Appendix K. Wildlife Targets

The goal for this appendix is to provide the rationale for the target methylmercury concentrations that should protect all wildlife in California. These wildlife targets will be used to establish water quality objectives for mercury to protect wildlife that will be part of the Provisions. Such wildlife targets have already been calculated as part of several different projects. This analysis (Appendix K) is partly a compilation of information from those previous projects, with frequent references to them. These previous projects are briefly described below.

In 2000, the United States Fish and Wildlife Service (USFWS) determined that the draft California Toxics Rule criteria for mercury (and other constituents) would not protect several threatened and endangered species. This decision was published in the Draft Jeopardy Ruling and Final Biological Opinion on the California Toxics Rule (USFWS & National Marine Fisheries Service (NMFS) 2000). As part of this determination, the USFWS determined protective methylmercury targets for wildlife. Later, the USFWS produced another detailed analysis of protective targets for threatened and endangered species in 2003 (USFWS 2003). This analysis was performed to determine if the United States Environmental Protection Agency's (U.S. EPA) human health criteria would provide adequate protection for threatened and endangered species (U.S. EPA 2001). The USFWS determined that the human health criteria would not be protective for California least tern, the Yuma Ridgeway's rail and possibly the light-footed Ridgeway's rail (formerly known as clapper rails).

Several California Regional Water Quality Control Boards (Regional Water Boards) have also developed protective targets for wildlife species in the development of site-specific water quality objectives as part of total maximum daily loads (TMDLs). The Central Valley Regional Water Board developed wildlife values as part of the site-specific objectives for Clear Lake, Cache Creek, and the Sacramento-San Joaquin Delta and Yolo Bypass (Central Valley Water Board 2002, 2005, 2010). The San Francisco Bay Regional Water Board developed site-specific objectives to protect wildlife for the Guadalupe River Watershed and Walker Creek (San Francisco Bay Water Board 2008a, 2008b). The USFWS reviewed the wildlife targets for Cache Creek (developed by the Central Valley Water Board) and calculated the wildlife targets for Guadalupe River Watershed. Additionally, the USFWS 2003 report incorporates information from Canada's water quality criterion (Canadian Council of Ministers of the Environment 2000), the Mercury Study Report to Congress (U.S. EPA 1997a,b), and the Great Lakes Initiative (U.S. EPA 1995).

K.1   Species of Concern

Considering the bioaccumulation and biomagnification of methylmercury in the aquatic food web, the upper trophic level wildlife species (i.e., predatory birds and mammals) are thought to have the greatest risk from exposure to methylmercury. Therefore, research into the effects of

methylmercury on wildlife has generally focused on birds and mammals that prey directly on fish and other aquatic organisms. Piscivorous (fish eating) birds and mammals are generally higher order predators than, for example, aquatic-dependent reptiles and amphibians, which may result in a greater potential for dietary exposure and subsequent toxicity. This same concept of greater potential risk to higher order piscivorous species may also hold for top predators that in turn prey on piscivorous wildlife (*e.g.*, a peregrine falcon preying on piscivorous waterfowl), due to the successive trophic level biomagnification. A list of species of concern was compiled from the previous analyses (below). Marine wildlife was excluded from this analysis because the geographic scope of the Provisions does not include the ocean.

Species that were included in the USFWS evaluation of the U.S. EPA methylmercury human health criterion are listed below (USFWS 2003). All of these species are federally listed as threatened or endangered, except the bald eagle which was delisted in 2007. Figure K-1 shows geographic locations where these species have been observed in California.

> Bald Eagle (*Haliaeetus leucocephalus,* delisted in 2007)
> California Least Tern (*Sterna antillarum browni*)
> California Ridgeway's Rail (*Rallus obsoletus*)*
> Light-Footed Ridgeway's Rail (*Rallus obsoletus levipes*)*
> Yuma Ridgeway's Rail (*Rallus obsoletus yumanensis*)*
> Western Snowy Plover (*Charadrius alexandrinus nivosus*)
> Southern Sea Otter (*Enhydra lutris nereis*)
>
> *Note that Ridgeway's rails were formerly a clapper rails, *Rallus longirostris.*

Threatened and endangered species that were considered in the USFWS Final Biological Opinion (USFWS & NMFS 2000) were similar to the above, except that the Final Biological Opinion did not include western snowy plover, while it did include the marbled murrelet. The marbled murrelet feeds mostly in the open ocean (CDFW 1990) which is beyond the geographic scope of this objective.

The California least tern, California Ridgeway's rail, light-footed Ridgeway's rail, and Yuma Ridgeway's Rail, and bald eagle are listed as endangered species and fully protected species under the California Endangered Species Act of 1984. This legislation requires State agencies to consult with the California Department of Fish and Wildlife (CDFW) on activities that may affect a State-listed species. Western Snowy Plover and the Southern Sea Otter are not on the State's list of threatened or endangered species.

The goal of water quality objectives is not just to protect threatened and endangered wildlife but all wildlife. Regional Water Boards included several other wildlife species in the development of site-specific objectives. Development of the Cache Creek site-specific objectives (Central Valley Water Board 2005) examined values for the following species:

Mink (*Mustela vison,* recently changed to *Neovison vision*)
River Otter (*Lutra canadensis*)
Belted Kingfisher (Mega*ceryle alcyon*)
Common Merganser (*Mergus merganser*)
Western Grebe (*Aechmophorus occidentalis*)
Double-crested Cormorant (*Phalacrocorax auritus*)
Osprey (*Pandion haliaetus*)
Bald Eagle (*Haliaeetus leucocephalus*)
Peregrine Falcon (*Falco peregrinus*)

These same species were used for the Sacramento-San Joaquin Delta site-specific objectives, in addition to the California least tern and the western snowy plover (Central Valley Water Board 2010)

Development of the Clear lake and Guadalupe River Watershed site-specific objectives (Central Valley Water Board 2002, USFWS 2005) included a few of the above species, and also considered:

Great blue heron (*Ardea herodias*)
Forster's tern (*Sterna forsteri*)
Common loon (*Gavia immer*)

For this analysis, additional species of concern were sought out in CDFW's current list of threatened and endangered species in California and in a list of birds in the Salton Sea (CDFW 2013, 2012). The list was reviewed for other piscivorous wildlife that feed in California inland surface waters, enclosed bays and estuaries. No additional species were identified that were clearly at high risk, some of the species that were considered more in depth are discussed later, in Section K.10 of this appendix.

K.2   Calculation of Protective Wildlife Values

The USFWS used the following equation to calculate a protective concentration for the overall diet of a given species (USFWS 2003). This calculation is based on information about the organism's body weight and daily food consumption.

$$WV = \frac{RfD \times BW}{FIR} \qquad (1)$$

where,
        WV = Wildlife Value (mg/kg in diet)
        RfD = Reference Dose (mg/kg of body weight/day)
        BW = Body Weight (kg) for species of concern
        FIR = Total Food Ingestion Rate (kg of food/day) for species of concern

The wildlife value is essentially a safe concentration of methylmercury in the diet for a particular wildlife species. More specifically, a wildlife value "represents the overall dietary concentration

of methylmercury necessary to keep the daily ingested amount at or below a sufficiently protective reference dose. Reference doses (RfD) may be defined as the daily exposure to a toxicant at which no adverse effects are expected" (USFWS 2003). The reference dose used in this appendix was from a study in mallard ducks, the same as used by USFWS (USFWS 2003). The use of the mallard reference dose was also supported by data in great egrets (Bouton et al. 1999 and Spalding et al. 2000 a,b, discussed in USFWS 2003).

Equation 1 converts a protective RfD into an overall dietary concentration (in mg/kg in diet). Table K-1 shows the calculated wildlife values for all species of concern listed in the previous section.

Table K-1. Wildlife Values (mg/kg in diet)

Species	RfD (mg/kg/day)	Body Weight (kg)	FIR (kg/day)	Wildlife Value[a] (mg/kg in diet)
Mink	0.018	0.60	0.140	0.077
River otter	0.018	6.70	1.124	0.107
Belted kingfisher	0.021	0.15	0.068	0.046
Common merganser	0.021	1.23	0.302	0.085 (0.099[b])
Western grebe	0.021	1.19	0.296	0.084
Double-crested cormorant	0.021	1.74	0.390	0.094
Osprey	0.021	1.75	0.350	0.105 (0.112[b])
Bald eagle	0.021	5.25	0.566	0.195 (0.184[c])
Peregrine falcon	0.021	0.89	0.134	0.139
Southern sea otter [FT]	0.018	19.8	6.5	0.055
California least tern [FE]	0.021	0.045	0.031	0.030
California Ridgeway's rail [FE]	0.021	0.346	0.172	0.042
Light-footed Ridgeway's rail [FE]	0.021	0.271	0.142	0.040
Yuma Ridgeway's rail [FE]	0.021	0.271	0.142	0.040
Western snowy plover [FT]	0.021	0.041	0.033	0.026
Great blue heron	0.021	2.20	0.378	0.122 [b]
Forster's tern	0.021	0.16	0.071	0.047 [b]
Common loon	0.021 [d]	4 [d]	0.800 [d]	0.105

[a] from the USFWS Cache Creek Targets (USFWS 2004) and the USFWS Evaluation of the U.S. EPA Human Health Criterion (USFWS 2003), except as otherwise noted
[b] from Guadalupe River Watershed targets (USFWS 2005)
[c] the two references (USFWS 2004 and USFWS 2003) provided different values
[d] from Clear Lake analysis (Central Valley Water Board 2002)
[FT/FE] on federal list of threatened or endangered species

Food ingestion rates (FIR, kg of food/day) for species of concern were taken from existing reports by the USFWS or Water Boards (see Table K-1 above). In general, food ingestion rates for birds that prey on fish are higher than food ingestion rates for birds that prey on terrestrial animals. This is because fish do not provide as much energy as birds and mammals, on an ounce-for-ounce basis (USFWS 2004).

Next, the USFWS considered the kind of fish to which the wildlife value should apply. Fish may fall into trophic level 2, 3, or 4 (TL2, TL3, or TL4) depending on their position in the food web. The methylmercury concentrations in the fish flesh will depend on the position of the fish on the food web; organisms higher on the food web accumulate more methylmercury. Trophic levels used in this evaluation were based on definitions provided in USFWS 2003, U.S. EPA 1997b:

Trophic Level 1 – Plants and detritus (*e.g.*, periphyton, phytoplankton)
Trophic Level 2 – Herbivores and detritivores (*e.g.*, copepods, water fleas)
Trophic Level 3 – Predators on trophic level 2 organisms (*e.g.*, minnows, sunfish, suckers)
Trophic Level 4 – Predators on trophic level 3 organisms (*e.g.*, bass, pikeminnow)

If a wildlife species consumes only equivalently sized fish from one trophic level, then the wildlife value may be used as the protective target for that trophic level. On the other hand, if a wildlife species consumes prey from more than one trophic level, the methylmercury in each trophic level should be considered when applying the wildlife value. Therefore, an understanding of the dietary composition for these wildlife species is needed to determine the limiting methylmercury concentrations for each trophic level to protect wildlife.

The USFWS and Regional Water Boards determined the diet for each species by reviewing the scientific literature for a particular species or by extrapolating from information about a similar species. The diets were then categorized by the relative portion from each trophic level that they consumed. The diet composition for each species is shown in Table K-2. The USFWS originally categorized diet only by trophic level (e.g. TL2, TL3 or TL4), while subsequent evaluations by the USFWS and the Regional Water Boards subdivided the diet into specific sizes ranges (e.g. TL3 less than 150 mm or TL3 150 – 500 mm, USFWS 2003). For light-footed Ridgeway's rail, California Ridgeway's rail, snowy plover and otter, all prey species that were classified as TL3 by the USFWS are still classified as simply TL3 in this analysis (USFWS 2003). These species included various species of crabs (Cancer spp.), nassa mud snails (scavengers), fish (killifish, longjaw mudsuckers), and crayfish. The diet for Californian Least tern was revised as described below. For bald eagle, the more recent diet composition from the USFWS was used (USFWS 2004), which was based on a publication by Jackman et al. (Jackman et al. 1999). However, a more recent article by Jackman et al. suggest that the proportion of TL4 fish, particularly bass, in the diet of eagles that live near reservoirs can be much higher than the previous findings, at 55% (Jackman et al. 2007).

Table K-2. Trophic Level (TL) Compositions (Expressed as Decimal Fractions) for Wildlife Species, Including Omnivorous Birds (OB), Piscivorous Birds (PB) and Other Foods (OF)

Species	TL2	TL2/3 < 50 mm	TL3 < 150 mm	TL3 150 – 500 mm	TL4 150 – 500 mm	OB	PB	OF
Mink			1.00					
River otter			0.80		0.20			
Belted kingfisher			1.00					
Common Merganser				1.00				
Western grebe				1.00[a]				
Double-crested cormorant			1.00					
Osprey				0.90	0.10			
Bald eagle				0.58	0.13	0.13	0.05	0.11
Peregrine falcon						0.10	0.05	0.85
Southern sea otter	0.80			0.20				
California least tern		1.00						
California Ridgeway's rail	0.85			0.05				
Light-footed Ridgeway's rail	0.82			0.18				
Yuma Ridgeway's rail	0.23			0.72				0.05
Western snowy plover	0.25							.75
Great blue heron			1.00[b]					
Forster's tern		1.00[b]						
Common loon				0.80[c]				

Note: most data are from the USFWS evaluation of the U.S. EPA human health criterion (Table 4, USFWS 2003), the USFWS Cache Creek targets (Table 4, USFWS 2004) and the Sacramento-San Joaquin Delta targets (Table 4.1 and Table 4.3, Central Valley Water Board 2010), except as otherwise noted.

