and nesting sites, and affect insect prey populations.

2A.20.5.2 Cowbird Parasitism

Brood parasitism from brown-headed cowbirds (*Molothrus ater*) has a major negative impact on least Bell's vireo. Livestock grazing has reduced and degraded the lower riparian vegetation favored by the least Bell's vireo (Overmire 1962) and provided foraging areas for the brown-headed cowbird. Sharp and Kus (2005) suggest that microhabitat cover around the nest is the most important habitat feature influencing brood parasitism of least Bell's vireo nests. They found unparasitized nests had fewer trees greater than 8 centimeters (3 inches) in diameter at breast height within 11.3 meters (37 feet) of the nest and had less canopy cover within 5 meters (16 feet) than parasitized nests. They also suggest that cover near the nest reduces the chance that a cowbird will observe nesting activity and later parasitize the nest.

Row crops and orchards also provide feeding grounds for the parasite. Young and Hutto (1997) found that distance to agriculture was the strongest predictor of cowbird presence and abundance. Riparian habitat that is fragmented by agriculture is therefore highly susceptible to cowbird brood parasitism. By as early as 1930, nearly every least Bell's vireo nest found in California hosted at least one cowbird egg (U.S. Fish and Wildlife Service 1998). Because a parasitized nest rarely fledges any vireo young, nest parasitism of least Bell's vireo results in drastically reduced nest success (Goldwasser 1978; Goldwasser et al. 1980; Franzreb 1989; Kus 1999, 2002b).

2A.20.5.3 Predation

Predation is a major cause of nest failure in areas where brown-headed cowbird nest parasitism is infrequent or has been reduced by cowbird trapping programs. Most predation occurs during the egg stage. Predators likely include western scrub jays (*Aphelocoma californica*), Cooper's hawks (*Accipiter cooperii*), gopher snakes (*Pituophis melanoleucus*) and other snake species, raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), coyotes (*Canis latrans*), long-tailed weasels (*Mustela frenata*), dusky-footed woodrats (*Neotoma fuscipes*), deer mice (*Peromyscus maniculatus*), rats (*Rattus* spp.), and domestic cats (*Felis domesticus*) (Franzreb 1989). Kus et al. (2008) investigated variables that influenced the likelihood of nest predation on least Bell's vireo at three spatial scales. They did not find strong predictors of predation risk at the nest site, surrounding habitat or landscape scale, with the exception of proximity to golf courses, parks, and wetlands. Nest predation increased with proximity to golf courses, whereas nests near wetland habitats were twice as likely to succeed as those that were farther from wetlands (Kus et al. 2008).

2A.20.6 Relevant Conservation Efforts

The least Bell's vireo is federally and state-listed as endangered. Critical habitat for the least Bell's vireo was designated in 1994, and the USFWS draft recovery plan was published in 1998. Aside from the protections and regulations offered under these plans, the Clean Water Act, Migratory Bird Treaty Act of 1918, and a Memorandum of Understanding between USFWS and Camp Pendleton Marine Corps Base for the purpose and objective of managing and perpetuating the least Bell's vireo on Camp Pendleton, also offer the least Bell's vireo regulatory protection. The least Bell's vireo is also listed as a covered species in 16 habitat conservation plans, including the *Coachella Valley Multiple Species Habitat Conservation Plan* (Coachella Valley Association of Governments 2007), *San Diego Multiple Species Conservation Plan* (San Diego County 1998), *Orange County Natural Community Conservation Plan/Habitat Conservation Plan* (Orange County 1997), and *Western Riverside Multiple Species Habitat Conservation Plan* (Riverside County 2003).

Riparian habitat creation and restoration is underway throughout California (Riparian Habitat Joint Venture 2004). The *Santa Clara River Enhancement and Management Plan* (AMEC Earth & Environmental 2005) is an especially significant effort to protect the ecological integrity of the longest unchannelized river in the South Coast bioregion. Current efforts to develop along the Santa Clara River and its tributaries may endanger the integrity of the plan.

Brown-headed cowbird trapping has proven to be an effective method of increasing the reproductive success of least Bell's vireo on a local scale. At Camp Pendleton, nest parasitism dropped from 47% to less than 1% in less than 10 years because of cowbird trapping efforts (U.S. Fish and Wildlife Service 1998). However, cowbird trapping should be considered a temporary and complementary aid to long-term restoration and habitat enhancement and preservation efforts.

Continued research and monitoring of key least Bell's vireo populations at Camp Pendleton and other southern California riparian areas provides important information on population trends and allows for the employment of appropriate adaptive conservation techniques. Point Reyes Bird Observatory's geographic information system (GIS) database of California Partners in Flight riparian study sites is a useful tool in identifying where riparian research is occurring. The riparian bird conservation plan developed by Riparian Habitat Joint Venture (2004) offers a comprehensive vision of conservation, education, and research activities necessary to conserve and restore the riparian habitats that least Bell's vireo requires.

2A.20.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.20.7.1 GIS Model Data Sources

The least Bell's vireo model uses vegetation types and associations from the following data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), and aerial photography (U.S. Department of Agriculture 2005). Using these data sets, the model maps the distribution of suitable least Bell's vireo nesting and migratory habitat in the Plan Area. Vegetation types were assigned based on the species requirements as described above and the assumptions described below.

2A.20.7.2 Habitat Model Description

Modeled nesting and migratory habitat in the Sacramento–San Joaquin River Delta includes the following valley riparian types from the BDCP composite vegetation layer.

- Black willow (*Salix gooddingii*)
- *Salix gooddingii*–*Populus fremontii* (*Quercus lobata*–*Salix exigua*–*Rubus discolor*)
- *Salix gooddingii*/*Rubus discolor*
- *Salix lasiolepis*–Mixed brambles (*Rosa californica*–*Vitis californica*–*Rubus discolor*)
- *Salix exigua*–(*Salix lasiolepis*–*Rubus discolor*–*Rosa californica*)
- *Salix gooddingii*/wetland herbs
- *Salix gooddingii*–*Quercus lobata*/wetland herbs
- Arroyo willow (*Salix lasiolepis*)
- *Salix lasiolepis*–*Cornus sericea*/*Scirpus* (currently known as *Schoenoplectus*) spp.–complex unit
- Shining willow (*Salix lucida*)
- Narrow-leaf willow (*Salix exigua*)
- Fremont cottonwood (*Populus fremontii*)
- White alder (*Alnus rhombifolia*)
- *Alnus rhombifolia*/*Salix exigua* (*Rosa californica*)
- Oregon ash (*Fraxinus latifolia*)
- Box elder (*Acer negundo*)
- *Acer negundo*–*Salix gooddingii*
- Hinds' walnut (*Juglans hindsii*)
- Coyote bush (*Baccharis pilularis*)
- California wild rose (*Rosa californica*)

- *Cornus sericea–Salix exigua*
- *Cornus sericea–Salix lasiolepis*/(*Phragmites australis*)
- Coast live oak (*Quercus agrifolia*)
- *Quercus lobata–Alnus rhombifolia* (*Salix lasiolepis–Populus fremontii–Quercus agrifolia*)
- *Quercus lobata*/*Rosa californica* (*Rubus discolor–Salix lasiolepis*/*Carex* spp.)
- *Quercus lobata–Acer negundo*
- *Quercus lobata–Fraxinus latifolia*
- Blackberry (*Rubus discolor*)
- Mexican elderberry (*Sambucus mexicana*)
- California dogwood (*Cornus sericea*)

Nesting and migratory habitat in Suisun Marsh and Yolo Basin includes the following valley riparian types from the BDCP composite vegetation layer.

- Fremont cottonwood–valley oak–willow riparian forest NFD alliance
- Mixed Fremont cottonwood–willow spp. NFD alliance
- Mixed willow super alliance
- *Salix laevigata*/*S. lasiolepis*
- *Salix lasiolepis*/*Quercus agrifolia*
- *Rosa californica*
- *Rosa*/*Baccharis*
- *Fraxinus latifolia*
- *Quercus agrifolia*
- *Rosa*/*Baccharis*
- *Rubus discolor*
- Valley oak alliance–riparian
- Willow trees

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. Additional detail regarding crop types was available for cultivated lands and was incorporated into the mapping. In the new analysis areas, the following natural communities were assumed to provide least Bell's vireo habitat.

- Valley/foothill riparian
    - Blackberry NFD (not formally defined) super alliance

- Fremont cottonwood–valley oak–willow (ash–sycamore) riparian forest NFD association
- Intermittently flooded to saturated deciduous shrubland
- Mixed Fremont cottonwood–willow species, NFD alliance
- Mixed willow super alliance
- Valley oak (*Quercus lobata*)
- Valley oak alliance–riparian

- Vernal Pool Complex

2A.20.7.3 Assumptions

- **Assumption:** Least Bell's vireo habitat is restricted to the vegetation types described in Section 2A.20.7.2, *Habitat Model Description*.

  Rationale: The least Bell's vireo is an obligate riparian breeder. While it can use adjacent nonriparian scrub habitats for foraging or dispersal (Kus and Miner 1989; Riparian Habitat Joint Venture 2004), suitable nonriparian habitats are largely absent from the Plan Area, which is primarily agricultural. Therefore, the habitat model is restricted to riparian vegetation. While least Bell's vireo typically nests in willow-dominated habitats, plant species composition does not seem to be as important a factor as habitat structure. Early successional riparian habitat typically supports the dense shrub cover required for nesting and a diverse canopy for foraging. While least Bell's vireo tends to prefer early successional habitat, breeding site selection does not appear to be limited to riparian stands of a specific age. Therefore, in addition to all willow-dominated types, all other riparian habitats that may consist of a dense shrub layer are included.

2A.20.8 Recovery Goals

The draft recovery plan for this species (U.S. Fish and Wildlife Service 1998) includes the following criteria that constitute the recovery goals.

Reclassification as a threatened species may be considered when Criterion 1 has been met for a period of 5 consecutive years.

- **Criterion 1.** Stable or increasing least Bell's vireo populations and metapopulations, each consisting of several hundred or more breeding pairs are protected and managed at the following sites: Tijuana River, Dalzura Creek/Jamul Creek/Otay River, Sweetwater River, San Diego River, San Luis Rey River, Camp Pendleton/Santa Margarita River, Santa Ana River, an Orange County/Los Angeles County metapopulation, Santa Clara River, Santa Inez River, and an Anza Borrego Desert metapopulation.

Delisting of the species may be considered when the species meets the criterion for downlisting and the following criteria have been met for 5 consecutive years.

- **Criterion 2.** Stable or increasing least Bell's vireo populations and metapopulations, each consisting of several hundred or more breeding pairs, have become established and are protected and managed at the following sites: Salinas River, a San Joaquin Valley metapopulation, and a Sacramento Valley metapopulation.

- **Criterion 3.** Threats are reduced or eliminated so that least Bell's vireo populations and metapopulations listed above are capable of persisting without significant human intervention, or perpetual endowments are secured for cowbird trapping and nonnative invasive plant control (e.g., giant reed, *Arundo donax*) in riparian habitat occupied by least Bell's vireo.

2A.20.9 References Cited

2A.20.9.1 Literature Cited

AMEC Earth & Environmental. 2005. *Santa Clara River Enhancement and Management Plan (SCREMP).* Prepared for Ventura County Watershed Protection District and Los Angeles County Department of Public Works and SCREMP Project Steering Committee. May. Available: <http://www.santaclarariverparkway.org/wkb/scrbiblio/scrempfinal/>. Accessed: July 11. 2012.

Barlow, J. C. 1962. Natural History of the Bell Vireo, *Vireo bellii*. Audubon. *University of Kansas Publication Museum of Natural History* 12:241–296.

Belding, L. 1878. A Partial List of the Birds of Central California. Proceedings of the United States National Museum 1:388-449. Cited in Kus 2002a. *Least Bell's Vireo (*Vireo bellii pusillus*).* In: *The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-Associated Birds in California*. California Partners in Flight. Available: <http://www.prbo.org/calpif/htmldocs/riparian_v-2.html>.

Bent, A. C. 1950. *Life Histories of North American Wagtails, Shrikes, Vireos and Their Allies.* United States National Museum Bulletin 197.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

California Department of Fish and Game. 2012. California Natural Diversity Database (CNDDB). Element Occurrence Query. RareFind, Version 4.0 (Commercial Subscription). Sacramento, California: CDFG, Biogeographic Data Branch. Available: <http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp>.

Chapin, E.A. 1925. *Food Habits of the Vireos*. U.S. Department of Agriculture Bulletin 1355.

Coachella Valley Association of Governments. 2007. *Coachella Valley Multiple Species Habitat Conservation Plan.* Final. September. Available: <http://www.cvmshcp.org/Plan_Documents.htm#plan>. Accessed: July 11, 2012.

Cooper, J. G. 1861. New California Animals. *Proceedings of the California Academy of Sciences* 2:118-123. Cited in Kus 2002a. Least Bell's Vireo (*Vireo bellii pusillus*). In: *The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-Associated Birds in California. California Partners in Flight.* Available: <http://www.prbo.org/calpif/htmldocs/riparian_v-2.html>.

Embree, E. T. 1992. *The Relationship between Population Density, Singing Behavior, and Reproductive Success in the Least Bell's Vireo, Vireo Bellii Pusillus*. Unpublished Master's thesis. San Diego State University, CA.

Franzreb, K. E. 1989. *Ecology and Conservation of the Endangered Least Bell's Vireo.* U.S. Fish and Wildlife Service Biological Report. 89(1).

Garrett K. and J. Dunn. 1981. *Birds of Southern California.* Los Angeles, CA: Los Angeles Audubon Society.

Goldwasser, S. 1978. *Distribution, Reproductive Success and Impact of Nest Parasitism by Brown-Headed Cowbirds of Least Bell's Vireos.* Final report. State of California, The Resources Agency, California Department of Fish and Game. Federal Aid in Wildlife Restoration W-54-R-10, Nongame Wildlife Program. Job W 1.5.1.

Goldwasser, S. 1981. *Habitat Requirements of the Least Bell's Vireo.* California Department of Fish and Game, Job IV-38.1.

Goldwasser, S., D. Gaines, and S. Wilbur. 1980. The Least Bell's Vireo in California: A *de facto* Endangered Race. *American Birds* 34:742–745.

Gray, M. V. and J. Greaves. 1981. *The Riparian Forest as Habitat for the Least Bell's Vireo (*Vireo bellii pusillus*).* Paper presented at the California Riparian Systems Conference, University of California, Davis; September 1981.

Grinnell, J. and A. H. Miller. 1944. *The Distribution of the Birds of California*. Berkeley, CA: Museum of Vertebrate Zoology, University of California.

Hendricks, B. J. and J. P. Rieger. 1989. Description of Nesting Habitat for the Least Bell's Vireo in San Diego County. Cited in D.L. Abell (ed). *California Riparian Systems Conference: Protection, Management, and Restoration for the 1990s*. 1988 September 22-24, Davis, Ca. Pacific Northwest Forest and Range Experiment Station, Berkeley, CA; USDA Forest Service General Technical Report PSW-110. Pages 285-292.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Howell, C. A., J. K. Wood, M. D. Dettling, K. Griggs, C. C. Otte, L. Lina, and T. Gardali. 2010. Least Bell's Vireo Breeding Records in the Central Valley Following Decades of Extirpation. *Western North American Naturalist* 70(1):105–113.

Katibah, E. F. 1983. A Brief History of Riparian Forests in the Central Valley of California. In: R. E. Warner and K. M. Hendrix (eds.). *California Riparian Systems: Ecology, Conservation, and Productive Management*. Berkeley, CA: University of California Press. Pages 23–29.

Kus, B. E. 1998. Use of Restored Riparian Habitat by the Endangered Least Bell's Vireo. *Restoration Ecology* 6:75–82. Cited in Howell, C. A., J. K. Wood, M. D. Dettling, K. Griggs, C. C. Otte, L. Lina, and T. Gardali. 2010. Least Bell's Vireo Breeding Records in the Central Valley Following Decades of Extirpation. *Western North American Naturalist* 70(1):105–113.

Kus, B. E. 1999. Impacts of Brown-Headed Cowbird Parasitism on Productivity of the Endangered Least Bell's Vireo. *Studies in Avian Biology* 18:160–166.

Kus, B. E. 2002a. Least Bell's Vireo (*Vireo bellii pusillus*). In The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian-Associated Birds in California. California Partners in Flight. Available: <http://www.prbo.org/calpif/htmldocs/riparian_v-2.html>.

Kus, B. E. 2002b. Fitness Consequences of Nest Desertion in an Endangered Host, the Least Bell's Vireo. *Condor* 104(4): 795–802.

Kus, B. E. no date. Unpublished data cited in U.S. Fish and Wildlife Service 2006.

Kus, B. E. and P. Beck. 1998. *Distribution and Abundance of the Least Bell's Vireo (*Vireo bellii pusillus*) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) at Selected Southern California Sites in 1997*. Sacramento, CA: California Department of Fish and Game, Wildlife Management Division.

Kus, B., S. L. Hopp, R. R. Johnson, and B. T. Brown. 2010. Bell's Vireo (*Vireo bellii*). In: A. Poole (ed.). *The Birds of North America Online*. Ithaca, NY: Cornell Lab of Ornithology. Available: <http:bna.birds.cornell.edu/bna/species/035doi:10.2173/bna.35>.

Kus, B. E. and K. L. Miner. 1989. The Use of Non-Riparian Habitats by Least Bell's Vireo (*Vireo bellii pusillus*). As cited in Abell, D. L. (ed.). *California Riparian Systems Conference: Protection, Management, and Restoration for the 1990s*. 1988 September 22-24, Davis, Ca. Pacific Northwest Forest and Range Experiment Station, Berkeley, CA; USDA Forest Service General Technical Report PSW-110. Pages 299–303.