[a] The U.S. Geological Survey grebe study team caught fish 18 – 123 mm as representative grebe prey (Ackerman et al. 2015). Also, fish found in the stomachs of western grebes were 27 – 88 mm (1 – 3.5 in) long (CDFW 1990). In any case, the larger size (used in Table K-2) is more protective.

[b] from Guadalupe River Watershed targets (Table 4 and 5, USFWS 2005).

[c] from Clear Lake targets (Table C-3, Central Valley Water Board 2002), reclassified based on the 200 – 400 mm size and CDFW 1990. Clear Lake report has the loon diet as "TL2" but "200 – 400 mm". Because of the size the fish are shown here as TL3. The CDFW life history account for loon: "Diet varies; usually about 80% fish, with crustaceans the next largest item… Most fish eaten are not sought by humans…" Burgess and Meyer report "We sampled small fish (76 – 127 mm in length) typically consumed as prey by loons (Barr 1996)"

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-6

For the California least tern, an additional diet category was developed by the USFWS. The USFWS recommended a protective target for terns for TL3 less than 50 mm based on the very small fish this species preys upon (USFWS 2004). This category was also used in the Guadalupe River Watershed target for Forster's tern (USFWS 2005), and this category is included in this analysis (Table K-2). In the environment it may be difficult to distinguish if a small fish is TL2 or TL3; therefore, the category was defined as TL2/3 less than 50 mm.

The Yuma Ridgeway's rail primarily preys upon crayfish (estimated to be 90% of the diet) along with small contribution from other TL2 organisms (isopods, damselfly nymphs, mollusks) and some non-aquatic organisms (USFWS 2003). The USFWS classified the crayfish as trophic level (TL) 2.8 and the whole diet was categorized as 72 % TL3 and 23 % TL2, with another 5% in non-aquatic plants or animals (USFWS 2003). This classification is shown in Table K-2. Yuma Ridgeway's rail is one of the more sensitive species that may influence the final recommended water quality objectives.

K.3   Calculation of Targets for Species that Eat from only One Trophic Level

The information on the diet of each species (Table K-2) was used to identify the species that only consumed prey from one trophic level. For these species the wildlife value (Table K-1) was used as the target. Targets for mink, belted kingfisher, double crested cormorant, great blue heron, Forster's tern, California least tern, and western snowy plover were derived this way. The resulting values are shown in Table K-3. The USFWS considered that food other than fish or birds ("other foods") had negligible amounts of methylmercury (USFWS 2003). For example, for western snowy plover the wildlife value was assigned to the TL2 portion of the diet and the "other food" portion was ignored.

K.4   Calculation of targets for species that consume prey from multiple trophic levels

K.4.1 Approaches for Including Multiple Trophic Levels

For wildlife that consume prey from *more than one trophic level* the analysis is more complex. As mentioned above, the wildlife value represents an average concentration of methylmercury in the overall diet necessary to keep the organism's daily ingested amount at or below the reference dose. Considering that the wildlife species may feed on organisms in multiple tropic levels, the wildlife value can also be expressed using Equation 2 (USFWS 2003):

$$WV = (\%TL2 \times [Hg]TL2) + (\%TL3 \times [Hg]TL3) + (\%TL4 \times [Hg]TL4) \quad\quad (2)$$

where,
  %TL2 = Percent of trophic level 2 biota in diet
  %TL3 = Percent of trophic level 3 biota in diet
  %TL4 = Percent of trophic level 4 biota in diet
  [Hg]TL2 = concentration in food from trophic level 2
  [Hg]TL3 = concentration in food from trophic level 3
  [Hg]TL4 = concentration in food from trophic level 4

[Hg]TL2, [Hg]TL3 and [Hg]TL4 can be related using values derived from the relationships of bioaccumulation and biomagnification between trophic levels, expressed as **food chain multipliers (FCM)**.

FCM2/3= Food chain multiplier from TL2 to TL3 biota
FCM3/4 = Food chain multiplier from TL3 to TL 4 biota

The [Hg]TL3 and [Hg]TL4 terms can then be expressed as functions of [Hg]TL2:

[Hg]TL3 = [Hg]TL2 × FCM3/2   (3)

[Hg]TL4 = [Hg]TL2 × FCM3/2× FCM4/3   (4)

This allows Equation 2 to be rearranged, substituting food chain multiplier equivalents, as:

WV = (%TL2 × [Hg]TL 2) + (%TL3 × [Hg]TL2 × FCM 3/2) + (%TL4 × [Hg]TL2 × FCM 3/2× FCM4/3)   (5)

This equation can then be solved for the mercury concentration in the lowest trophic level:

[Hg]TL2 = WV / [(%TL2) + (%TL3 × FCM3/2) + (%TL4 × FCM3/2 × FCM4/3)]   (6)

Once the concentration in TL2 is determined, the concentration in the remaining trophic levels can be calculated by rearranging equations 3 and 4 above.

To translate between methylmercury concentrations in the different trophic levels one can use food chain multipliers, as described above, or **trophic level ratios (TLR)**. Trophic level ratios represent the concentration relationship between similarly sized fish feeding at different positions in the food web (also referred to as a food chain). Food chain multipliers on the other hand, assume that there is a direct predator-prey relationship between the trophic levels, with methylmercury concentrations in the higher trophic level fish resulting from ingesting the methylmercury found in fish from the next lower trophic level. However, as an example, the Cache Creek TMDL staff report points out, a 350 mm sunfish (TL3) is too large to be consumed by a 350 mm smallmouth bass (TL4). That is why this relationship is not described by food chain multipliers (Central Valley Water Board 2005).

The USFWS pointed out that trophic level ratios provide an equally valid way to develop fish tissue targets, with the following caveats: 1) the fish prey of the wildlife species of concern must be approximately the same size, regardless of trophic level, and 2) the resultant limiting concentrations calculated with these trophic level ratios are applied to the appropriate size classes of fish (*i.e.,* using the example of bass and sunfish provided above, the limiting concentration for TL3 must be applied to fish 250 mm or larger, *not* to the small individuals that

would be preyed upon by large TL4 fish). Both caveats stem from the general trend of increasing tissue methylmercury concentrations with increasing fish size (Davis et al. 2010, Davis et al. 2013).

While California TLRs were derived for this analysis, California specific FCMs could not be calculated, since sufficient data were not available on fish < 150 mm or TL2 organisms. The FCMs are only used for a few species where a California TLR could not be used, including: river otter, southern sea otter, California Ridgeway's rail and light-footed Ridgeway's rail. Additionally, when possible, targets from site-specific projects and from site-specific data were included in Table K-3, such as for river otter. A range of values form various California projects, as well as targets derived from national values are included in Table K-3, to show some of the uncertainty in these values. However, this does not include all the uncertainly in these targets (see section K.9).

K.4.2 River Otter (Food Chain Multiplier Approach)

For river otter, the USFWS suggested the use of a food chain multiplier since prey comes from mainly TL3 less than 150 mm, and otters also catch larger TL4 fish, so there would be a predator-prey relationship between the two categories of fish. Site-specific data were used to derive a food chain multiplier of 5 for Cache Creek, and a food chain multiplier of 8.1 for the Sacramento-San Joaquin Delta. These food chain multipliers were used to calculate the protective target for river otter (shown in Table K-3). For this analysis, the U.S. EPA national food chain multiplier of 4 was also used to calculate targets for river otter (Table K-3).

K.4.3 Southern Sea Otter, California Ridgeway's Rail and Light-Footed Ridgeway's Rail (Food Chain Multiplier Approach)

For the small threatened and endangered species that eat from TL2 and TL3 the food chain multiplier approach was also used. These species were southern sea otter, California Ridgeway's rail, and light-footed Ridgeway's rail. The USFWS used the U.S. EPA food chain multiplier of 5.7 for TL2 to TL3 (FCM2/3), since California data were not available to calculate a California specific value. The same food chain multiplier of 5.7 was used for this analysis. The targets for each trophic level are shown in Table K-3.

K.4.4 Osprey (Trophic Level Ratio Approach)

Ospreys (and bald eagles) prey on fish from TL3 and TL4, and the fish preyed on from the two trophic levels are likely to be similarly sized fish, mostly above 150 mm. The USFWS 2005 had a more detailed account of the size of fish eaten by ospreys and recommended the target for osprey be applied to fish in the size range of 150 – 350 mm, although it was noted that ospreys will occasionally take larger and smaller fish. Bald eagles generally consume fish over 300mm, however some are over 500 mm (USFWS 2003). Following the rational from the USFWS, a trophic level ratio is more appropriate for calculating methylmercury concentrations in the prey of these species.

There were no existing national or statewide trophic level ratios. The trophic level ratios used in previous analyses were calculated based on site-specific data (for Cache Creek, the Sacramento-San Joaquin Delta and Clear Lake), and these trophic level ratios (relating TL3 to TL4) ranged from 1.7 to 3. The resulting protective targets calculated with these site-specific trophic level ratios are shown in Table K-3. These can be used as a range of possible conditions in California. However, the trophic level ratios are all based on data from one geographic area of California, the California Central Valley. Different areas of Northern California outside the Central Valley are not well represented and no Southern California areas are represented.

As part of this analysis, a statewide trophic level ratio for California was calculated (see Appendix L for calculation). The goal was to collect data from all over the state, but the available data were again mostly from the Central Valley (see map in Figure L-1 and Figure L-2 in Appendix L). The data used to calculate the ratios were collected from 35 locations throughout the state, including 17 rivers, 11 sloughs, and 7 lakes and reservoirs and 4 other water bodies (see Appendix L). This 'statewide' data set likely included more recent data not included in past analyses. The trophic level ratio for TL4 fish 150 – 350 mm to TL3 fish 150 – 350 mm was 2.1.

An example calculation of osprey targets using equation 5 (above) with the statewide trophic level ratio is shown below, and the resulting values are also shown in Table K-3. Since osprey do not eat from TL2 the equation can be reduced, and solved for [Hg]TL3:

$[Hg]TL3 = WV / [(\%TL3) + (\%TL4 \times TLR4/3)]$
$[Hg]TL3 = 0.105$ mg/kg$/ [(0.9) + (0.1 \times 2.1)]$
$[Hg]TL3 = 0.09545 =$ **0.09 mg/kg**

The target for [Hg] TL3 can then be used to find the osprey target for [Hg] TL4:

$[Hg]TL4 = [Hg]TL3 \times TLR4/3$
$[Hg]TL4 = 0.09545 \times 2.1 = 0.1909 =$ **0.20 mg/kg**

K.5 Calculation of Targets for Species that Eat Fish and Piscivorous Birds

K.5.1 Peregrine Falcon

Developing wildlife targets for the two remaining species of concern, bald eagle and peregrine falcon, required further modifications to the approach used above because both eagles and falcons can consume a wide variety of avian prey. Avian prey that is aquatic-dependent, may be omnivorous or piscivorous. Methylmercury biomagnification from the aquatic food web into these prey birds can be a significant source of dietary exposure for eagles and falcons, and must be incorporated into the equations to calculate protective targets. Non aquatic-dependent avian prey is considered as part of "other foods" which USFWS assumed to have insignificant levels of mercury (Section K.3). To include the aquatic-dependent avian prey, Equation 2 must be modified with additional terms, presented below as Equation 7 (equation 7 from USFWS 2004):

$$WV = (\%TL3 \times [Hg]TL3) + (\%TL4 \times [Hg]TL4) + (\%OB \times [Hg]OB) + (\%PB \times [Hg]PB) \qquad (7)$$

where,
$\%OB$ = percent of omnivorous birds (TL2-consumers) in diet
$\%PB$ = percent of piscivorous birds (TL3 fish-consumers) in diet
$[Hg]OB$ = methylmercury concentration in omnivorous bird prey
$[Hg]PB$ = methylmercury concentration in piscivorous bird prey

And:
$[Hg]OB = [Hg]TL2 \times MOB$
$[Hg]PB = [Hg]TL2 \times FCM3/2 \times MPB$

where,
MOB = biomagnification factor representing biomagnification into omnivorous bird prey
MPB = biomagnification factor representing biomagnification into piscivorous bird prey

Substituting in the new terms and solving for $[Hg]TL2$:

$$[Hg]TL2 = WV / [(\%TL3 \times FCM3/2) + (\%TL4 \times FCM3/2 \times TLR4/3) + (\%OB \times MOB) + (\%PB \times FCM3/2 \times MPB)] \qquad (8)$$

$FCM3$ = 5.7 from the U.S. EPA national BAF (used in USFWS 2003, Cache Creek targets (Central Valley Water Board 2005, USFWS 2004), and the Sacramento-San Joaquin Delta targets (Central Valley Water Board: 2010))
TLR = 1.7 from Cache Creek (USFWS 2004), 3 for the Sacramento-San Joaquin Delta (Central Valley Water Board 2010), 2.1 for California (Appendix L)
MOB = 10 (USFWS 2003)
MPB = 12.5 (USFWS 2003)

For peregrine falcon, the resulting targets in the previously published wildlife target reports were all the same (Table K-3). A value for the food chain multiplier is needed, but a value for the trophic level ratio is not needed, since this species does not eat fish from TL4 (see equation 7). The food chain multiplier used in the USFWS and Central Valley Regional Water Board analyses was the U.S. EPA national food chain multiplier since the habitat of the birds that the falcon preys upon is most likely larger than a single water body (unlike prey fish, which are confined to a water body). This species has a lower risk compared to others since it consumes a fair amount of omnivorous birds.