Kus, B. E., B. L. Peterson, and D. H. Deutschman. 2008. A Multiscale Analysis of Nest Predation on Least Bell's Vireo (*Vireo bellii pusillus*). *Auk* 125:227–284.

Kus, B. E. and M. J. Whitfield. 2005. Parasitism, Productivity, and Population Growth: Response of Least Bell's Vireo (*Vireo Bellii Pusillus*) and Southwestern Willow Flycatchers (*Empidonax Traillii Extimus*) to Cowbird (*Molothrus* Spp.) Control. *Ornithological Monographs* 57:16–27. Cited in Howell, C. A., J. K. Wood, M. D. Dettling, K. Griggs, C. C. Otte, L. Lina, and T. Gardali. 2010. Least Bell's Vireo Breeding Records in the Central Valley Following Decades of Extirpation. *Western North American Naturalist* 70(1):105–113.

Miner, K. L. 1989. Foraging Ecology of the Least Bell's Vireo, *Vireo bellii pusillus*. Master's thesis. San Diego State University, CA.

Newman, J. 1992. Relationships between Territory Size, Habitat Structure and Reproductive Success in the Least Bell's Vireo, *Vireo bellii pusillus*. Master's thesis. San Diego State University, CA.

Olson, T. E. and M. V. Gray. 1989. Characteristics of Least Bell's Vireo Nest Sites along the Santa Ynez River. Cited in D.L. Abell (ed). *California Riparian Systems Conference: Protection, Management, and Restoration for the 1990s*. 1988. September 22-24, Davis, Ca. Pacific Northwest Forest and Range Experiment Station, Berkeley, CA; USDA Forest Service General Technical Report PSW-110. Pages 278–284.

Orange County. 1997. *Natural Community Conservation Plan & Habitat Conservation Plan.* Final. July 17.Available: < http://www.naturereserveoc.org/NCCP%20Parts%20I%20&%20II%20-%20Plan.pdf>. Accessed: July 11, 2012.

Overmire, T. G. 1962. Nesting of the Bell Vireo in Oklahoma. *Condor* 64:75.

Regional Environmental Consultants. 1989. *Comprehensive Species Management Plan for the Least Bell's Vireo* (Vireo bellii pusillus). Prepared for San Diego Association of Governments, San Diego.

Riparian Habitat Joint Venture. 2004. Version 2.0. *The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian Associated Birds in California.* California Partners in Flight. Available: <http://www.prbo.org/calpif/pdfs/riparian.v-2.pdf>.

Riverside County. 2003. *Western Riverside Multiple Species Habitat Conservation Plan.* June 17. Available: < http://www.wrc-rca.org/library.asp>. Accessed: July 11, 2012.

Roberson, D., S. F. Bailey, and D. S. Singer. 1997. Middle Pacific Coast. *Field Notes* 51: 924–925.

Salata, L. 1981. *Least Bell's Vireo Research, Camp Pendleton Marine Corps Base, San Diego County, California, 1981*. Unpublished report. Camp Pendleton, CA: Natural Resources Office.

Salata, L. 1983. *Status of the Least Bell's Vireo on Camp Pendleton, California: Report on Research Done in 1983*. Unpublished report. Laguna Niguel, CA: U.S. Fish and Wildlife Service.

San Diego County. 1998. *Final Multiple Species Conservation Program. MSCP Plan.* Available: <http://www.co.san-diego.ca.us/dplu/mscp/docs/SCMSCP/FinalMSCPProgramPlan.pdf>. Accessed: July 11, 2012.

Sedgwick, J. A. and F. L. Knopf. 1987. Breeding Bird Response to Cattle Grazing of a Cottonwood Bottomland. *Journal of Wildlife Management* 51:230-237.

Sharp, B. L. and B. E. Kus. 2005. Factors Influencing the Incidence of Cowbird Parasitism of Least Bell's Vireos. *The Journal of Wildlife Management* 70:682–690.

TAIC. 2008. *Yolo County Regional Vegetation*. July 2008. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program*. Farm Service Agency Aerial Photography Field Office, Salt Lake City, UT.

U.S. Fish and Wildlife Service. 1998. *Draft Recovery Plan for the Least Bell's Vireo*. Portland, OR.

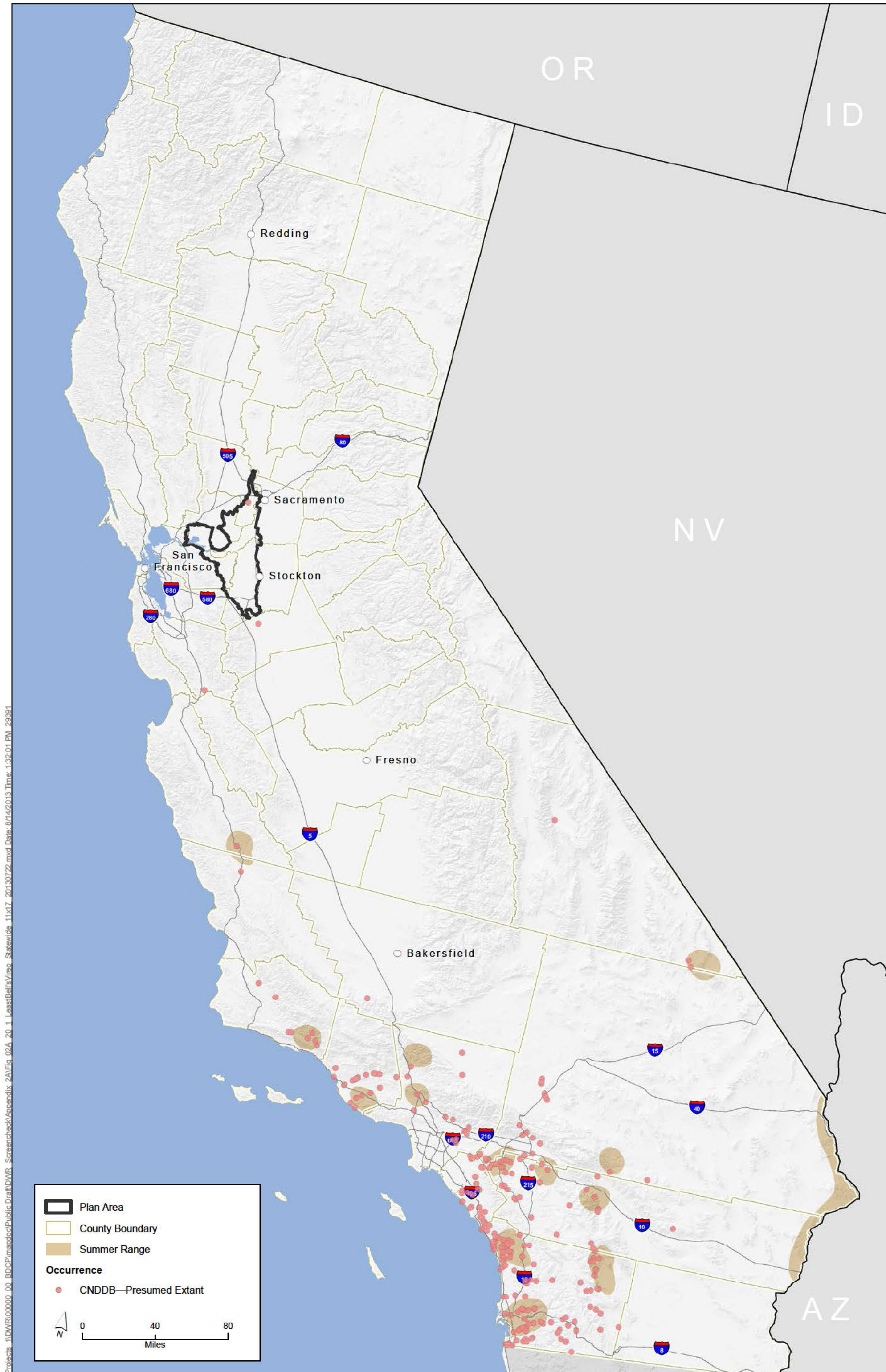
U.S. Fish and Wildlife Service. 2006. *Least Bell's Vireo* (Vireo bellii pusillus), *Five-Year Review Summary and Evaluation*. Carlsbad, CA.

Young, J. S. and R. L. Hutto. 1997. Habitat Relationships of Brown-Headed Cowbirds in the Northern Rockies. Cited in Morrison, M. L. and L. S. Hall. *Research and Management of the Brown-Headed Cowbird in Western and Eastern Landscapes.* Partners in Flight program and abstracts. October 23–25. Page 21.

2A.20.9.2 Federal Register Notices Cited

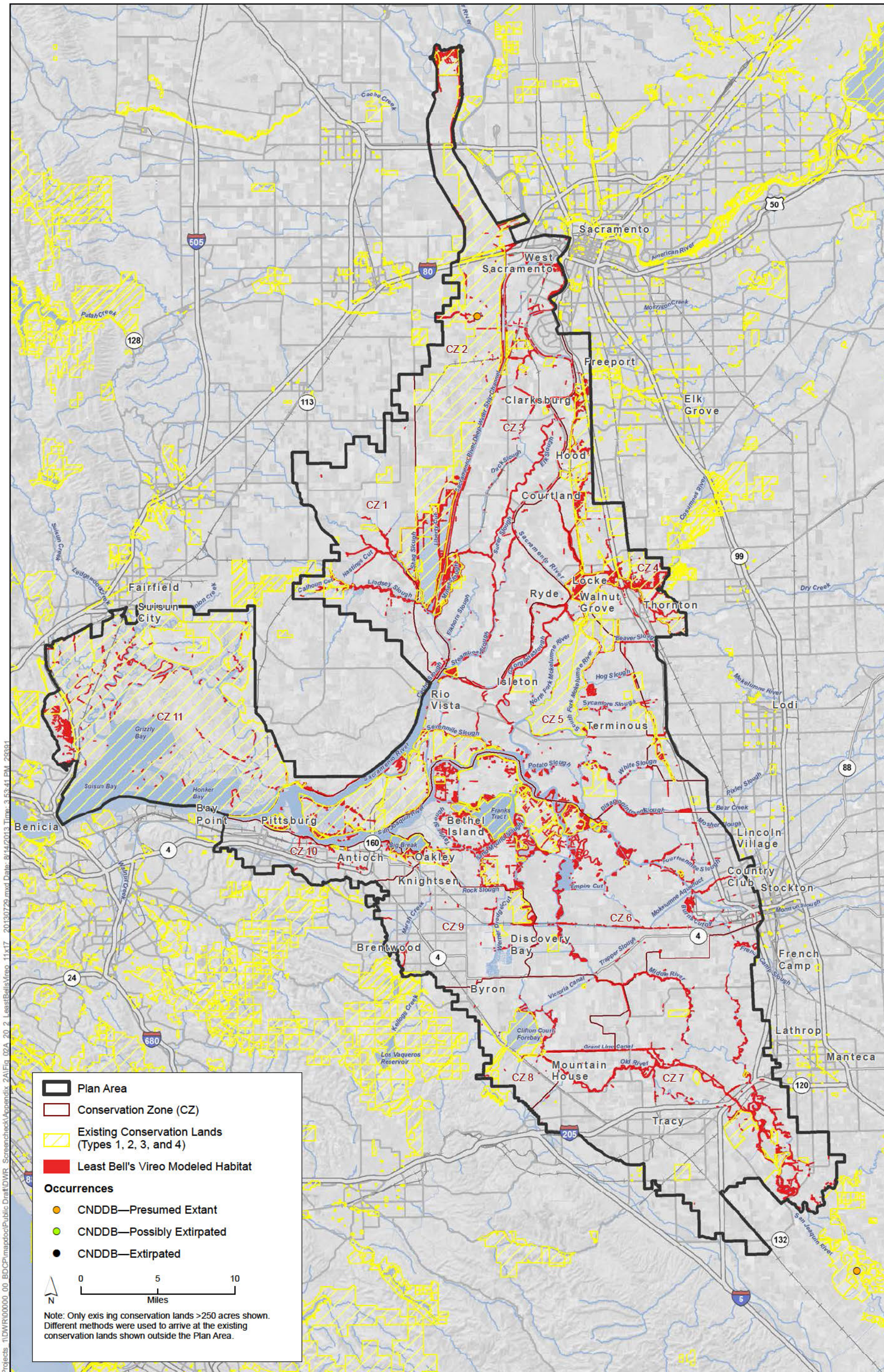
51 FR 16474. 1986. Final Rule: Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Least Bell's Vireo. *Federal Register* 51:16474.

59 FR 4845. 1994. Final Rule: Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Least Bell's Vireo. *Federal Register* 59:4845.



GIS Data Sources: Occurrences, CNDDB June 2013;
Range, DFG WHR 2008.

Figure 2A.20-1
Least Bell's Vireo Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB June 2013.

Figure 2A.20-2
Least Bell's Vireo Habitat Model and Recorded Occurrences

Appendix 2A.21

Suisun Song Sparrow (*Melospiza melodia maxillaris*)

2A.21.1 Legal Status

The Suisun song sparrow (*Melospiza melodia maxillaris*) has no federal legal status. A petition for listing it as a federal endangered species was submitted in 1987, but the U.S. Fish and Wildlife Service (USFWS) considered the petition unwarranted.

The species is a third-priority California Bird Species of Special Concern (Spautz and Nur 2008).

2A.21.2 Species Distribution and Status

2A.21.2.1 Range and Status

The Suisun song sparrow is one of 24 subspecies of *Melospiza melodia*, and one of three that occur in the San Francisco Bay estuary (Modesto song sparrow [*M. m. mailliardi*] may be a fourth subspecies; however, its taxonomic status is currently under review, and further research is necessary to determine its status as a valid subspecies [Gardali 2008]). *M. m. samuelis* occurs in salt marshes of north San Francisco and San Pablo Bays, and *M. m. pusillula* occurs in salt marshes of south San Francisco Bay. The Suisun song sparrow is endemic to the salt marshes of the Suisun Bay, and while it has been confirmed to be phenotypically distinct from neighboring subspecies (Patten 2001), genetic differentiation has not been confirmed (Chan and Arcese 2002). Its year-round range is confined to tidal salt and brackish marshes of the Suisun Bay area from the Carquinez Strait east to Antioch at the confluence of the San Joaquin and Sacramento Rivers (Grinnell and Miller 1944; Spautz and Nur 2008). The current range remains relatively unchanged since Grinnell and Miller's (1944) description. However, the current distribution of the species in this area is defined by the extent of remaining tidal marsh habitats, which occur primarily along the fringes of the Carquinez Strait and Suisun Bay (Figure 2A.21-1).

Spautz and Nur (2008), citing unpublished data from the Point Reyes Bird Observatory, estimated the total population of Suisun song sparrows as 43,000 to 66,000 breeding pairs, approximately one third of the estimated historical population size (Spautz and Nur 2008). The subspecies occurs in virtually every tidal marsh in Suisun Bay; however, densities differ widely based on habitat conditions and suitability (Spautz and Nur 2008).

2A.21.2.2 Distribution and Status in the Plan Area

The range of the Suisun song sparrow extends eastward into the Plan Area to approximately Kimball Island. However, the majority of the range of the species is included in the Suisun Marsh Restoration Opportunity Area (ROA) (Figure 2A.21-2). There are several reported occurrences from Kimball Island, Browns Island, and in the Suisun Marsh in the western portion of the Plan Area.

2A.21.3 Habitat Requirements and Special Considerations

Suisun song sparrows are associated with tidal marsh habitats dominated by *Salicornia* , *Spartina*, and *Grindelia*. In brackish marsh habitats, these types are interspersed mostly with *Schoenoplectus* (formerly known as *Scirpus*), *Typha*, and *Juncus*. Dense vegetation is required for nesting sites, song perches, and refuge from predators (Marshall 1948). There is also an association with tidal channels in areas where *Salicornia* or *Spartina* are the dominant landscape cover and *Grindelia* or shrubs occur along the edges of the channels, providing nesting and perching habitat (Spautz and Nur 2008). The association with channels is weaker in brackish marshes with extensive cover of *Schoenoplectus* and *Typha* (Spautz and Nur 2008).

While dense vegetation is characteristic, exposed ground is important for foraging. In tidal marsh habitats, openings in the dense *Salicornia*, created by small mammals or tidal action, are required for foraging access. In *Schoenoplectus*/*Typha*-dominated habitats, plant spacing needs to be sufficient to provide openings for foraging and movement on the ground (Marshall 1948).

Spautz et al. (2006) analyzed abundance with a series of vegetation and habitat variables. They found a positive correlation with shrub cover, particularly *Grindelia stricta* and *Baccharis pilularis* (coyote bush), marsh size, and proportion of adjacent natural upland. In general, they found that song sparrows tend to be denser along upland edges of large marshes, especially where shrubs are present (Spautz et al. 2006). Abundance ranges from approximately 3 to 15 birds per hectare (1.2 to 6 per acre), depending on habitat value (Marshall 1948; Marshall and Dedrick 1994; Spautz and Nur 2008).

Nesting territories are established linearly every 10 to 50 meters (33 to 164 feet) along sloughs or other channels or along upland edges of marshes. Open marshes away from meandering channels are usually avoided. Each territory requires sufficient area for nesting and foraging, including tidally exposed mud, water, and vegetation suitable for nesting and cover (Walton 1975).

Nests are constructed in a variety of substrates, including *Schoenoplectus americanus*, *Bolboschoenus maritimus* subsp*. paludosus (*formerly *S. maritimus*), *S. acutus*, *Grindelia stricta*, *Lepidium latifolium*, *Salicornia pacifica*, and *Distichlis spicata*, among others (Spautz and Nur 2008). Nest heights average 36 centimeters (1.2 feet) (Herzog et al. 2004; Spautz et al. 2006) and are usually placed at a height in the vegetation where they can clear flood tide levels while still having cover from taller plants to minimize exposure to predation (Johnston 1956).