Calculation of peregrine falcon targets using equation 8 is shown below:

$$[Hg]TL2 = WV / [(\%TL3 \times FCM3/2) + (\%TL4 \times FCM3/2 \times TLR4/3) + (\%OB \times MOB) + (\%PB \times FCM3/2 \times MPB)]$$

A majority (85%) of the diet of the peregrine falcon is "other foods", including terrestrial avian prey (Table K-2), and USFWS assumed terrestrial avian prey to be an insignificant source of mercury (Section K.3) and is, therefore, not included in the equation. The calculation (below) includes the other portion of the peregrine falcon's diet, which is 10% ominous bird and 0.5 % piscivorous birds). Peregrine falcon does not eat from TL3 or TL4, so the equation reduces to:

$$[Hg]TL2 = 0.139 \text{ mg/kg} / [(0.10 \times 10) + (0.05 \times 5.7 \times 12.5)]$$
$$[Hg]TL2 = 0.03047 \text{ mg/kg}$$

$$[Hg]TL3 = [Hg]TL2 \times FCM3/2$$
$$[Hg]TL3 = 0.03047 \times 5.7 = 0.1737 = \textbf{0.17 mg/kg}$$

$$[Hg]TL4 = [Hg]TL3 \times TLR4/3$$
$$[Hg]TL4 = 0.1737 \times 2.0 = 0.3473 = \textbf{0.35 mg/kg}$$

$$[Hg]OB = [Hg]TL2 \times MOB$$
$$[Hg]OB = 0.03047 \times 10 = 0.3047 = \textbf{0.30 mg/kg}$$

$$[Hg]PB = [Hg]TL2 \times FCM3/2 \times MPB$$
$$[Hg]PB = 0.03047 \times 5.7 \times 12.5 = 2.171 = \textbf{2.17 mg/kg}$$

K.5.2 Bald Eagle

For bald eagle, the USFWS 2004 and Central Valley Regional Water Board analyses used the U.S. EPA national food chain multiplier to translate between TL2 and TL3, and site-specific trophic level ratios to translate from TL3 to TL4, ranging from 1.7 to 3 (the same as used for the osprey analyses). The resulting targets calculated for bald eagle with the different trophic level ratios are shown in Table K-3 along with targets calculated using the statewide trophic level ratio of 2.1 calculated in Appendix L.

An example calculation of bald eagle targets using equation 8 and the statewide trophic level ratio is shown below:

$[Hg]TL2 = WV / [(\%TL3 \times FCM3/2) + (\%TL4 \times FCM3/2 \times TLR4/3) + (\%OB \times MOB) + (\%PB \times FCM3/2 \times MPB)]$

$[Hg]TL2 = 0.195\ mg/kg / [(0.58 \times 5.7) + (0.13 \times 5.7 \times 2.0) + (0.13 \times 10) + (0.05 \times 5.7 \times 12.5)]$
$[Hg]TL2 = 0.02021\ mg/kg$

$[Hg]TL3 = [Hg]TL2 \times FCM3/2$
$[Hg]TL3 = 0.02021 \times 5.7 = 0.1152 =$ **0.11 mg/kg**

$[Hg]TL4 = [Hg]TL3 \times TLR4/3$
$[Hg]TL4 = 0.1152 \times 2.0 = 0.2303 =$ **0.24 mg/kg**

$[Hg]OB = [Hg]TL2 \times MOB$
$[Hg]OB = 0.02021 \times 10 = 0.2021 =$ **0.20 mg/kg**

$[Hg]PB = [Hg]TL2 \times FCM3/2 \times MPB$
$[Hg]PB = 0.02021 \times 5.7 \times 12.5 = 1.440 =$ **1.43 mg/kg**

Table K-3. Protective Wildlife Targets (in mg/kg, wet weight) in Various Trophic Levels (TL), Omnivorous Birds (OB) or Piscivorous Birds (PB), and the Most Sensitive Species in Each TL Category (Shaded Gray)

Species	TL2	TL2/3 < 50 mm	TL3 < 150 mm	TL3 150 – 500 mm	TL4 150 – 500 mm	OB	PB
Mink			0.077 [a,b]				
River Otter			0.04 [a] 0.059 [b] 0.067 [g]		0.30 [b] 0.36 [a] 0.27 [g]		
Belted Kingfisher			0.046 [a,b,c]				
Common Merganser				0.085 [a,b] 0.099 [c] (150 – 300 mm)			
Western Grebe				0.084 [a,b] (150 – 300 mm)			
Double-crested Cormorant			0.094 [a,b]				
Osprey				0.09 [a,d,g] 0.10 [b,c,e]	0.26 [a] 0.17 [b] 0.20 [c,g] 0.19 [d] 0.18 [e]		
Bald Eagle				0.11 [a,g] 0.12 [b,e] 0.09 [d] 0.08 [f]	0.31 [a] 0.20 [b] 0.22 [d] 0.23 [e] 0.28 [f] 0.24 [g]	0.19 [a] 0.21 [b] 0.20 [g]	1.35 [a] 1.50 [b] 1.29 [d] 1.43 [g]
Peregrine Falcon				(0.17) [a,b,e]		0.30 [a,b,e]	2.17 [a,b,e]
Southern sea otter [FT]	0.028 [f]			0.16 [f]			
California least tern [FE]		0.03 [b]					
California Ridgeway's rail [FE]	0.037 [f]			0.21 [f]			
Light-footed Ridgeway's rail [FE]	0.022 [f]			0.12 [f]			
Yuma Ridgeway's rail [FE]	0.009 [f]			0.050 [f]			
Western snowy plover [FT]	0.104 [f]						
Great blue heron			0.12 [c]				
Forster's tern		0.047 [c]					
Common loon					0.11 [d]		

[a] from Sacramento-San Joaquin Delta targets (Table 4.3, Central Valley Water Board 2010)

[b] from the Cache Creek targets (USFWS 2004, Table 5 and Table 6)

[c] from Guadalupe River Watershed targets (Table 5, USFWS 2005)

[d] from Clear Lake analysis (Table C-3,C-4 Central Valley Water Board 2002).

[e] from Cache Creek targets (Central Valley Water Board 2005)

[f] calculated from information in the USFWS evaluation of the human heath criterion (USFWS 2003)

[g] calculated as part of this report for California, see text above.

[FT/FE] on federal list of threated or endangered species

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-14

K.6   Suggested protective targets

K.6.1 Approach to Determine Targets to Use as Water Quality Objectives

Table K-3 shows protective targets for each species. Multiple values are shown, including values derived for this analysis and values derived from previously published analyses, as indicated in the table. It would be ideal to have only one water quality objective to protect wildlife and human health, as opposed to setting multiple water quality objectives for each fish trophic level and size category shown in Table K-3. One objective would be much easier to implement and monitor. Past monitoring has been directed at TL4 fish to assess common sport fish and the worst case scenario for human consumers. The final recommended human health water quality objective will most likely be applied to TL4 fish 150 – 500 mm, thus the goal was to derive the final wildlife target in terms of the TL4 fish 150 – 500 mm.

A reasonable approach for deriving a target to protect all wildlife species would be to identify the species with the lowest target and use that target to protect all wildlife. However, it is not obvious which species is the most sensitive from Table K-3. The targets in Table K-3 apply to different categories of fish, so they are not directly comparable to one another as they are shown. All targets must be converted to the same trophic level and size of fish for comparison.

In the following section, one final target for TL4 150 – 500 mm fish was derived by first identifying the lowest target (most sensitive species) in each trophic level and size category. These targets are highlighted in gray in Table K-3. Then, estimates of the corresponding TL4 concentration are made using ratios (trophic level ratio or food chain multiplier) or other information. The resulting lowest estimated TL4 concentration should protect all species. The final recommendations are rounded to one significant figure since the mercury water quality objective(s) will be expressed with one significant figure (based on U.S. EPA 2001).

Top predator birds like bald eagle could be most at risk because methylmercury bioaccumulates up the food chain. However, this analysis suggests that some species that feed lower on the food chain such as the terns and rails may need a higher degree of protection because of their small body size and their complete dependence on aquatic prey. No targets are recommended for avian prey species, although Table K-3 includes values for avian species. This is because the USFWS concluded that meeting the appropriate targets in fish tissue would adequately reduce methylmercury levels in the avian prey species that eat fish or invertebrates from these watersheds.

K.6.2 Target for Wildlife That Prey on TL4 Fish, 150 – 500 mm Long

Osprey had the lowest targets in the TL4 category with values ranging from 0.17 to 0.26 mg/kg (Table K-3). For bald eagle, targets were a little higher ranging from 0.20 to 0.31 mg/kg. The osprey targets apply to fish 150 – 350, while bald eagle targets apply to larger fish (150 – 500)

which will have higher methylmercury concentrations. Since bald eagle prey is already categorized as TL4 150 – 500 mm this target does not need converting.

To determine the concentration in 150 – 500 mm TL4 fish that would provide concentrations in 150 – 350 mm TL4 fish to protect osprey, a ratio of methylmercury in fish tissue for TL4 150 – 500 mm to TL4 150 – 350 mm was calculated in Appendix L. The ratio of 1.2 was used to estimate from the concentration in larger TL4 fish to smaller TL4 fish: (0.3 mg/kg)/(1.2) = 0.25 mg/kg. From this estimation it seems that 0.3 mg/kg in TL4 Fish 150 – 500 mm is not clearly protective for osprey, because it may equate to 0.25 mg/kg in TL4 150 – 350 mm, but it is close to achieving the targets for osprey which are 0.20 mg/kg on average. **A target of 0.2 mg/kg TL4 fish 150 – 500 mm (total length) is recommended to protect bald eagle and osprey.**

K.6.3 Target for Wildlife That Prey on TL3 Fish, 150 – 500 mm Long
Common merganser and western grebe have the lowest targets in the TL3 150 – 500 mm category. The targets actually apply to smaller TL3 fish that are 150 – 300 mm (see Table K-3). To protect these species, **TL3 fish between 150 – 300 mm (total length) should have methylmercury concentrations no greater than 0.08 mg/kg, wet weight.**

To relate this concentration in TL3 150 – 300 mm fish back to a methylmercury concentration in TL4 150 – 500 mm fish, a ratio of 2.5 for TL4 150 – 500 mm vs. TL3 150 – 350 mm fish was used (Appendix L). The corresponding TL4 concentration is: 2.5 * 0.08 mg/kg = 0.20 mg/kg. **To maintain 0.08 mg/kg in TL3 150 – 350 mm (total length) fish, mercury concentrations in TL4 fish 150 – 500 mm should not be higher than 0.2 mg/kg.**

K.6.4 Target for Wildlife That Prey on TL3 Fish, Less Than 150 mm Long
The most sensitive wildlife species for the TL3 less than 150 mm category are the river otter with values of 0.04 and 0.06 mg/kg, and 0.05 mg/kg for belted kingfisher (Table K-3). To protect these species, TL3 fish less than 150 mm should have methylmercury concentrations no greater than 0.05 mg/kg, wet weight.

To relate the target concentration in TL3 less than 150 mm fish back to TL4 150 – 500 mm fish, information in the USFWS analysis can be used. The USFWS concluded that **attainment of the 0.08 mg/kg in TL3 150 – 300 mm fish is likely to result in attainment of 0.05 mg/kg target in TL3 less than 150 mm fish** (USFWS 2003)**.** And to achieve 0.08 mg/kg in TL3 fish 150 – 350 mm, as described above, **0.2 mg/kg in TL4** is recommended.

An alternative way to relate the concentration back to TL4 is by using a food chain multiplier. A food chain multiplier can be used because there can be a predatory prey relationship between these two fish classifications (TL3 less than 150 mm and TL4 150 – 500 mm). Three food chain multiplies were found. The USFWS used the U.S. EPA national food chain multiplier of 4 in their 2003 analysis. For Cache Creek, the USFWS recommended a food chain multiplier of 5 for the

relationship between TL4 fish larger than 180 mm and TL2/TL3 fish less than 105 mm. For the Sacramento-San Joaquin Delta a food chain multiplier of 8 was derived for TL3 50 – 150 mm fish to TL4 150 – 350 mm fish. The results using these three food chain multipliers were 0.16, 0.20 and 0.32 mg/kg in TL4 fish. Since there is a fair bit of uncertainty as to which food chain multiplier is more appropriate and the resulting estimates have a fair range, the average is recommended (0.23 mg/kg). (There was not a good data set available to calculate a state wide ratio of fish less than 150 mm and TL4 fish 150 – 500 mm. See Appendix L.) **To achieve the targets in TL3 less than 150 mm (total length), mercury concentrations in TL4 fish 150 – 500 mm should not be higher than 0.2 mg/kg.**

K.6.5 Target for Wildlife that Prey on TL3 Fish, 0 – 500 mm
Yuma Ridgeway's rail has the lowest values in this category of small and large TL3 fish. This size range of TL3 fish can be related back to TL4 fish with the U.S. EPA national food chain multiplier of 4, giving: 0.05 mg/kg x 4 = 0.2 mg/kg in TL4 fish. A food chain multiplier (instead of a trophic level ratio) can be used because there is a predatory-prey relationship between these two fish classifications: Yuma Ridgeway's rail prey on crayfish, and bass will eat crayfish. **To maintain 0.05 mg/kg in TL3 fish 0 – 500 mm, mercury concentrations in TL4 fish 150 – 500 mm should not be higher than 0.2 mg/kg.**

K.6.6 Target for Wildlife that Prey on TL3 Fish, Less Than 50 mm
To protect California least tern, fish less than 50 mm (total length) should have methylmercury concentrations no greater than 0.03 mg/kg (Table K-3). This target was the most difficult to relate back to TL4 concentrations, because of a lack of data to derive a ratio. Also maintaining this target is very important because the California least tern is an endangered species. Therefore, for this target is recommended as a separate site-specific water quality objective.