Low marsh habitats dominated by *Schoenoplectus acutus* and *S. californicus* do not provide breeding habitat, but they are used by Suisun song sparrows for foraging and can be part of the breeding territory. In addition, upland transition zones provide both foraging habitat and refuge during extreme high-tide events. Finally, managed wetlands in general provide only marginal habitat for this species.

2A.21.4 Life History

2A.21.4.1 Description

The Suisun song sparrow is a small passerine with a large head and plump build, conical bill, short rounded wings, and slender tail with a blunt tip (Arcese et al. 2002). Plumage is characterized by a dark streaked breast and mantle, usually well-defined on a gray or whitish background. The longitudinal streaks align into rows on the back and ventrally gather into a variably defined spot on the chest, leaving the lower belly largely unstreaked. Eyebrows are grayish, and a broad, dark stripe borders the whitish throat. Legs and feet are a pinkish color. The Suisun song sparrow is the darkest of the three subspecies occurring in the San Francisco Bay estuary. Coloration on the back is dark reddish-brown, which distinguishes it from the olive-brown of *M. m. samuelis* and the yellowish gray or plain gray of *M. m. pusillula* (Larsen 1989). The Suisun song sparrow also has a larger, thicker bill than the other neighboring subspecies (Marshall 1948).

2A.21.4.2 Seasonal Patterns

The Suisun song sparrow is nonmigratory and occupies the same territory year-round.

2A.21.4.3 Reproduction

The Suisun song sparrow begins breeding relatively early in the spring, an adaptation thought to avoid the highest spring tides, which is a mortality factor for eggs and young (Johnston 1954). Breeding occurs from early March to July (Spautz and Nur 2008), but this species can produce more than one brood per year and construct up to five nests each year. These activities are influenced by tidal activity and associated habitat and food availability and the outcome of the initial nesting attempt (Johnston 1954). Clutch size averages 3.2 eggs per nest; over the breeding season, the average total number of eggs per pair ranges from 7.5 to 9.1 (Johnston 1956). Productivity per pair over the season varies from 2.0 to 5.8 fledglings per pair, per season (Johnston 1956).

2A.21.4.4 Home Range and Territory Size

During the breeding season, the Suisun song sparrow occupies small territories (approximately 0.04 hectares [0.1 acre] in optimal habitat), usually adjacent to the territories of other Suisun song sparrows in a single linear arrangement along the edges of sloughs and bays. Each pair remains within its limited territory during the breeding season. All requirements for nesting and foraging, including tidally exposed mud, water, light, and vegetation suitable for nesting and cover are met within the territory. During the fall and winter, adults and young may range up to 183 meters (600 feet) from the territory and occupy adjacent seasonal marshes or grasslands, but continue to occupy the same general area and return to the same breeding territory each year (Marshall 1948; Walton 1975).

2A.21.4.5 Foraging Behavior and Diet

Suisun song sparrows forage on the bare surface of tidally exposed mud and along slough margins in the salt and brackish marshes of Suisun Bay during low tides. They feed on *Schoenoplectus* and other seeds once they have fallen to the ground, insects (mostly mosquito larvae and flies), and other invertebrates exposed during low tides (Marshall 1948; Walton 1975). While foraging, the Suisun song sparrow hops along the ground with both feet together, scratches leaf litter by pushing both feet simultaneously, or catches flies using hopping and darting motions with outstretched wings for balance (Bent 1968).

2A.21.5 Threats and Stressors

2A.21.5.1 Habitat Loss and Fragmentation

Habitat loss and fragmentation, caused by diking, levee construction, channelization, invasive species, and urbanization, is considered the primary threat to the continued existence of the Suisun song sparrow (Larsen 1989; Spautz and Nur 2008). Diking, channelization, development, and a substantial decrease in freshwater outflow from the Sacramento–San Joaquin River Delta (Delta) have greatly reduced the habitat that supports this subspecies. Throughout most of Suisun Marsh, the tidal marsh has been reduced to small fragments or strips of vegetation (Larsen 1989), although larger patches remain at Hill Slough and Rush Ranch. Large-scale habitat loss can also occur through the effects of global climate change and the resulting rise in sea level. With a projected 0.4-meter (1.3-foot) rise in sea level (Intergovernmental Panel on Climate Change 2001), large areas of tidal marsh in Suisun Marsh could be inundated, thus making them unsuitable for the Suisun song sparrow (Spautz and Nur 2008; Veloz et al. 2011). This is of particular concern in Suisun Marsh and similar areas where urbanization around the marsh perimeter has removed adjacent natural habitat and thus restricted potential expansion of the marsh in response to sea level rise over time (Orr et al. 2003).

2A.21.5.2 Nest Predation

Spautz and Nur (2008) note that reproductive failure caused by high levels of nest predation may be a significant threat to the Suisun song sparrow. Nonnative predators include the house cat (*Felis catus*), Norway rat (*Rattus norvegicus*), and red fox (*Vulpes vulpes*). Native predators include the American crow (*Corvus brachyrynchos*) and common raven (*C. corax*).

2A.21.5.3 Toxics

While there are regulations that protect most of the remaining tidal marshes inhabited by Suisun song sparrows, the urbanization of the surrounding area contributes to other threats that may alter water salinity and introduce toxins into the system, such as oil spills, chemical contamination, sewage, and other waste. Shipping activities along major channels, including oil tanker traffic and the presence of toxic waste dumps in the area, pose potential contamination issues (Larsen 1989).

2A.21.5.4 Salinity Changes

Normal salinity of Suisun Marsh is a function of the amount of freshwater outflow it receives from the Delta. Disruption of normal outflows can have a detrimental effect on this species. While the Suisun song sparrow has the ability to adapt to short-term changes in water salinity, sea level rise could permanently increase marsh salinity, affecting song sparrow habitat (Veloz et al. 2011). Significant alterations in the salinity content can result in undesirable habitat changes, lower reproductive output, competition, and genetic dilution from neighboring subspecies that have a greater range of tolerance (Larsen 1989).

2A.21.6 Relevant Conservation Efforts

Suisun Marsh has been the subject of various conservation efforts for many years, particularly with respect to development and issues related to water quality within its boundaries. The California Department of Water Resources (DWR) Suisun Marsh Program (2012) summarizes the major agreements, management plans, and legislation that have directed management of the Suisun Marsh since the mid-1970s. These efforts focus on the preservation and restoration of tidal marsh habitats.

2A.21.6.1 The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act (1974)

The California Legislature enacted the Suisun Marsh Preservation Act to protect the marsh from urban development. It required the San Francisco Bay Conservation and Development Commission to develop a plan for the marsh and provides for various restrictions on development within marsh boundaries.

2A.21.6.2 Suisun Marsh Protection Plan (1976)

This plan was developed by the Bay Conservation and Development Commission and defines and limits development within primary and secondary management areas for the "future of the wildlife values of the area as threatened by potential residential, commercial and industrial development." It recommends that the State of California purchase 1,800 acres and maintain water quality. While the focus of the plan is on maintaining waterfowl habitat, it also addresses the importance of tidal wetlands and recommends restoring historical marsh areas to wetland status (managed or tidal).

2A.21.6.3 The Suisun Marsh Protection Act (1977)

This act adopts and calls for implementation of the Suisun Marsh Protection Plan. Assembly Bill (AB) 1717 designates the Bay Conservation and Development Commission as the state agency with regulatory jurisdiction of the marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the marsh. The bill identifies (and focuses on) actions for the preservation of waterfowl needs, along with the retention of the diversity of wildlife. It states that land in Suisun Marsh, when no longer managed for waterfowl, should be acquired for public use or resource management if it is suitable for restoration to tidal or managed marsh, but that such restoration cannot be required as a condition of private development.

2A.21.6.4 State Water Resources Control Board Water Rights Decision 1485 (1978)

The State Water Resources Control Board (State Water Board) adopted the Water Quality Control Plan for the Delta and issued Water Rights Decision 1485. The decision sets channel water salinity standards for the period from October to May and preserves the area as brackish water tidal marsh. It sets water quality standards in the marsh as a condition of export pumping. These come from the California Department of Fish and Wildlife (CDFW) recommendations, which were based on the following elements:

- The relative value of marsh plants as food for ducks.

- The influence of soil salinity and other factors on distribution and growth of marsh plants.
- The relationships between channel water salinity and soil salinity.

CDFW concluded that improved management practices, improved drainage, water control facilities, and adequate water quality were needed to achieve desired soil salinity conditions for waterfowl food plants.

2A.21.6.5 Plan of Protection for the Suisun Marsh (1984)

DWR and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) developed and began implementing the Plan of Protection in accordance with Water Rights Decision 1485. The implementation strategy was to construct large facilities and distribution systems to meet salinity standards (lower channel water salinity), in lieu of significant State Water Project (SWP)/Central Valley Project (CVP) storage releases estimated as much as 2 million acre-feet in dry/critical water years. The six-phase plan was the programmatic blue print (required by the State Water Board and embodied in the original Suisun Marsh Preservation Agreement). Two of the six phases were completed, including the Initial Facilities and the Suisun Marsh Salinity Control Gates.

2A.21.6.6 Suisun Marsh Preservation Agreement (1987)

This contractual agreement between DWR, Reclamation, CDFW, and Suisun Resource Conservation District contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP/CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement requires DWR and Reclamation to meet salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. The Suisun Marsh Monitoring Agreement and the Suisun Marsh Mitigation Agreement were also signed at this time. The Suisun Marsh Mitigation Agreement defines habitat requirements to mitigate effects of facilities and operations, and the Suisun Marsh Monitoring Agreement defines requirements for monitoring salinity and species in Suisun Marsh.

2A.21.6.7 Bay-Delta Accord (1994)

On December 15, 1994, federal and state agencies, working with agricultural, environmental, and urban stakeholders, reached an agreement on water quality standards and related provisions that would remain in effect for 3 years. This agreement, known as the Bay-Delta Accord, was based on a proposal developed by the stakeholders. Elements of the agreement include the following:

- Springtime export limits expressed as a percentage of Delta inflow.
- Regulation of the salinity gradient in the estuary so that a salt concentration of two parts per thousand is positioned where it may be more beneficial to aquatic life.
- Specified springtime flows on the lower San Joaquin River to benefit Chinook salmon.
- Intermittent closure of the Delta Cross Channel gates to reduce entrainment of fish into the Delta.

2A.21.6.8 State Water Resources Control Board Water Quality Control Plan (1995 to 1998)

In 1994, wildlife and fishery agencies and urban water users expressed concerns about the appropriateness of western Suisun Marsh channel water salinity standards. In May 1995, the State Water Board modified the Suisun Marsh salinity objectives in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta estuary. Modeling analysis by the Suisun Marsh Planning Program showed that Suisun Marsh standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the western Suisun Marsh that participants in the Suisun Marsh Preservation Agreement agreed could be mitigated by more active water control by landowners.

2A.21.6.9 State Water Resources Control Board Water Rights Decision 1641 (1999)

The State Water Board issued Decision 1641 in December 1999, which updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta provided indirect benefits to Suisun Marsh. DWR proposed that the State Water Board adopt the Amendment Three actions for Suisun Marsh in this decision. However, the State Water Board was unable to adopt Amendment Three actions because the Section 7 consultation with USFWS had not concluded. However, the State Water Board did relieve Reclamation and DWR of their responsibility to meet salinity objectives at S-35 and S-97 in the western Suisun Marsh.

2A.21.6.10 Suisun Marsh Charter Implementation Plan (2001)

The Suisun Marsh Charter was completed in 2001, and development of an Implementation Plan commenced. Charter participants collaborated on a joint presentation to the State of the Estuary Conference on the principles of the Charter Plan, including coordinated water quality, endangered species, and heritage value protection in Suisun Marsh.

2A.21.6.11 Habitat Management, Preservation, and Restoration Plan (2010)

The Charter process was expanded to include additional federal and state agencies to develop a Suisun Marsh Plan that would balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement, and other management and restoration programs in Suisun Marsh in a manner that is responsive to the concerns of all stakeholders and is based on voluntary participation by private landowners.

In addition, several facilities have been constructed in Suisun Marsh to protect and improve water quality and protect and enhance wildlife habitat.

- Roaring River Distribution System (1979 to 1980)
- Morrow Island Distribution System (1979 to 1980)
- Goodyear Slough Outfall (1979 to 1980)
- Suisun Marsh Salinity Control Gates (1988)

- Cygnus and Lower Joice Facilities (1991)

The Suisun song sparrow is also a covered species under the *Solano Multispecies Habitat Conservation Plan* (Solano County Water Agency 2009).

2A.21.7 Species Habitat Suitability Model

The methods used to formulate species habitat suitability models, and the limitations of these models, are described in Section 2A.0.17, *Species Habitat Suitability Model Methods.*

2A.21.7.1 GIS Model Data Sources

The Suisun song sparrow model uses vegetation types and associations from the following geographic information system (GIS) data sets: BDCP composite vegetation layer (Hickson and Keeler-Wolf 2007 [Delta], Boul and Keeler-Wolf 2008 [Suisun Marsh], TAIC 2008 [Yolo Basin]), aerial photography (U.S. Department of Agriculture 2005), and land use survey of the Delta and Suisun Marsh area - version 3 (California Department of Water Resources 2007). Using these data sets, the model maps the distribution of suitable Suisun song sparrow habitat in the Plan Area. Vegetation types were assigned based on the species requirements, as described above, and the assumptions described below.

2A.21.7.2 Habitat Model description

There are two Suisun song sparrow modeled habitat components: primary breeding habitat and secondary habitats that provide lesser ecological functions. Modeled Suisun song sparrow primary breeding habitat consists of all *Salicornia*-dominated tidal brackish emergent wetland and all *Typha-Schoenoplectus* (formerly known as *Scirpus*) and *Juncus*-dominated tidal freshwater emergent wetland in the Plan Area west of Sherman Island, with the exception that *Schoenoplectus acutus* and *S. californicus* plant communities (low marsh) and all of the plant communities listed below that occur in managed wetlands are classified as secondary habitat. Further, upland transitional zones, providing refugia during high tides, within 150 feet of the wetland edge were also included as secondary habitat. A 1-acre minimum mapping unit was applied to primary and secondary modeled habitat. A GIS constraint layer was developed to limit suitable habitat to west of Sherman Island.

Suisun song sparrow primary habitat in the Delta, but west of Sherman Island, consists of the following vegetation types from the BDCP composite vegetation layer.

- *Scirpus* spp. in managed wetlands
- *Distichlis spicata–Salicornia pacifica* (formerly *S. virginica*)
- *Distichlis spicata–Juncus balticus*
- *Juncus bufonius* (salt grasses)
- *Juncus balticus*–meadow vegetation
- Pickleweed (*Salicornia virginica*, now *Salicornia pacifica*)
- *Salicornia virginica–Cotula coronopifolia*
- Broad-leaf cattail (*Typha latifolia*)

- Mixed *Schoenoplectus* mapping unit
- Mixed *Schoenoplectus*/floating aquatics complex
- Mixed *Schoenoplectus*/submerged aquatics complex
- Hard-stem bulrush (*Schoenoplectus acutus*) (secondary)
- *Schoenoplectus acutus* pure (secondary)
- *Schoenoplectus acutus*–*Typha angustifolia* (secondary)
- *Schoenoplectus acutus*–*Typha latifolia* (secondary)
- *Schoenoplectus acutus*–(*Typha latifolia*)–*Phragmites australis* (secondary)
- California bulrush (*Schoenoplectus californicus*) (secondary)
- *Schoenoplectus californicus*–*Eichhornia crassipes* (secondary)
- *Schoenoplectus californicus*–*Schoenoplectus acutus* (secondary)
- American bulrush (*Schoenoplectus americanus*)
- Narrow-leaf cattail (*Typha angustifolia*)
- *Typha angustifolia*-*Distichlis spicata*

Suisun song sparrow primary habitat in Suisun Marsh consists of the following vegetation types from the BDCP composite vegetation layer.

- Bulrush–cattail freshwater marsh not formally defined (NFD) super alliance
- *Grindelia stricta* var. *stricta*
- *Juncus balticus*
- *Juncus balticus*/*Conium*
- *Juncus balticus*/*Lepidium*
- *Juncus balticus*/*Potentilla*
- *Lepidium* (generic)
- *Lepidium*/*Distichlis*
- *Salicornia* (generic)
- *Salicornia virginica*
- *Salicornia*/annual grasses
- *Salicornia*/*Atriplex*
- *Salicornia*/*Cotula*
- *Salicornia*/*Crypsis*
- *Salicornia*/*Polygonum*–*Xanthium*–*Echinochloa*
- *Salicornia*/*Sesuvium*
- *Schoenoplectus* (*californicus* or *acutus*)–*Typha* spp. (secondary)

- *Schoenoplectus* (*californicus* or *acutus*)–*Rosa* (secondary)
- *Schoenoplectus* (*californicus* or *acutus*)/wetland herb (secondary)
- *Schoenoplectus americanus* (generic)
- *Schoenoplectus americanus*/*Lepidium*
- *Schoenoplectus americanus*/*Potentilla*
- *Schoenoplectus americanus*/*S. californicus*–*S. acutus*
- *Schoenoplectus californicus*/*S. acutus* (secondary)
- *Schoenoplectus maritimus*
- *Schoenoplectus maritimus*/*Salicornia*
- *Schoenoplectus maritimus*/*Sesuvium*
- *Typha angustifolia* (dead stalks)
- *Typha angustifolia*/*Distichlis*
- *Typha angustifolia*/*Phragmites*
- *Typha angustifolia*/*Polygonum*–*Xanthium*–*Echinochloa*
- *Typha angustifolia*/*S. americanus*
- *Typha* species (generic)

Suisun song sparrow secondary habitat in the upland transition zone adjacent to tidal wetlands consists of the following types from the BDCP composite vegetation layer.