This target is probably not that inconsistent with the other targets, given the trend of decreasing mercury with decreasing fish length and trophic level, and given the decreasing mercury concentrations for the targets for each successive smaller fish size/ trophic level category that are consistent with achieving 0. 2 mg/kg in TL4 fish (0.08 mg/kg in TL3 fish 150 – 300 mm, and 0.05 mg/kg in TL3 fish less than 150 mm).

K.6.7 Target for Wildlife That Prey on TL2 Fish
All of the TL2 targets should be met if the TL3 targets are met. This is because the three lowest TL2 targets (Table K-3) were calculated directly from the TL3 targets by dividing by the national food chain multiplier of 5.7. The corresponding TL3 targets (southern sea otter, California Ridgeway's rail and light-footed Ridgeway's rail) are all higher than the lowest target in the TL3 150 – 500 mm category (0.08 mg/kg). **The TL2 target should be met if the TL3 150 – 500**

mm target is met (0.08 mg/kg)**, which according to rational above, should be met if the TL4 150 – 500 mm target of 0.2 mg/kg is met.**

K.7   Comparison of Suggested Targets to Recent Information

K.7.1 Grebe in California
A further comparison of the wildlife targets was made to Ackerman et al.'s. recent study on mercury concentrations in grebe blood. This study also characterized the relationship between mercury in prey fish and mercury in sport fish. The comparison suggests that the 0.2 mg/kg sport fish target correlates to about 1 mg/kg wet weight in grebe blood (Ackerman et al. 2015a,b). The concentration of 1 mg/kg mercury in blood is the boundary concentration from low risk to moderate risk category in a study of loons (Evers et al. 2004).

Ackerman et al. suggested that the State Water Resources Control Board could consider lowering this target value of 0.2 mg/kg in sport fish to ensure protection of all individual grebes, but did not suggest a specific target (Ackerman et al. 2015a). However, while the 1 mg/kg in blood is associated with some risk, the authors who derived that threshold, Evers et al., did not derive a "no risk" threshold (the "low risk" category was 0 – 1 mg/kg mercury in blood), making the value of 1 mg/kg the lowest threshold (other than 0). Also, the same researchers, Evers et al., used the benchmark that defined the threshold for their "high risk" category of 3 mg/kg mercury in blood as their adverse effects threshold (Evers et al. 2004, pg 56, Evers et al. 2008b). Evers et al. did not assert the 3 ppm threshold or the 1 ppm threshold should be a protective criterion for loon (Evers et al. 2008), although it was clear that a protective criterion should be no higher than 3 ppm in blood.

Ackerman et al. did not derive a threshold for prey fish that would be protective of grebes. But data in Ackerman et al.' report suggests that the concentration of 1 mg/kg in grebe blood correlates to about 0.048 mg/kg in prey fish 10 – 123 mm (weight wet, Ackerman et al. 2015a). This is similar to our recommended target for fish smaller than 150 mm, which is 0.05 mg/kg. For this comparison, mercury on a wet weight basis (HgWw) was calculated from the value 0.2 mg/kg mercury dry weight (HgDw, 1 mg/kg in grebe blood corresponded to 0.2 mg/kg in prey fish dry weight in Figure 5, Ackerman et al. 2015a) using 76% moisture for prey fish (Ackerman et al. 2015a) and the equation:

> $HgWw = HgDw*(1 - proportion\ moisture)$

K.7.2 Common Loon
Recent studies in the common loon have made them one of the most well studied species in regards to the effects of methylmercury in birds. Common loons are widely distributed geographically and long lived. They feed preferentially on small fish (100–150 mm in size) from lakes within established territories (Depew et al. 2012). Several thresholds for loon are shown in Tables J-1 (Appendix J), which are close to the wildlife targets and are discussed below.

Burgess and Meyer measured mercury concentrations in small fish, blood mercury levels in adult male, female and juvenile common loons, lake pH, and loon productivity from 120 lakes in Wisconsin, USA and New Brunswick and Nova Scotia, Canada (Burgess and Meyer 2008). The fish sampled for the study were small fish (76–127 mm in length) typically consumed as prey by loons (supported by Barr 1996). Quantile regression analysis indicated that maximum observed loon productivity dropped 50% when fish mercury levels were 0.21 mg/kg (wet weight), and failed completely when fish mercury concentrations were 0.41 mg/kg. The authors did not determine a no effect threshold. The target for fish 50 – 150 mm (the same size as loon prey fish) is 0.05 mg/kg, which is four times lower than the threshold from Burgess and Meyer. Given that the threshold was a 50% effect threshold on reproduction, the target may not seem protective enough. However, the authors explain that this threshold is not well suited to deriving regulatory thresholds: "The relationships between measures of loon mercury exposure and reproduction presented in this paper are correlative. Empirical dose–response studies will further define toxicity thresholds" (Burgess and Meyer 2008).

Kenow et al. conducted controlled laboratory studies with common loon chicks (Kenow et al. 2007, 2010). The authors note the importance of controlled laboratory studies since quantifying the impact of contaminant exposure on wild populations is complicated by the confounding effects of other environmental stressors (Kenow 2010). No effects to the chicks behavior were found at 0.08 mg/kg in the diet (Kenow 2007, 2010), which is above the target of 0.05 mg/kg for fish 50 – 150 mm (comparable to loon prey fish).

In another subsequent study on loons, screening benchmarks for use in ecological risk assessment were derived (Depew et al. 2012b). The results from Burgess and Meyer 2008 were incorporated into Depew et al. benchmarks, which were derived from a larger compilation of toxicity data. The lowest screening benchmark derived was 0.1 mg/kg (fish tissue, wet weight) for adult behavioral abnormalities, which was the midpoint of range for adverse adult behavior lowest effect level (0.05 – 0.15 mg/kg). The significant reproductive impairment threshold was 0.18 mg/kg, which included impacts to productivity and hatch success. The third threshold was for reproductive failure: 0.40 mg/kg. All these thresholds are above the target of 0.05 mg/kg for fish 50 – 150 mm (comparable to the size of loon prey fish).

Of the three thresholds derived by Depew et al., the lowest threshold of 0.1 mg/kg (fish tissue, wet weight, Depew et al. 2012) may be the best threshold to compare to the targets. However, the authors noted: "Importantly, the degree to which these adult behavioral changes will affect adult or chick survival in the wild or population dynamics is presently unknown; therefore, the suitability of this benchmark for ecological risk assessment remains limited." On the other hand, the remaining screening benchmarks (0.18 mg/kg and 0.4 mg/kg , wet wt) are proposed to be indicative of significant impairment. They were not meant to be protective criteria. Unfortunately, a no effect level was not derived for survival, growth, or reproduction. As stated above, the target of 0.05 mg/kg for the prey fish (the same size as loon prey on), appears

protective of loon since it is lower than the lowest benchmark of 0.1 mg/kg from the study (Depew et al. 2012).

K.7.3 Ibis

The lowest mercury toxicity threshold for wildlife found in the literature was for white ibis (Table J-1 in Appendix J). White ibis (*Eudocimus albus*) do not have habitat in California, although another species within the same family, the white faced ibis do (*Plegadis chihi*) (Cornell Lab of Ornithology 2016). This threshold was 0.05 mg/kg in the diet which was the LOAEL (Lowest Observed Adverse Effect Level) for effects on breeding behavior, which came from a 3 year experiment. The results of this experiment were described in multiple papers that are summarized here briefly. White ibises were exposed to environmentally relevant dietary methylmercury concentrations (0.05 – 0.3 mg/kg wet weight) over 3 years in captivity. The lowest effect level for a breeding behavior in white ibises was 0.05 mg/kg (wet weight). The effects were increases in male–male pairing behavior and dose-related reductions in key courtship behaviors for female-male paring. Also females exposed to 0.3 mg/kg fledged 34 % fewer young per female than control females, but the difference was not statistically significant (Frederick and Jayasena 2010). There was no effect on survival (Frederick et al. 2011). A specific threshold for toxicity was not suggested. Since the data that would mostly clearly demonstrate a detrimental effect on reproduction (vs. behavior) were not statically significant, this study does not provide a strong value for deriving a water quality objective. The endpoints of survival, growth or reproduction were the focus of USFWS evaluation (USFWS 2003) and the Great Lakes Initiative (U.S. EPA 1995).

Nevertheless, the LOAEL of 0.05 mg/kg for white ibis (based on behavior, Frederick and Jayasena 2010), can be compared to the suggested targets derived in this Appendix. To approximate a no effect level for ibis, the ibis LOAEL of 0.05 mg/kg was divided by 2 (as done in Zhang et al. 2013 and U.S. EPA 1995) resulting in a no effect dietary threshold of 0.025 mg/kg for ibis. Ibis have a mixed diet of TL2 and TL3 organisms (see Section K.10). If the ibis is assumed to eat 40% TL3 fish, equation 2 can be used to estimate the resulting mercury concentration in TL3 prey fish (with U.S. EPA's FCM of 5.7, as shown below). The result is 0.05 mg/kg in fish, which is equivalent to the target of 0.05 mg/kg in prey fish (50 – 150mm). This suggests ibis could eat up to 40% TL3 fish and be protected. This estimate may be conservative since ibis may actually eat more insects and invertebrates and little fish.

$[Hg]TL2 = WV / [(\%TL2) + (\%TL3 \times FCM3/2)]$
$[Hg]TL2 = 0.025 \text{ mg/kg} / [(0.6) + (0.4 \times 5.7)]$
$[Hg]TL2 = 0.00868 \text{ mg/kg}$

$[Hg]TL3 = [Hg]TL2 \times FCM3/2$
$[Hg]TL3 = 0.00868 \times 5.7 = 0.04947 = \textbf{0.05 mg/kg in TL3 fish}$

K.8   Recommended Targets for Use as Water Quality Objectives

After reviewing all of the information for each size and trophic level classification, 0.2 mg/kg was the best choice for a target in TL4 fish that is consistent with all the other targets. **Therefore, based on all the information together, 0.2 mg/kg in TL4 150 – 500 mm (total length) fish is recommended as the water quality objective to provide protection for most species.**

It is hardest to judge the relationship between the methylmercury concentration in TL4 fish and the methylmercury concentration in lowest trophic level prey fish (either TL2 fish or TL2/3 fish less than 50 mm). Several of the threatened or endangered species eat in these lower tropic levels. The USFWS has previously recommended a target for fish less than 50 mm (total length) to protect the California least tern, one of the sensitive endangered species. This target of 0.03 mg/kg in fish less than 50 mm has been adopted by the Water Boards as a site-specific objective in San Francisco Bay and the Sacramento-San Joaquin Delta. It is therefore recommended to set a second water quality objective for fish less than 50 mm to ensure the protection of this species. Since the California least tern lives only in select geographical areas (Figure K-1) this objective could be applied only to the water bodies in which this species feeds. Generally, California least tern inhabit San Francisco Bay down along the coast to the California border with Mexico. **The objective of 0.03 mg/kg (in fish less than 50 mm) should apply to specific water bodies listed in Section K.11, Table K-5**. The geographic areas where the California least tern live are also inhabited by other endangered species: the California Ridgeway's rail and light-footed Ridgeway's rail. This target would offer these species added protection as well. The California Ridgeway's rail is believed to be adversely affected, at least in part due to methylmercury (Schwarzbach et al. 2006).

Further analysis indicated a third water quality objective is needed to ensure protection of all wildlife. California has warm waters that support species of black bass and cold waters that are trout dominated, generally speaking (see Figure K-3). Bass are a TL4 species that accumulates higher concentrations of mercury than trout[21], which are mostly TL3 species. In waters that lack TL4 fish, the objective of 0.2 mg/kg would be applied to the TL3 fish. In these waters TL3 fish are the top of the food web in that water body, so this is protective of species that eat from the top of the food web (humans and some wildlife species such as eagles), but ultimately the application of the objective is less stringent, since TL3 accumulate less mercury. Therefore, this situation needs to be carefully considered to ensure protection of all wildlife.

Examples of water bodies that have no TL4 fish species include trout dominated waters of the Sierra Nevada Mountains and the northern most parts of California (Figure K-3). Also, the Salton Sea does not support TL4 species because of the high salinity. Tilapia, which is a TL3 fish, is the dominant species in the Salton Sea.

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[21] Although, the USFWS analyses categorized trout as TL4 fish in the bald eagle diet (USFWS 2003, USFWS 2004, USFWS 2005). Either way, the objective is protective of bald eagle, because bald eagle are protected by 0.2 mg/kg in the overall diet.

Applying the objective of 0.2 mg/kg to TL3 fish in waters where TL4 fish are absent cannot ensure protection for some wildlife. This because the mercury level in TL3 fish (0.2 mg/kg) would exceed the targets for merganser, grebe and belted king fisher and osprey in TL3 fish (0.05 – 0.1 mg/kg). Merganser, grebe and belted king fisher and osprey have habitat that overlaps with trout dominated waters, which lack TL4 fish (see maps in Section K.13, especially Figure K-4). Additionally, some trout are recently planted hatchery fish, which are poor indicators of the water quality and the resulting methylmercury concentrations in lower trophic level resident fish.

The recommended solution to address waters that lack TL4 fish is to establish an additional objective based on the targets in Table K-3. For example, an objective could be established of 0.08 mg/kg in fish 150 – 300 mm to protect grebe and merganser based on the targets in Table K-3. Alternatively, since belted kingfisher are more ubiquitous, **an objective could be established of 0.05 mg/kg in TL3 fish 50 – 150 mm based on the targets (Table K-3) for kingfisher.** This objective should be consistent with achieving 0.08 mg/kg in 150 – 300 mm TL3 fish (see Section K.6). Narrowing the size range from 0 – 150 mm to 50 – 150 mm will distinguish this objective from the California Least Tern Prey Fish Objective, which applies to fish 0 – 50 mm long. The more narrow size range is also more protective, since larger fish have higher mercury concentration.

This objective could be applied *only* to waters that lack TL4 fish, to save monitoring resources. Alternatively, if the objective is applied statewide, in order to save monitoring resources, monitoring could be prioritized for waters that lack TL4 fish, especially those with fish from hatcheries. Also, where data on sport fish (either TL3 or TL4) indicates that a water body is impaired, monitoring prey fish would be unnecessary to show that the water body is indeed impaired. However, data from prey fish would be needed to show that the water body is no longer impaired. Also where prey fish less than 50 mm long are monitored, it would be unnecessary to also monitor prey fish that are 50 – 150 mm long.

Another endangered species that appears to be more sensitive to methylmercury is the Yuma Ridgeway's Rail, which inhabits the Salton Sea, and the Colorado River according to the USFWS draft recovery plan (USFWS 2009, see also Figure K-1). There are no TL4 fish in the Salton Sea and so the objective of 0.2 mg/kg would be applied to TL3 fish which is less stringent. Therefore, a **second objective should also be applied to the Salton Sea and the Colorado River to ensure protection for the Yuma Ridgeway's rail.** This could be accomplished one of several ways: 1) if the objective of 0.05 in fish 50 – 150 mm is adopted statewide (recommended); 2) propose the objective of 0.03 in fish less than 50 mm apply to the Salton Sea and Colorado River; 3) propose an objective of 0.04 mg/kg in crayfish, which is the prey for Yuma Ridgeway's rail (Table K-2 and text in Section K.2).

Regional Water Boards may adopt site-specific objectives for mercury and may modify the application of the objective of 0.2 mg/kg in TL4 fish based on site-specific human consumption

pattern. If the Regional Water Board does this, the Regional Water Board must also ensure protection for wildlife species. If a Regional Water Board is considering a site-specific objective or is concerned for sensitive wildlife and there are no TL4 fish species, monitoring of the target of 0.05 mg/kg in TL3 fish 50 – 150 mm could be used to ensure wildlife are protected. If the species of concern is the California least tern, then the target of 0.03 mg/kg in fish less than 50 mm should be used instead. Other targets or objectives may be developed for the particular species that feed in the affected water body.

The final objective for TL4 fish should be applied to the fillet to protect human health because most humans eat the fillet of TL4 fish. Also, monitoring programs typically measure mercury in the fillet. Mercury concentrations are slightly higher in the fillet than in the whole fish, so this provides some extra protection for wildlife and humans who eat the whole fish. On the other hand, it is recommended that the two objectives for prey fish (the objective for TL2/3 fish less than 50 mm and the objective for TL3 fish less than 150 mm) be applied to whole fish, since this objective is meant to protect wildlife only, which will likely consume the fish whole.
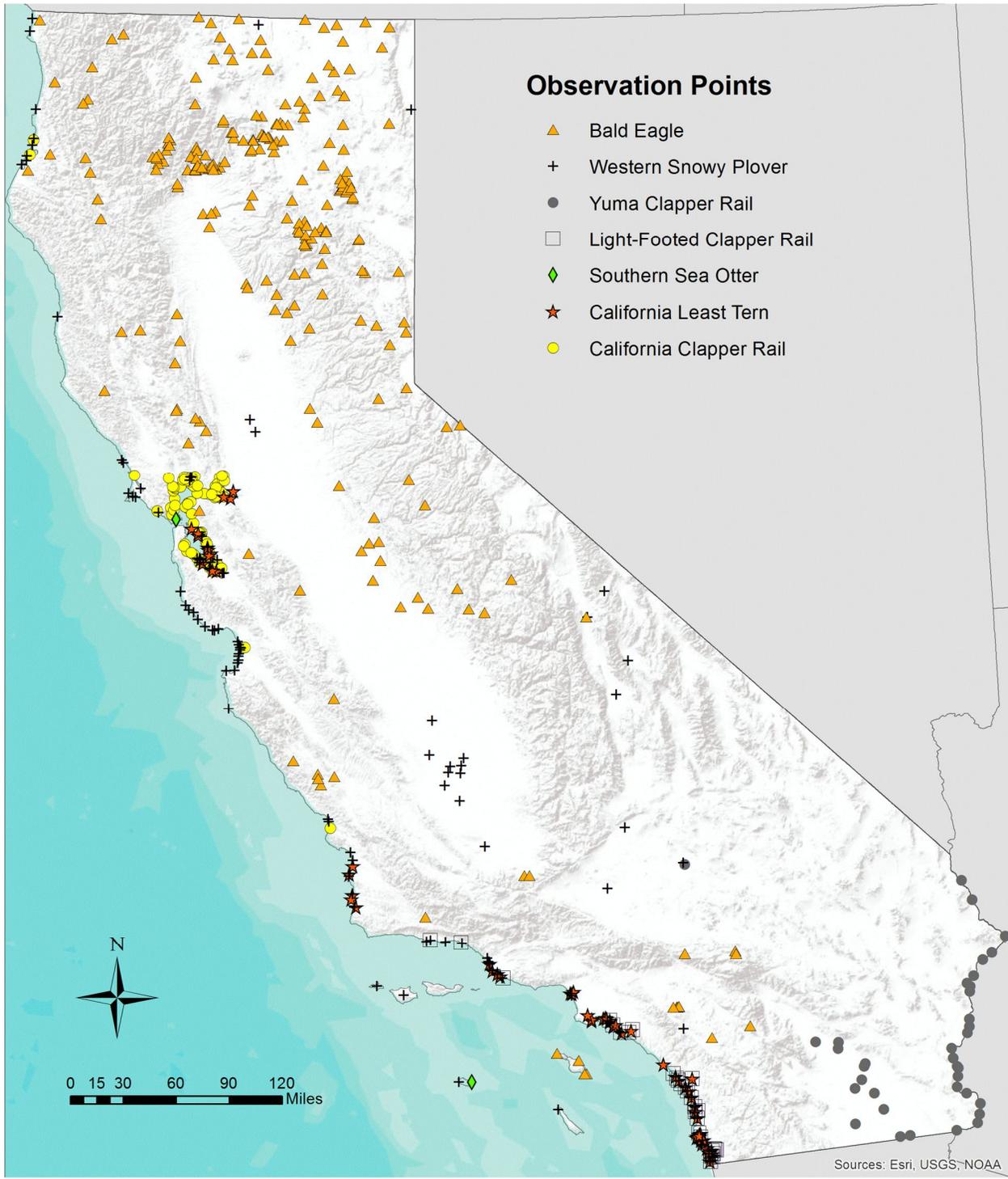
Figure K-1. Observation locations of threatened or endangered species included in this analysis and bald eagle (recently delisted).

The recommended objective for TL4 fish is shown in Table K-4 in comparison to other site-specific objectives that have been adopted by California Water Boards.

Table K-4. Comparison of Adopted Site-specific TL4 Water Quality Objectives to the Sport Fish Water Quality Objective

Geographic Area	Objective	Applicable TL4 Fish Size (mm)	Other Water Quality Objectives?	Wildlife Equally or More Sensitive Than Human Health (Human Fish Consumption Rate Used)?
Clear Lake (Central Valley Water Board 2002)	0.19	300 – 400	TL3 (no size specified)	Yes (17.5 g/day)
San Francisco Bay (San Francisco Bay Water Board 2006)	0.2	Varies by species 250 – 1350	Fish < 50 mm	No (32 g/day), only California least tern
Cache Creek (Central Valley Water Board 2005)	0.23	250 – 350	TL3 fish 250 – 350 mm	Yes (17.5 g/day)
Sacramento-San Joaquin Delta (Central Valley Water Board 2010)	0.24	150 – 500	TL3 fish 150 – 500 mm, and fish < 50 mm	No (32 g/day), only California least tern
Provisions	0.2	200 – 500	Fish < 50 mm, and TL 3 fish 50 - 150 mm	Wildlife targets require similar stringency as used for recreational fishing (32 g/day) in warm waters with black bass. However, measuring mercury in TL4 fish may not ensure objectives are met in TL3 and TL2 fish, especially in trout dominated waters (see text in Section K.8).

K.9 Limitations and Sources of Uncertainty in this Analysis

K.9.1 General Points of Uncertainty

This section reviews some of the assumptions and sources of uncertainty in these calculations. This section is broken down into two parts 1) factors that seem to suggest these calculations are conservative, and 2) factors that suggested these calculations may not be conservative enough. A few points of uncertainly that were not obviously in either category are discussed first.

The food chain multipliers (FCMs) and trophic level ratios (TLRs) are estimates that add to the uncertainty in these calculations. Some are site-specific while some were derived from national data. These values may not accurately represent all of California's waters, but a more accurate alternative is not available. More specially, FCMs could not be calculated, since sufficient data were not available for fish < 150 mm or TL2 organisms. California's statewide monitoring program has collected a great deal of data on large TL4 and TL3 fish, but much less data on fish <150 mm or TL2 organisms. While there was a large data set for large TL4 and TL3 fish, the data that could be used to derive the TLRs provided poor geographic representation of the California (see Appendix L). Since the TLRs were limited and a California FCM was not possible to calculate, values form various California projects, as well as targets derived from national values are all included in Table K-3 to provide and idea of the uncertainly in these values. However, this will not capture all of the uncertainly. If minimum and maximum values for the FMCs and TLRs were used the variation in the targets would be larger. The actual amount of mercury in fish in various waters will vary by the food web in a particular water body and other waterbody specific factors. The variation in mercury concentrations in prey fish vs. sport fish in a particular water body is exemplified in the recent USGS grebe study (Ackerman et al. 2015, Figure 5, see also Section K.7.1). Only average FCM and TLR values were used in this analysis to provide estimates for the whole state. These estimates may be either over protective or under protective for a particular water body

There are a couple of points of uncertainty associate with each wildlife value. These include the lack of long term studies for mammals, lack of a no adverse effect level for birds, and extrapolation from one species to another. More specifically, all avian wildlife values are based on one study by Heinz et al. (1979) in mallard ducks. Since then, no appropriate type of controlled dose-response study has been done on more relevant wildlife species. An uncertainty factor of three was used to derive a concentration that should cause no adverse effects in ducks, because the methylmercury concentration used in the study caused adverse effects in the ducks (a decrease in ducklings, compared to control). It is very difficult to determine how accurately the resulting wildlife values represent the wildlife species of concern.

Some conservative estimates were used by the USFWS to derive the diet for each species, but these diet estimates were revised in subsequent analyses. For example, California supports wintering and resident bald eagles with a variety of suitable foraging habitat. Because of this variation in habitat, eagle diets likely span a wide range of possible food types and trophic level combinations. To account for this variation, the USFWS used a conservative approach to establish a diet based on the highest trophic level

compositions that were reasonably likely to occur (USFWS 2003). Subsequent analyses, though, revised the proportion of TL4 fish in the diet, reducing it to 13% of the diet. However, Jackman et al. observed that 55% of the prey that bald eagles brought back to their nests was bass at Shasta Lake (Jackman et al. 2007). The estimated diets may be non-conservative for some areas, such as Shasta Lake, or the estimated diets may be conservative for other areas.

The lack of available data precludes evaluating exposure to insectivorous wildlife that consume the terrestrial stages of aquatic insects and may be exposed to relatively high concentrations of methylmercury. High concentrations of methylmercury (1.66 ppm) have been measured in the blood of riparian song sparrows downstream of New Almaden, the site of a large mercury mine (Robinson et al. 2011, Section K.10.2). These concentrations were similar to those that were associated with a 25% to 30% reduction in nest success of Carolina Wrens along two mercury-contaminated rivers in Virginia (Jackson et al. 2011). Additional studies will be required to determine the relationship between mercury concentrations in prey fish and sport fish and those of aquatic insects that inhabit the same water bodies.

K.9.2 Points of Uncertainty That Suggest a Less Stringent Objective

Wildlife likely consume whole fish, while many humans often only eat the fillet of the fish. The mercury concentration in the fillet is higher than in the whole fish. Therefore, wildlife targets applied to fillet will a have some level of extra protection. The mercury concentration in the fillet can be converted to the mercury concentration in the whole-body with the formula (Peterson et al. 2007):

$$[\log (\text{fillet biopsy Hg}) = 0.2545 + 1.0623 \log (\text{whole-fish Hg})]$$

If the fillet has 0.3 mg/kg mercury then the corresponding whole fish concentration will be 0.185 mg/kg mercury. It is not recommended that this conversion be applied to the targets since the final objective will be applied to the fillet. It will then be difficult to ensure that targets in whole fish will be achieved. Doing so will add additional layers of uncertainty. In general, this information suggests that the water quality objective for TL 4 fish should be conservative for wildlife. Although, for the two prey fish objectives (fish less than 50 mm and TL3 fish 50 – 150 mm), the objective is recommended for whole fish, since these are only meant for wildlife.