- Annual grassland (generic)
- Annual grasses/weeds (generic)
- Ruderal herbaceous grasses & forbs
- California annual grasslands–herbaceous
- *Bromus diandrus*–*Bromus hordeaceus*
- *Atriplex lentiformis*
- *Atriplex triangularis*
- *Atriplex*/annual grasses
- *Atriplex*/*Distichlis*
- *Atriplex*/*Schoenoplectus maritimus*
- *Atriplex*/*Sesuvium*
- *Baccharis*/annual grasses
- *Bromus* spp./*Hordeum*
- *Hordeum*/*Lolium*
- Vernal pools

- Degraded vernal pool complex–California annual grasslands–herbaceous
- Degraded vernal pool complex–Italian ryegrass (*Lolium multiflorum*)
- Degraded vernal pool complex–rabbitsfoot grass (*Polygpogon maritimus*)
- Degraded vernal pool complex–ruderal herbaceous grasses & forbs
- Degraded vernal pool complex–vernal pools

In 2011, and again in 2012, the species habitat models were updated to include previously unmapped portions of the Plan Area. The methods used to map these new analysis areas differ from the original methods and are described in Section 2A.0.1.7, *Species Habitat Suitability Model Methods*. For most areas newly mapped, vegetation data were not available at the alliance level as in the rest of the Plan Area and so most of the new analysis areas were mapped at the natural community level. Additional detail regarding crop types was available for cultivated lands and was incorporated into the mapping. In the new analysis areas, the following natural community was assumed to provide Suisun song sparrow habitat when it occurred west of Sherman Island.

- Tidal brackish emergent wetland

2A.21.7.3 Assumptions

- **Assumption**: Suisun song sparrow habitat in the Plan Area is geographically constrained to Suisun Marsh and the Delta west of Sherman Island.

  Rationale: Suisun song sparrows are found exclusively in tidal marshes and adjacent uplands of the Suisun Bay and as far east as Kimball Island in the western Delta (Spautz and Nur 2008).

- **Assumption:** Suisun song sparrow habitat is restricted to the vegetation types described in Section 2A.18.7.2, *Habitat Model Description*.

  Rationale: Suisun song sparrows nest and forage in tidal brackish emergent wetland habitats dominated by *Spartina*, *Salicornia*, and *Grindelia* spp. and tidal freshwater emergent wetland habitats dominated by *Schoenoplectus*, *Typha*, and *Juncus* spp. and, to an increasing extent, *Lepidium latifolium* (Spautz and Nur 2008). Low marsh habitats dominated by *Schoenoplectus acutus* and *S. californicus* and managed wetlands in general provide lesser habitat value. Specific habitat elements, including proximity to tidal channels, percentage of shrub cover, and site-specific vegetation associations that could potentially refine the extent of the suitable habitat conditions were not sufficiently identified in the GIS databases, and were not used in the model. Therefore, the model likely overestimates the extent of potentially occupied tidal marsh habitat.

2A.21.8 Recovery Goals

The CALFED Bay-Delta Ecosystem Restoration Program Plan's *Multi-Species Conservation Strategy* designates the salt marsh harvest mouse as a Contribute to Recovery species (CALFED Bay-Delta Program 2000). This means that the Ecosystem Restoration Program will undertake actions under its control and within its scope that are necessary to contribute to the recovery of the species. Recovery is equivalent to the requirements of delisting a species under federal and state endangered species acts.

2A.21.9 References Cited

2A.21.9.1 Literature Cited

Arcese, P., M. K. Sogge, A. B. Marr, and M. A. Patten. 2002. Song Sparrow (*Melospiza melodia*). *The Birds of North America*. A. Poole (ed.). Ithaca, NY: Cornell Lab of Ornithology. Available: <http://bna.birds.cornell.edu/bna/species/704>.

Bent, A. C. 1968. *Life Histories of North American Cardinal, Grosbeaks, Buntings, Towhees, Finches, Sparrows, and Allies*. Part 3. New York, NY: Dover Publications.

Boul, P. and T. Keeler-Wolf. 2008. *2006 Vegetation Map Update for Suisun Marsh, Solano County, California*. Sacramento, CA: California Department of Water Resources.

CALFED Bay-Delta Program. 2000. *Ecosystem Restoration Program Plan. Volume II: Ecological Management Zone Visions. Final Programmatic ESI/EIR Technical Appendix.* Available: <http://www.delta.dfg.ca.gov/erp/docs/reports_docs/ERPP_Vol_2.pdf>.

California Department of Water Resources. 2007. *Land Use Survey of Delta and Suisun Marsh Area.* Version 3 GIS dataset. Sacramento, CA.

California Department of Water Resources. 2012. *Suisun Marsh Program.* Last revised: December 22, 2009. Available: <http://www.water.ca.gov/suisun/program/>. Accessed: July 11, 2012.

Chan, Y. and P. Arcese. 2002. Subspecific Differentiation and Conservation of Song Sparrows (*Melospiza melodia*) in the San Francisco Bay Region Inferred by Microsatellite Loci Analysis. *Auk* 119:641–657.

Gardali, T. 2008. Song Sparrow (*Melospiza melodia*) ("Modesto" Population). In: Shuford, W.D. and T. Gardali (eds.). *California Bird Species of Special Concern: A Ranked Assessment of Species, Subspecies, and Distinct Population of Birds of Immediate Conservation Concern in California*. Studies of Western Birds 1. Camarillo, CA: Western Field Ornithologists; Sacramento, CA: California Department of Fish and Game.

Grinnell, J. and A. H. Miller. 1944. *The Distribution of the Birds of California*. Berkeley, CA: Museum of Vertebrate Zoology, University of California.

Herzog, M., L. Liu, N. Nur, H. Spautz, and N. Warnock. 2004. San Francisco Bay Tidal Marsh Project Annual Report 2004. *Distribution, Abundance, and Reproductive Success of Tidal Marsh Birds*. Petaluma, CA: PRBO Conservation Science.

Hickson, D. and T. Keeler-Wolf. 2007. *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta.* Sacramento, CA: California Department of Fish and Game, Bay Delta Region. Available: <http://dfg.ca.gov/biogeodata/vegcamp/veg_classification_reports_maps.asp>.

Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. T. Houghton, Y. Ding. D. J . Griggs, M. Noguer, P. J . van der Linden, X. Dai, K. Maskell, and C. A. Johnson (eds.). Cambridge, UK: Cambridge University Press.

Johnston, R. F. 1954. Variation in Breeding Season and Clutch Size in Song Sparrows of the Pacific Coast. *Condor* 56(5):268–273.

Johnston, R. F. 1956. Population Structure in Salt Marsh Song Sparrows. Part 1: Environment and Annual Cycle. *Condor* 58:24–44.

Larsen, C. J. 1989. *A Status Review of the Suisun Song Sparrow* (Melospiza melodia maxillaris) *in California, Report to the Fish and Game Commission.* Department Candidate Species Status Report 89-6. Sacramento, CA: California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section,

Marshall, J. T., Jr. 1948. Ecologic Races of Song Sparrows in the San Francisco Bay Region. Part 1: Habitat and Abundance. *Condor* 50:193–215.

Marshall, J. T., Jr. and K. G. Dedrick. 1994. Endemic Song Sparrows and Yellowthroats of San Francisco Bay. *Studies in Avian Biology* 15:316–327.

Orr, M., S. Crooks, and P. B. Williams. 2003. Will Restored Tidal Marshes Be Sustainable? *San Francisco Estuary and Watershed Science* [online serial]. 1(1): Article 5.

Patten, M. A. 2001. *The Roles of Habitat and Signaling in Speciation: Evidence from a Contact Zone of Two Song Sparrow (*Melospiza melodia*) Subspecies*. PhD dissertation. University of California, Riverside.

Solano County Water Agency. 2009. *Solano Multispecies Habitat Conservation Plan.* Final Administrative Draft. June 15. Available: <http://www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx>. Accessed: December 22, 2011.

Spautz, H. and N. Nur. 2008. Suisun Song Sparrow (*Melospiza melodia maxillaris*). In: W. D. Shuford and T. Gardali (eds.), *California Bird Species of Special Concern: A Ranked Assessment of Species, Subspecies, and Distinct Population of Birds of Immediate Conservation Concern in California*. Studies of Western Birds 1. Camarillo, CA: Western Field Ornithologists; Sacramento, CA: California Department of Fish and Game.