The osprey seems to be a more sensitive species from this analysis and from the results of the Heinz et al. comparative study (Heinz et al. 2009). However, no adverse effects on reproduction in osprey have been observed near Clear Lake, California, which has highly elevated fish methylmercury concentrations from mercury mining (Cahill et al. 1998, Anderson et al. 2008). These results suggest that the targets in this analysis may be conservative because the targets are much lower than the concentrations observed in these studies.

K.9.3 Points of Uncertainty That Suggest a More Stringent Objective

Studies in grebe, loon and ibis contain some suggestions that toxic effect could occur near the mercury water quality objectives. However, evidence was not found that clearly indicated a lower water quality objective is needed. These studies are discussed in detail in Section K.7.

The wildlife values for all avian species were based on a reference dose for mallard ducks. Heinz et al. investigated the relative toxicity to methylmercury using 23 avian species to determine if other species are more or less sensitive than mallard ducks. They found that mallards were one of the least sensitive species, which indicates that the wildlife values calculated here are likely non-conservative. However, it is very difficult to determine more appropriate wildlife values at this time with the available information. The most sensitive of the species in the study were American kestrel (_Falco sparverius_), osprey (_Pandion haliaetus_), white ibis (_Eudocimus albus_), snowy egret (_Egretta thula_), and tri-colored heron (_Egretta tricolor_). The least sensitive species were mallards (_Anas platyrhynchos_), hooded merganser (_Lophodytes cucullatus_), lesser scaup (_Aythya affinis_), Canada goose (_Branta canadensis_), double-crested cormorant (_Phalacrocorax auritus_), and laughing gull (_Leucophaeus atricilla_). Species categorized as having medium sensitivity were the Ridgeway's rail (_Rallus longirostris_), sandhill crane (_Grus canadensis_), ring-necked pheasant (_Phasianus colchicus_), chicken (_Gallus gallus_), common grackle (_Quiscalus quiscula_), tree swallow (_Tachycineta bicolor_), herring gull (_Larus argentatus_), common tern (_Sterna hirundo_), royal tern (_Sterna maxima_), Caspian tern (_Sterna caspia_), great egret (_Ardea alba_), brown pelican (_Pelecanus occidentalis_), and anhinga (_Anhinga anhinga,_ Heinz et al. 2009).

The USFWS also considered another reference dose (used to calculated wildlife values) that was three times lower; 0.007 mg/kg/day for California Ridgeway's rail, light-footed Ridgeway's rail, Yuma Ridgeway's rail and western snowy plover (USFWS 2003). This reference dose was calculated with an additional uncertainty factor to account for greater susceptibility of rail as indicated by egg injection studies, which were not final at the time of writing the USFWS analysis (USFWS 2003). The results of the egg injection studies were later published as Heinz et al. 2009. Since then, there has been no additional information on the sensitivity of rails. USFWS did not use this information to unequivocally recommend the lower reference dose for rails (0.007 mg/kg/day vs. 0.021 mg/kg/day). USFWS stated "The diet-to-egg transfer efficiency can vary widely between different species, as evidenced by the controlled feeding studies with mallards (Heinz, 1979) and pheasants (Fimreite, 1971). It would be imprudent to assume that similar sensitivities to egg concentrations between the clapper rail and the pheasant would necessarily be caused by the same dietary concentration" (see p 20 – 21of USFWS 2003). A non-conservative choice was made not to include this information in the calculations because there was little other evidence to support that rails have a significantly higher risk in the environment. Rails exposure to mercury is generally low since they eat food lower on the food chain, which puts them at lower risk of mercury toxicity.

A couple subsequent studies tried to gather more information on rails, but these two studies do not suggest a threshold for effects. On one study, the body condition of California clapper rails

was negatively related to mercury concentrations within tidal marsh habitats of San Francisco Bay, California. Model averaged estimates indicated a potential decrease in body mass of 20 – 22 g (5 – 7%) over the observed range of mercury concentrations (Ackerman et al. 2012).

Later in another study in the same area, total mercury was measured in six macroinvertebrates and one fish species, representing Clapper Rail diets. The average mercury concentrations in all species was above 0.05 mg/kg (roughly 0.05 – 0.1 mg/kg wet weight for all except the eastern mudsnail, Casazza et al. 2014). Mercury concentrations in the eastern mudsnail were about 4 times higher than the other species: Baltic clam, soft-shell clam, ragworm, ribbed horse mussel, mud crab, staghorn sculpin. These organisms are TL2 and TL3. The sculpin were the only finfish included and they were 30 – 60 mm long, so the most comparable mercury water quality objective is 0.03 mg/kg in fish less than 50 mm long. This water quality objective (0.30 mg/kg in fish < 50 mm) has already been adopted as site-specific objective in San Francisco Bay. San Francisco Bay is known to be heavily impacted by mercury and is listed as impaired due to mercury. Therefore, the fact that Ackerman et al. 2012 found a small effect on body condition is not in conflict with the mercury water quality objectives. This information is not detailed enough to suggest whether or not a lower threshold is needed to protect rails.

If birds migrate or have a large feeding range, that behavior could make them less vulnerable to mercury hot spots. However, some species, including rails which are a sensitive species, are year round residents. More importantly, the exposure during breeding or nesting season may be the most significant, and movement during those times tends to be limited. Ackerman et al. noted grebes become flightless after they arrive at their summer locations. They lose feathers and wings atrophy (Ackerman et al. 2015). Terns, avocets and stilts were found to stay relatively close to their capture site in San Francisco Bay and mercury concentrations in the blood of the birds varied by location, showing that mercury hotspots can have an impact on locally breeding birds (Ackerman et al. 2007, Ackerman et al. 2008). Additionally, the assumption that "other foods" (see Section K.3) have no mercury is a non-conservative assumption.

A final point of uncertainty that is very difficult to incorporate is the combined effect of methylmercury with other contaminants and habitat loss. For example Heniz and Hoffman (1998) found that the combined treatment with selenium and methylmercury reduced survival of ducklings and produced more embryo deformities than in either treatment alone. Many areas of California also have high levels of selenium.

K.10 Other species Considered, but for Which Wildlife Values and Targets were not Calculated

K.10.1 California Brown Pelican

The California Brown Pelican was delisted from state and federal endangered status in 2009. The brown pelican feeds in the open ocean off the southern California coast, but also in the Salton Sea. Contamination of food supply by DDT and other chlorinated hydrocarbons reduced

nesting productivity in California nearly to zero in 1969-71, from eggshell thinning and altered parental behavior. Since then, contamination has been reduced and productivity has increased (CDFW 1990). A separate analysis for the brown pelican is not included because most areas the pelicans inhabit are outside the geographic scope of the Provisions, except the Salton Sea. Also, pelicans should be protected by the targets for osprey. Brown pelicans primarily consume fish (vs. other types of food) and in this analysis osprey were considered to eat 100% fish. The brown pelican is probably less sensitive than ospreys based on the equations provided by the USFWS (equation 1) because brown pelicans are larger (2.75 – 5.5 kg) than ospreys (1.75 kg), although pelicans could eat more TL4 fish which would have higher mercury levels.

K.10.2 Sparrows

A recent study of riparian songbirds (song sparrows) in streams in the San Francisco Bay area found blood mercury concentrations high enough to cause reduced reproductive success (Robinson et al., 2011). Blood methylmercury concentrations were highest (1.66 ppm) downstream of New Almaden. These birds are insectivorous, not piscivorous. Song Sparrows are very small, smaller than the California least tern. Song sparrows weigh about 32 g, which according to equation 1, would make songs sparrows a more sensitive species to methylmercury toxicity. To drive a protective wildlife value for this species, a food intake rate would need to be calculated. Forster's terns were also captured in a site downstream of the New Almaden mining district. These terns had slightly higher blood mercury concentrations (averaging 2 ppm), than the sparrows (Ackerman et al. 2008). This comparison would suggest that an objective that protects Forster's tern should also protect the sparrows.

K.10.3 Marbled Murrelet

The marbled murrelet is listed by the USFWS as threatened. It is a coastal species, similar to the California least tern, but the marbled murrelet inhabits the northern California coast instead of the southern California coast. The USFWS did not have sufficient information about this species when writing their Biological Opinion to develop a suggested criterion, but stated that the criteria for the California least tern would be applicable for protection of the marbled murrelet. This species was not included in the USFWS's later evaluation (USFWS 2003). The marbled murrelet feeds in the open ocean, which is beyond the geographic scope of this objective. It feeds closer to shore during breading season, in water less than 95 ft. deep and it nests inland (CDFW 1990).

K.10.4 Ibis

White Ibis were one of the most sensitive species reported by Heinz et al. 2009 and a wildlife value for this species was lacking for this analysis. White ibis (*Eudocimus albus*) do not inhabit California (Cornell Lab of Ornithology 2016), while the white-faced Ibis (*Plegadis chihi*) do inhabit California (CDFW 1990). The white-faced ibis was a California Species of Special Concern, but is no longer on the list (Shuford and Gardali, 2008). The white-faced ibis eats

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-30

earthworms, insects, crustaceans, amphibians, small fishes, and miscellaneous invertebrates (CDFW 1990). Other authorities on ibis report that white faced ibis eats mainly insects (Cornell Lab of Ornithology 2016). A threshold for ibis was the lowest found in the literature compared to thresholds found for other species (Table J-1 in Appendix J), which is discussed in Section K.7.

K.11 Locations where the Objective to Protect the California Least Tern Should be Applied

A list of water bodies where the objective of 0.03 mg/kg in fish less than 50 mm should apply is given in Table K-5, which is based on management areas defined by the USFWS (USFWS 2006). Additionally, this objective may be applied to a few other waters as described in Section K.8 to ensure protection for the Yuma Ridgeway's rail, unless another objective is adopted to protect the Yuma Ridgeway's rail (e.g. 0.05 mg/kg in fish 50 – 150mm). Other waters should be added by the appropriate Regional Water Boards based on local knowledge or as information becomes available. The applicable water bodies include only inland surface waters, enclosed bays, and estuaries. The open ocean is not part of the geographic scope of the Provisions.

Since 1970, California least tern nesting sites have been recorded from San Francisco Bay to Baja California. The nesting range in California has always been widely discontinuous, with the majority of birds nesting in southern California, from Santa Barbara County down through San Diego County. On the other hand, between the city of Santa Barbara and Monterey Bay, there are few known regularly used breeding sites (USFWS 1985).

The California least tern obtains most of its food from shallow estuaries and lagoons, and nearshore ocean waters. Feeding activity at the few sites that have been studied occurs mostly within 3.2 km (2 miles) of breeding colonies, and at many sites foraging is primarily in nearshore ocean waters less than 18.3 m (60 feet) deep. Colonies located near productive estuarine habitats appear to utilize such areas heavily, but data regarding the relative value of estuaries to feeding least terns are scarce. The increased use of freshwater marsh systems, lakes, lagoons, and estuarine areas during post-breeding dispersal suggests the special importance of such habitats during the breeding cycle, when juveniles are learning to fish for themselves (USFWS 1985).