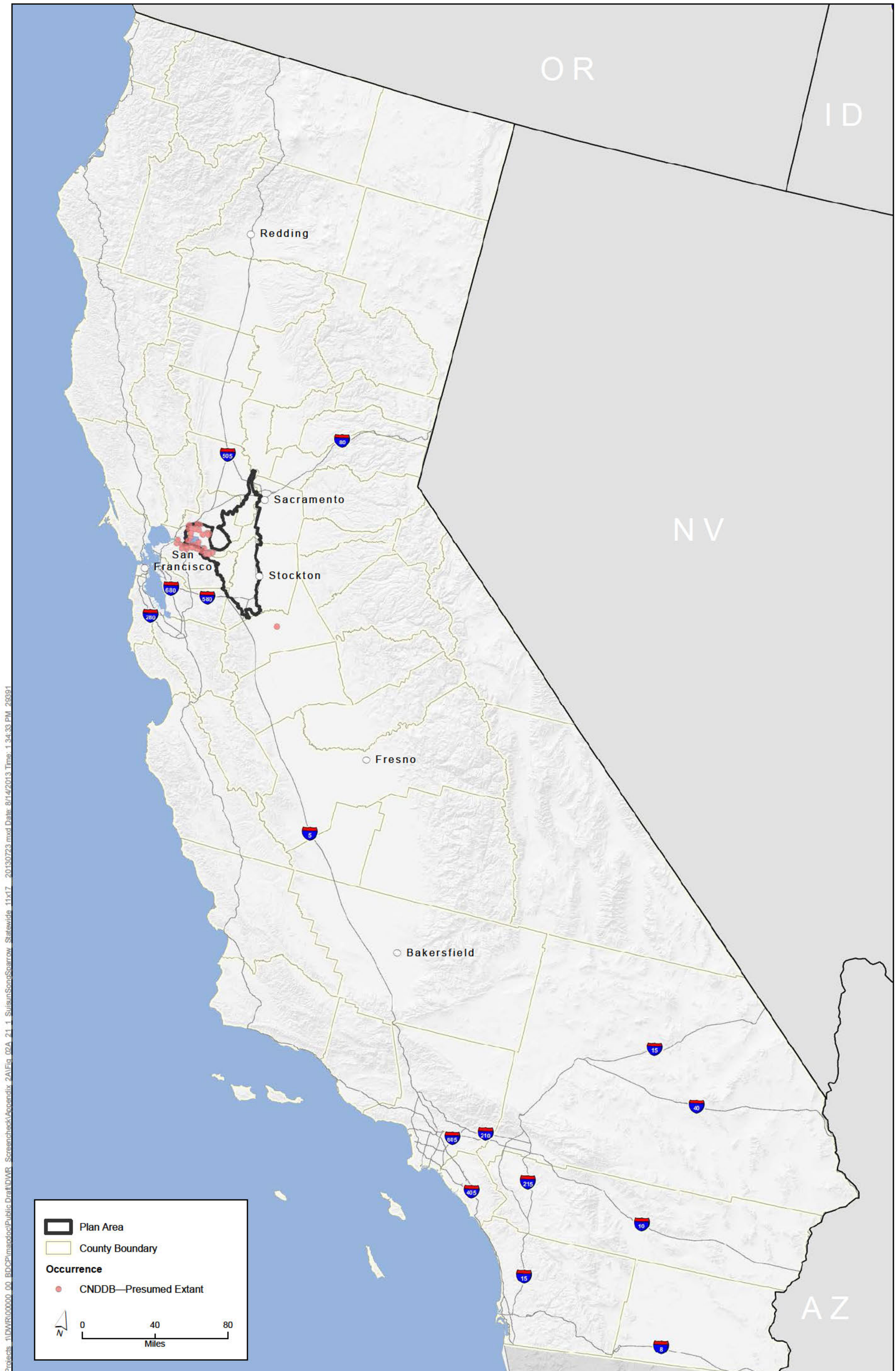
Spautz, H., N. Nur, D. Stralberg, and Y. Chan. 2006. Multiple-Scale Habitat Relationships of Tidal-Marsh Breeding Birds in the San Francisco Bay Estuary. *Studies in Avian Biology* 32:247–269.

TAIC. 2008. *Yolo County Regional Vegetation*. July. Available: <http://www.yoloconservationplan.org/yolo_data/YoloCounty_RegionalVegetation_July08.shp>.

U.S. Department of Agriculture. 2005. *National Agricultural Imaging Program*. USDA Farm Service Agency Aerial Photography Field Office. Salt Lake City, UT.

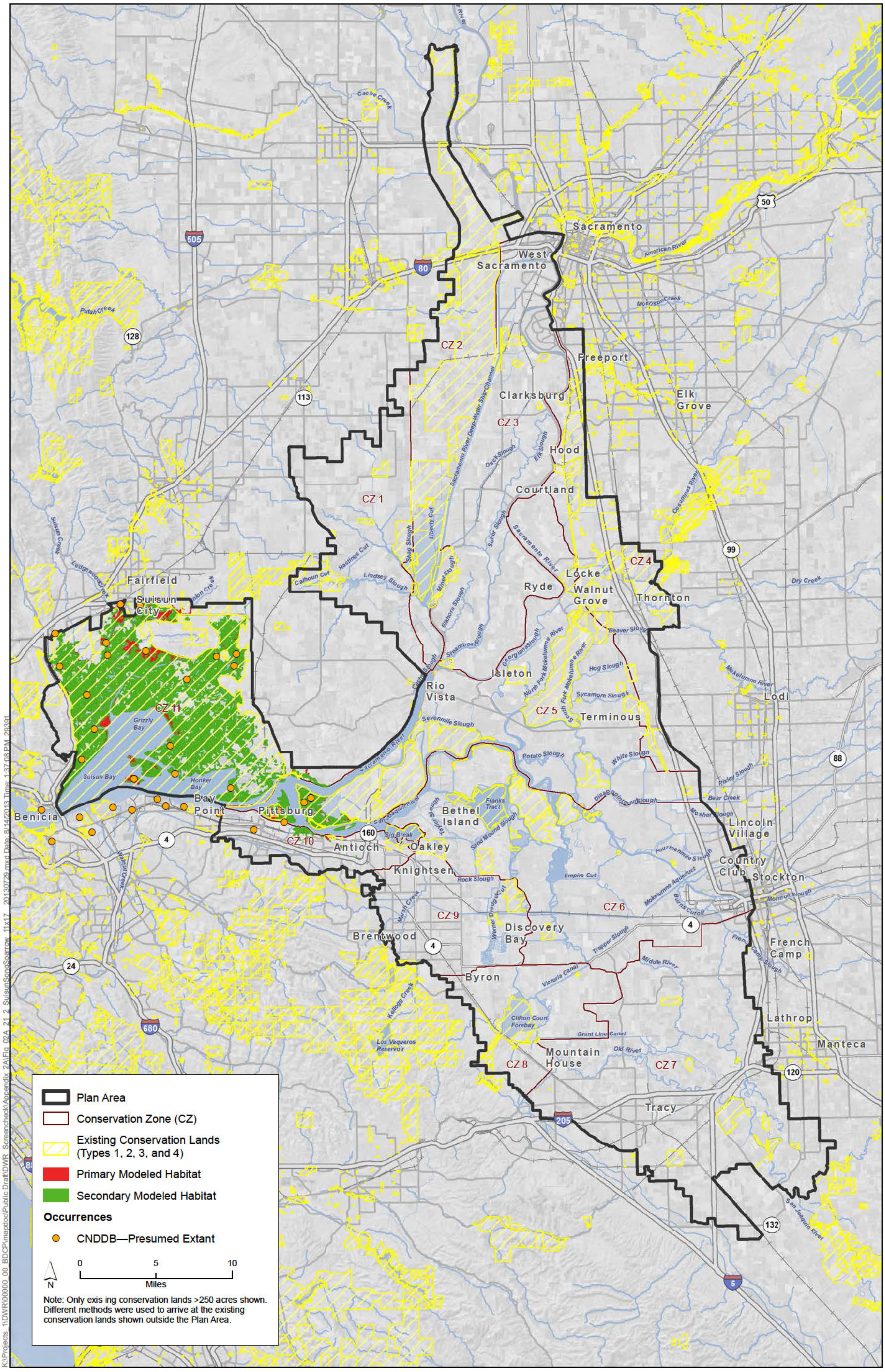
Veloz, S., N. Nur, L. Salas, D. Stralberg, D. Jongsomjit, J. Wood, L. Liu, and G. Ballard. 2011. *Tidal Marsh Bird Population and Habitat Assessment for the San Francisco Estuary under Future Climate Change Conditions. Technical Report Version 1.0.* Report to the California Landscape Conservation Cooperative.

Walton, B. J. 1975. *San Francisco Bay Region Salt Marsh Song Sparrow Survey, 1974.* Report to California Department of Fish and Game. Sacramento, CA.



GIS Data Sources: Occurrences, CNDDB June 2013.

Figure 2A.21-1
Suisun Song Sparrow Statewide Range and Recorded Occurrences



GIS Data Source: Existing Conservation Lands Outside Plan Area, CPAD 2013 and CDFG-WCB 2011; Occurrences, CNDDB 2013.

Figure 2A.21-2
Suisun Song Sparrow Habitat Model and Recorded Occurrences