Table K-5. Waters for the Least Tern Prey Fish Water Quality Objective and the Corresponding Regional Water Board

RB	Mgt.[1] Area	County	USFWS Site Name	Applicable inland surface water, enclosed bay[2] or estuary[3]	RARE Designation In Regional Water Quality Control Plan (Basin Plan)?
2	A	Alameda	Alameda Naval Air Station	An objective that is protective of the California Least tern has already been adopted for Lower San Francisco Bay	Yes: San Francisco Bay Region
		Alameda	Alvarado Salt Ponds		
		Alameda	Oakland Airport		
		San Mateo	Bair Island	Bair Island Marsh	Yes: San Francisco Bay Region
3	B	San Luis Obispo	Pismo Beach	Pismo Creek Estuary, Pismo Creek, Arroyo Grande Estuary, Arroyo Grande Creek, downstream (Oceano Lagoon, Meadow Creek, Pismo Marsh (Lake), Los Berros Creek), Big Pocket Lakes (Dune Lakes)	Yes: Central Coast Region
		San Luis Obispo	Oso Flaco Lake	Oso Flaco Lake, Oso Flaco Creek	Yes: Central Coast Region
3	C	Santa Barbara	Santa Maria River	Santa Maria Estuary, Santa Maria River (except Corralitos Canyon Creek, Sisquoc River, downstream), Orcutt Creek	Yes: Central Coast Region
3	D	Santa Barbara	San Antonio Creek	San Antonio Creek, San Antonio Creek Estuary	Yes: Central Coast Region
		Santa Barbara	Purisima Point (North, South)	None – (coast/open ocean)	Yes: Central Coast Region
		Santa Barbara	Santa Ynez River	Santa Ynez River Estuary, Santa Ynez River, downstream	Yes: Central Coast Region
4	E	Ventura	Santa Clara River	Santa Clara River Estuary, Santa Clara River Reach 1	Yes: Los Angeles Region
4	F	Ventura	Ormond Beach	Ormond Beach Wetlands	Yes: Los Angeles Region
		Ventura	Mugu Lagoon	Calleguags Creek Reach 1 (also called Mugu Lagoon)	Yes: Los Angeles Region
4	G	Los Angeles	Venice Beach	Ballona lagoon, Marina Del Rey (except Harbor),	Yes: Los Angeles Region
		Los Angeles	Playa del Rey	Ballona Wetlands, Ballona Creek Estuary	Yes: Los Angeles Region
4	H	Los Angeles	Terminal Island	Los Angeles/Long Beach Inner Harbor, Los Angeles/Long Beach Outer Harbor	Yes: Los Angeles Region
		Los Angeles	San Gabriel River	Alamitos Bay: Los Cerritos Wetlands, San Gabriel Estuary, Los Cerritos Channel Estuary, Long Beach Marina	Yes: Los Angeles Region
4	I	Los Angeles	Cerritos Lagoon		
		Los Angeles	Costa Del Sol		

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-32

Table K-5. Waters for the Least Tern Prey Fish Water Quality Objective and the Corresponding Regional Water Board

RB	Mgt.[1] Area	County	USFWS Site Name	Applicable inland surface water, enclosed bay[2] or estuary[3]	RARE Designation In Regional Water Quality Control Plan (Basin Plan)?
8	J	Orange	Anaheim Bay	Anaheim Bay	Yes: Santa Anna Region
		Orange	Surfside Beach	Anaheim Bay	Yes: Santa Anna Region
8	K	Orange	Bolsa Chica (North, South)	Bolsa Bay, Bolsa Chica Ecological Reserve	Yes: Santa Anna Region
8	L	Orange	Huntington Beach	Santa Ana River Salt Marsh, Tidal Prism of Santa Ana River (to within 1000' of Victoria Street) and Newport Slough	Yes: Santa Anna Region
8	M	Orange	Upper Newport Bay	Upper Newport Bay	Yes: Santa Anna Region
9	N	San Diego	San Mateo Creek	San Mateo Creek Mouth	Yes: San Diego Region
		San Diego	Aliso Creek	Aliso Canyon (in San Onofre Creek Watershed. Not in Orange County)	Yes: San Diego Region
		San Diego	Santa Margarita River	Santa Margarita Lagoon	Yes: San Diego Region
9	O	San Diego	Buena Vista Lagoon	Buena Vista Creek	Yes: San Diego Region
9	P	San Diego	Agua Hedionda Lagoon	Agua Hedionda Lagoon	Yes: San Diego Region
9	Q	San Diego	Batiquitos Lagoon	Batiquitos Lagoon	Yes: San Diego Region
9	R	San Diego	San Elijo Lagoon	San Elijo Lagoon	Yes: San Diego Region
9	S	San Diego	San Dieguito Lagoon	San Dieguito Lagoon	Yes: San Diego Region
		San Diego	Whispering Palms Encinitas	None[4]	None: San Diego Region
9	T	San Diego	Los Penasquitos Lagoon	Los Penasquitos Lagoon	Yes: San Diego Region
9	U	San Diego	FAA Island	Mission Bay	Yes: San Diego Region
		San Diego	North Fiesta Island	Mission Bay	Yes: San Diego Region
		San Diego	Stony Point	Mission Bay	Yes: San Diego Region
		San Diego	South Sea World Drive	Mission Bay	Yes: San Diego Region
		San Diego	Clover Leaf	Mission Bay	Yes: San Diego Region

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-33

Table K-5. Waters for the Least Tern Prey Fish Water Quality Objective and the Corresponding Regional Water Board

RB	Mgt.[1] Area	County	USFWS Site Name	Applicable inland surface water, enclosed bay[2] or estuary[3]	RARE Designation In Regional Water Quality Control Plan (Basin Plan)?
9		San Diego	Naval Training Center	San Diego Bay	Yes: San Diego Region
		San Diego	San Diego Int. Airport	San Diego Bay	Yes: San Diego Region
		San Diego	Chula Vista Wildlife Reserve	San Diego Bay	Yes: San Diego Region
		San Diego	Sweetwater River	Sweetwater River, Hydrologic Unit Basin Number 9.21	Yes: San Diego Region
		San Diego	North Island	San Diego Bay	Yes: San Diego Region
		San Diego	Delta Beach	San Diego Bay	Yes: San Diego Region
	V	San Diego	Coronado Cays	San Diego Bay	Yes: San Diego Region
		San Diego	Saltworks	San Diego Bay	Yes: San Diego Region
9	W	San Diego	Tijuana River Mouth	Tijuana River Estuary	Yes: San Diego Region

[1]Based on the Californian least tern coastal management areas and sites from the USFWS (USFWS 2006).

[2]"Enclosed Bays" means indentations along the coast that enclose an area of oceanic water within distinct headlands or harbor works. Enclosed bays include all bays where the narrowest distance between the headlands or outermost harbor works is less than 75 percent of the greatest dimension of the enclosed portion of the bay. Enclosed bays include, but are not limited to, Humboldt Bay, Bodega Harbor, Tomales Bay, Drake's Estero, San Francisco Bay, Morro Bay, Los Angeles-Long Beach Harbor, Upper and Lower Newport Bay, Mission Bay, and San Diego Bay. Enclosed bays do not include inland surface waters or ocean waters (State Water Board 2005).

[3]"Estuaries" means waters, including coastal lagoons, located at the mouths of streams that serve as areas of mixing for fresh and ocean waters. Coastal lagoons and mouths of streams that are temporarily separated from the ocean by sandbars shall be considered estuaries. Estuarine waters shall be considered to extend from a bay or the open ocean to a point upstream where there is no significant mixing of fresh water and seawater. Estuarine waters included, but are not limited to, the Sacramento-San Joaquin Delta, as defined in Water Code Section 12220, Suisun Bay, Carquinez Strait downstream to the Carquinez Bridge, and appropriate areas of the Smith, Mad, Eel, Noyo, Russian, Klamath, San Diego, and Otay rivers. Estuaries do not include inland surface waters or ocean waters (State Water Board 2005).

[4]In the USFWS list of management areas (USFWS 2006) Whispering Palms, San Diego Country, is labelled with an asterisk rather than identified as a numbered management area since it only had nesting one year and the location was developed by the following season. Therefore it is no longer a suitable site. A single least tern's nest was found on the site in 1979 on the levees of the old County sanitation ponds off of Via de la Valle. Prior to the 1980 season, the site was bulldozed and developed into the Whispering Palms Golf Course.

Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-34

K.12   Considerations for Monitoring and Assessment

For monitoring and assessment of prey of the Californian Least tern, there is a long list of water bodies to which the objective should apply (Table K-5). However, certain sites could be prioritized for monitoring to save resources. The 2012 annual monitoring report reported that 74% of the breeding pairs were found at six locations: Naval Base Coronado, Point Mugu, Batiquitos Lagoon Ecological Reserve, Camp Pendleton, Huntington State Beach, and Alameda Point (Frost 2013).

The tern feeds primarily in shallow estuaries or lagoons where small fish are abundant. The tern hovers, and then plunges for fish near the surface, without submerging completely. Therefore, the relevant monitoring species are any that swim near the surface, not bottom dwelling fish. Prey in California includes anchovy (Engraulis sp.), silversides (Atherinops sp.) and shiner surfperch (*Cymatogaster aggregata*). Considerable feeding also takes place near shore in the open ocean, especially where lagoons are nearby, or at mouths of bays (CDFG 1990).

Fish tissue monitoring studies have found that fish mercury concentrations can vary by season and also suggests spring is the best time for monitoring. Eagles-Smith and Ackerman measured mercury in small fish, which are typical prey for Forester's tern in the San Francisco Bay Estuary (Eagles-Smith and Ackerman 2009). Fish mercury concentrations varied substantially over time, increasing 40% in spring (March – May) then decreasing 40% in early summer (May – July). This peak in mercury concentrations coincides with breeding. The increase in mercury concentrations may be due to seasonal changes in water quality that affect methylmercury production or changes in food web dynamics.

Fish tissue monitoring should be done during the breading season because impacts of mercury on reproduction have been frequently observed (Scheuhammer et al. 2007). The California least tern nesting season extends from approximately mid-April into early August, with the majority of nests completed by mid-June.   Incubation usually lasts from 20 to 25 days. Flight stage is reached at approximately 20 days of age, but the young birds do not become fully proficient fishers until after they migrate from the breeding grounds. A second wave of nesting occurs from mid-June to early August. These are mainly re-nests after initial failures and second year birds nesting for the first time. Most authorities agree that least terns are capable of successfully raising only one brood per pair in a season (USFWS 1985).

Ackerman et al. found that the risk of mercury toxicity for waters birds is highest at hatching and fledging (Ackerman et al. 2011). Researchers examined total mercury and methyl-mercury concentrations in blood, liver, kidney, muscle, and feathers of Forster's tern (*Sterna forsteri*), black-necked stilt (*Himantopus mexicanus*) and American avocet (*Recurvirostra americana*) chicks as they aged from hatching through postfledging in San Francisco Bay. Mercury concentrations in internal tissues were highest immediately after hatching, due to maternally deposited mercury in eggs. Concentrations then rapidly declined as chicks aged and diluted their mercury concentrations through growth in size and as mercury is transferred into growing feathers. Mercury concentrations then increased during fledging when tissue growth and feather growth slowed, while chicks continued to

acquire mercury through their diet. Springtime monitoring in fish should be representative of mercury in the eggs at hatching. Most chicks hatch in May or June, except in the northern sites near San Francisco they tend to hatch in June or July (Frost 2013).

Some birds have a fairly small range during breeding, which is import to consider when designing monitoring and assessment procedures. Ackerman et al. radio-marked and tracked 72 Forster's terns (*Sterna forsteri*) in San Francisco Bay to determine locations of dietary mercury uptake. The radiotelemetry data revealed that Forster's terns generally remained near their site of capture and foraged in nearby waters. On average, tern locations were 2.2 km to 7.7 km from their capture site, and mercury concentrations in blood differed among capture sites. Breeding terns are likely to be even more at risk because blood mercury concentrations more than tripled during the 45-day pre-breeding time period (Ackerman et al. 2008). In another study in San Francisco Bay, radio telemetry data for American avocets (*Recurvirostra americana*) and black-necked stilts (*Himantopus mexicanus*) showed these species had stronger site fidelity. The areas that avocets and stilts occupied half the time were 1 – 4 km^2 and the area they occupied 95% of the time was 8 – 25 km^2. Species differences in habitat use and foraging strategies may increase mercury exposure in stilts more than avocets (Ackerman et al. 2007). The fact that movement during breeding or nesting season tends to be limited is also discussed in Section K.9 on points of uncertainty.

For monitoring grebe prey, Ackerman et al. recommend sampling at least 20 individual prey fish from a minimum of two different species from each water body and analyzing total mercury concentrations on an individual, rather than a composite, basis. Prey fish should be sampled during the breeding season ("approximately April – July") when wildlife are at greatest risk to potential mercury-induced impairment (Ackerman et al. 2015). Sampling date should be standardized for annual monitoring programs because seasonal variation in prey fish mercury concentrations can be substantial (Eagles-Smith and Ackerman, 2009).

Information on relevant wildlife breeding periods was compiled in Table K-6. This information was used to recommend the averaging periods for the water quality objectives for wildlife. The recommended averaging period for the objective that applies to TL3 fish 50 – 150 mm is February 1 – July 31. The recommended averaging period for the objective that applies to fish less than 50 mm long for the California Least Tern is April 1 – August 31. Averaging periods are used in evaluating whether the water quality objective is achieved. The State Water Board's assessment policy allows for the use of different averaging periods as specified by particular water quality objectives (State Water Board 2004). All data collected within the same averaging period will be combined into a single resultant value (see section 6.1.5.6 of State Water Board 2004). Data collected during another averaging period (for example, in this case, the breeding season of the next year) would be combined into separate additional values. The values are then evaluated to determine if the water quality objective is being exceeded according to State Water Board's assessment policy (State Water Board 2004).

Table K-6 Wildlife Breeding Period for Prey Fish Collection Time

Aquatic-dependent Wildlife Species	Typical Breeding or Gestation Period	Citation
Bald eagle	February – July (a)	CDFW 1990
River otter	January – May (b)	CDFW 1990
Osprey	March – September (a)	CDFW 1990
Common merganser	Mid-April – August	Mallory and Metz 1999
Western grebe	April – September	Ackerman et al. 2015
Great blue heron	Mid-February – July	CDFW 1990
Double-crested cormorant	January – August	CDFW 1990
Mink	Late-January – May	CDFW 1990
Belted kingfisher	April – Mid-August	CDFW 1990
Forster's tern	April – Mid-August	Ackerman et al. 2014
California least tern	April – August	USFWS 1985
Western snowy plover, Pacific Coast population	March – Mid-September	USFWS 2007
Yuma Ridgeway's rail	March – July	USFWS 2009
California Ridgeway's rail	Late March – August	USFWS 2010
Light-footed Ridgeway's rail	Mid-February – Mid-July	Zembal et al. 2014
a) Timing of egg laying varies with latitude b) Reproductive cycle of river otters is extended and includes peak breeding season of avian species of concern. Otter mating typically occurs December through April and reproductive cycle may include delay of implantation of the fertilized embryo up to eight months. Kits typically born in March and April after two months gestation (CDFW 1990).		

K.13   Habitat Range Maps

The following maps are provided to support protections for wildlife, discussed in Section K.8 of this appendix. In Table K-3, some values showing the most sensitive species for each trophic level category are shaded gray. For these species, California Wildlife Habitat Relationship System range maps are shown below, as well as maps for some similarly sensitive species. More range maps can be found on the California Department of Fish and Game website (as well as downloadable GIS data http://www.dfg.ca.gov/biogeodata/cwhr/). Maps are also provided in Figure K-3 and Figure K-4 to show the general location of trout dominated waters, because the water quality objectives may be applied differently in trout dominated waters (see end of Section K.8), which could impact the level of protection for species that inhabit those waters. These maps support the discussion on the recommended water quality objectives in Section K.8.

Figure K-2. California Wildlife Habitat Relationship System range maps for select wildlife species.

Figure K-2 (continued). California Wildlife Habitat Relationship System range maps for select wildlife species.

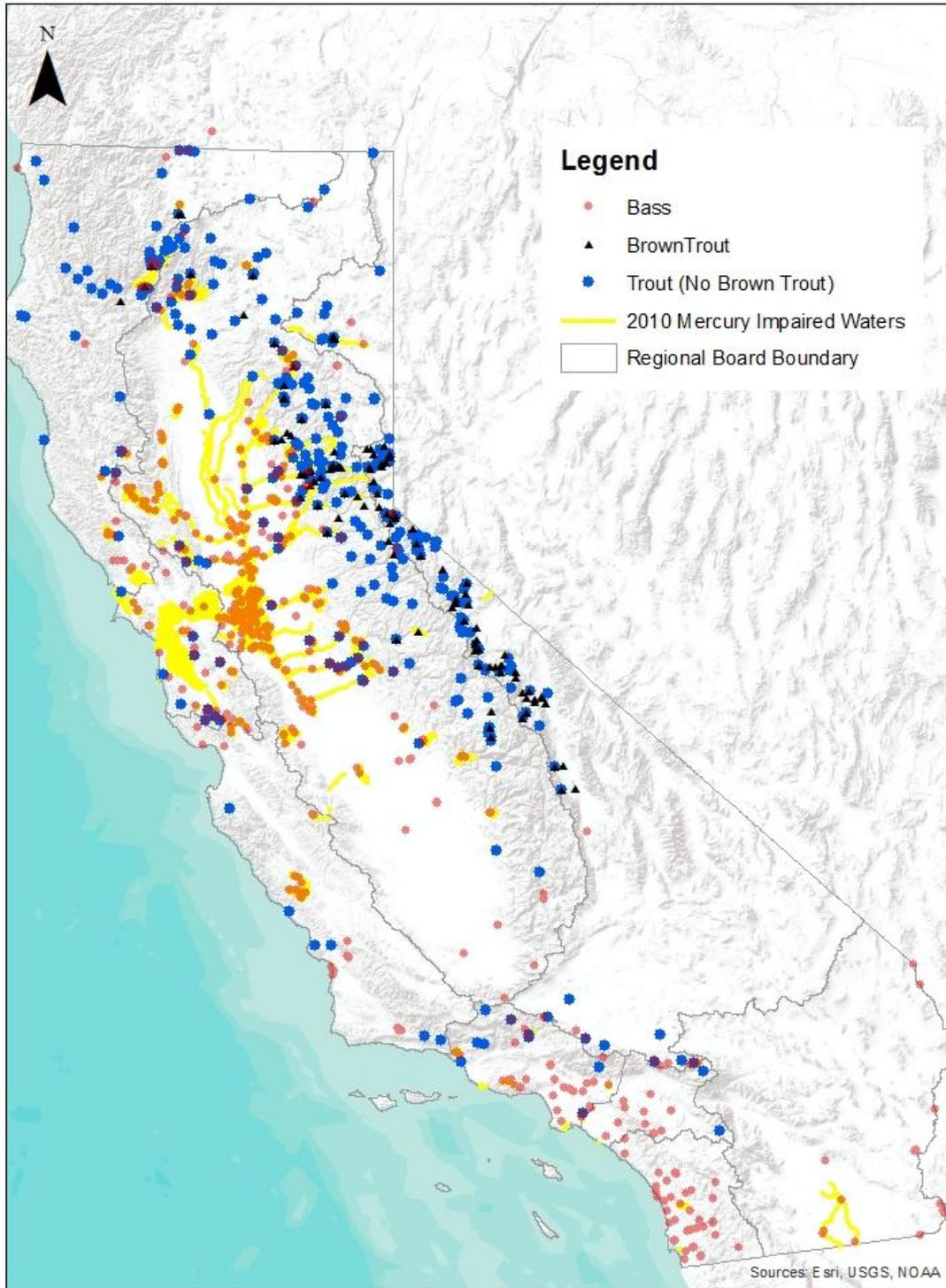Draft Staff Report: Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California – Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions

K-39

Figure K-3. Locations where Water Boards related monitoring programs have caught bass (largemouth bass, smallmouth bass and spotted bass), trout (rainbow trout, brook trout, lake trout, eagle lake trout), and brown trout. Data obtained from the California Environmental Data Exchange Network (CEDEN, www.ceden.org/).
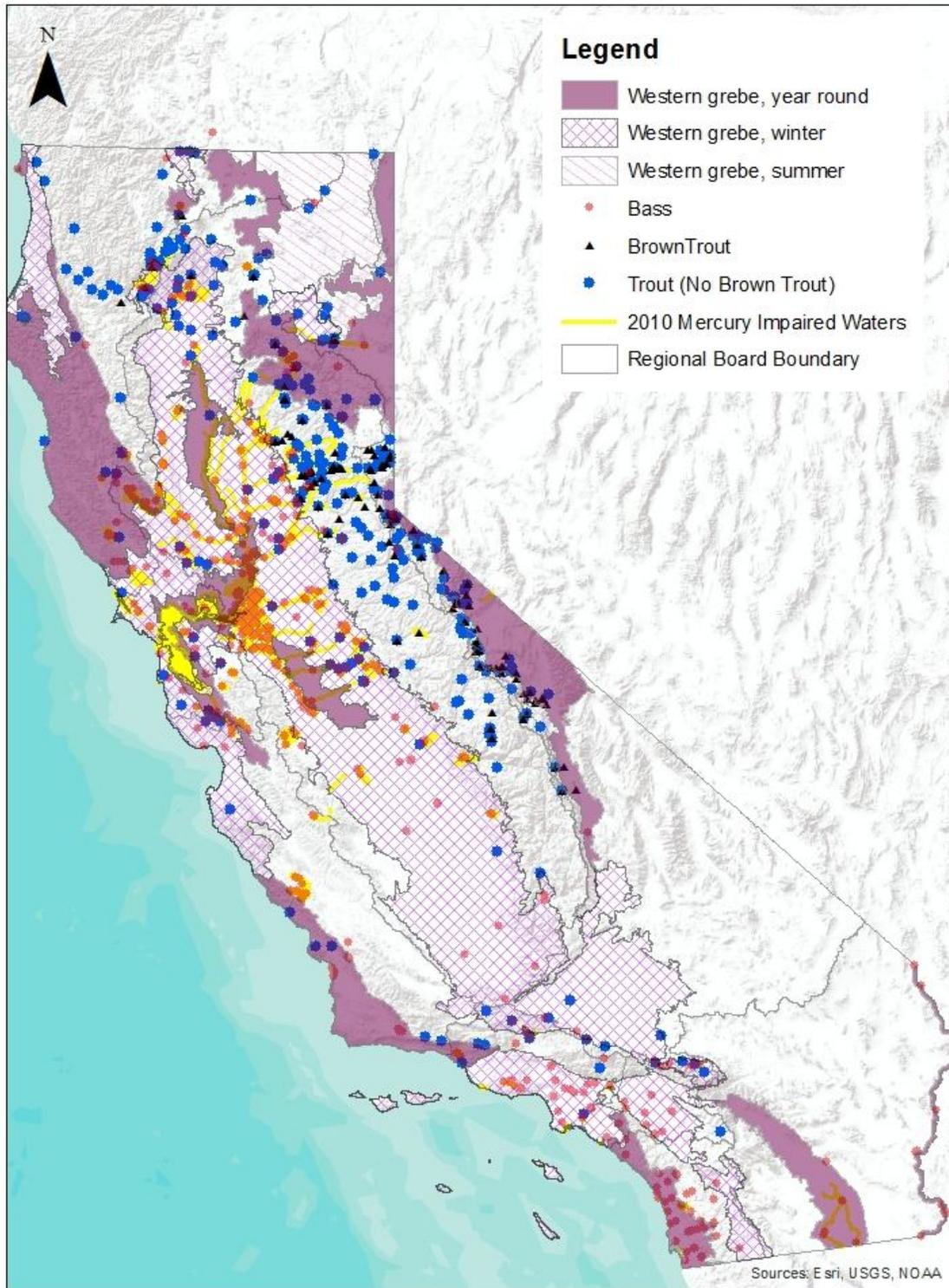
Figure K-4. Sensitive species habitat ranges that may overlap with trout dominated waters (see Figure K-3). Habitat ranges from California Wildlife Habitat Relationships (GIS shapefiles from www.dfg.ca.gov/biogeodata/cwhr/).
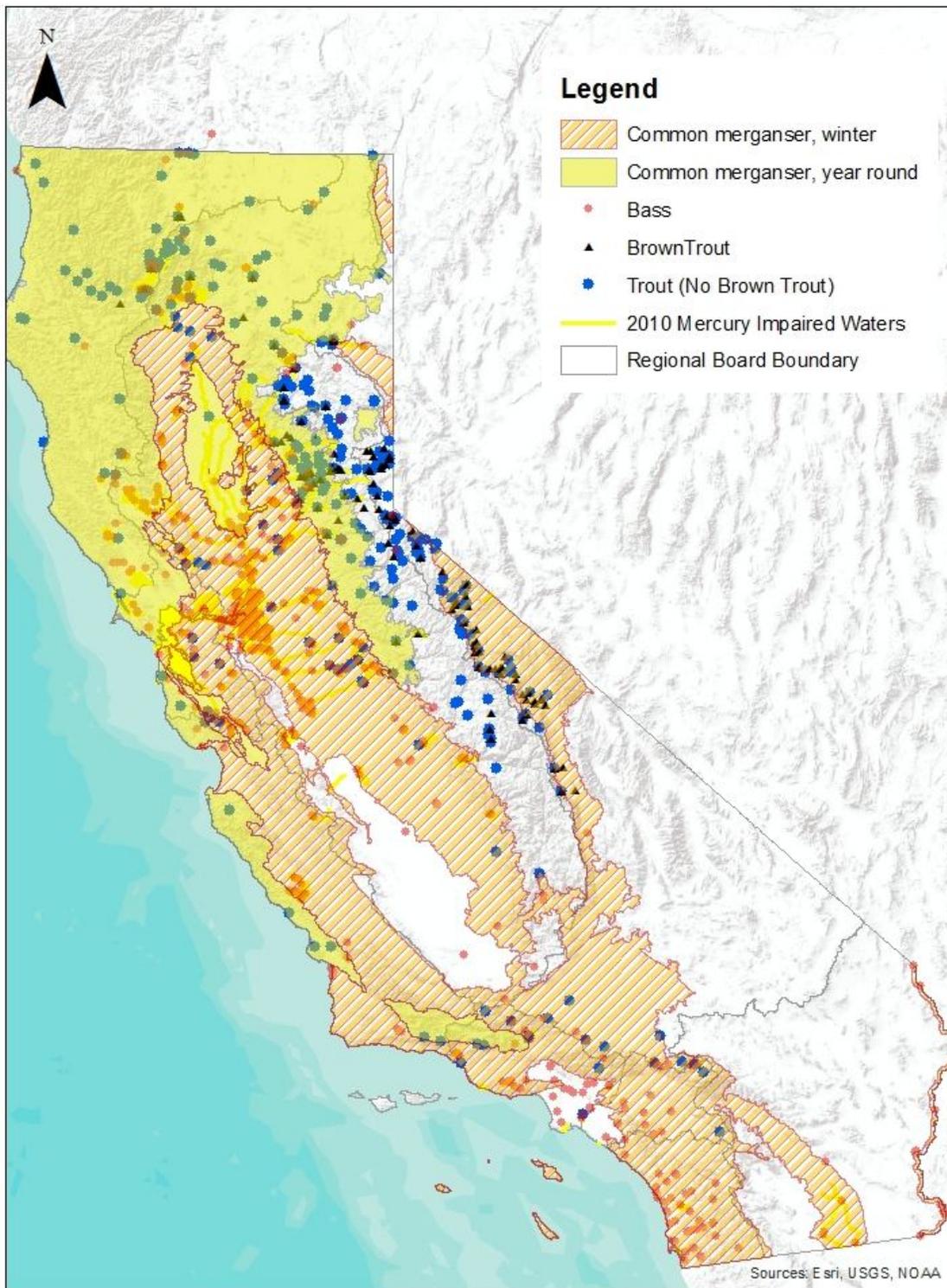
Figure K-4 (continued). Sensitive species habitat ranges that may overlap with trout dominated waters (see Figure K-3). Habitat ranges from California Wildlife Habitat Relationships (GIS shapefiles from www.dfg.ca.gov/biogeodata/cwhr/).

Figure K-4 (continued). Sensitive species habitat ranges that may overlap with trout dominated waters (see Figure K-3). Habitat ranges from California Wildlife Habitat Relationships (GIS shapefiles from www.dfg.ca.gov/biogeodata/cwhr/).
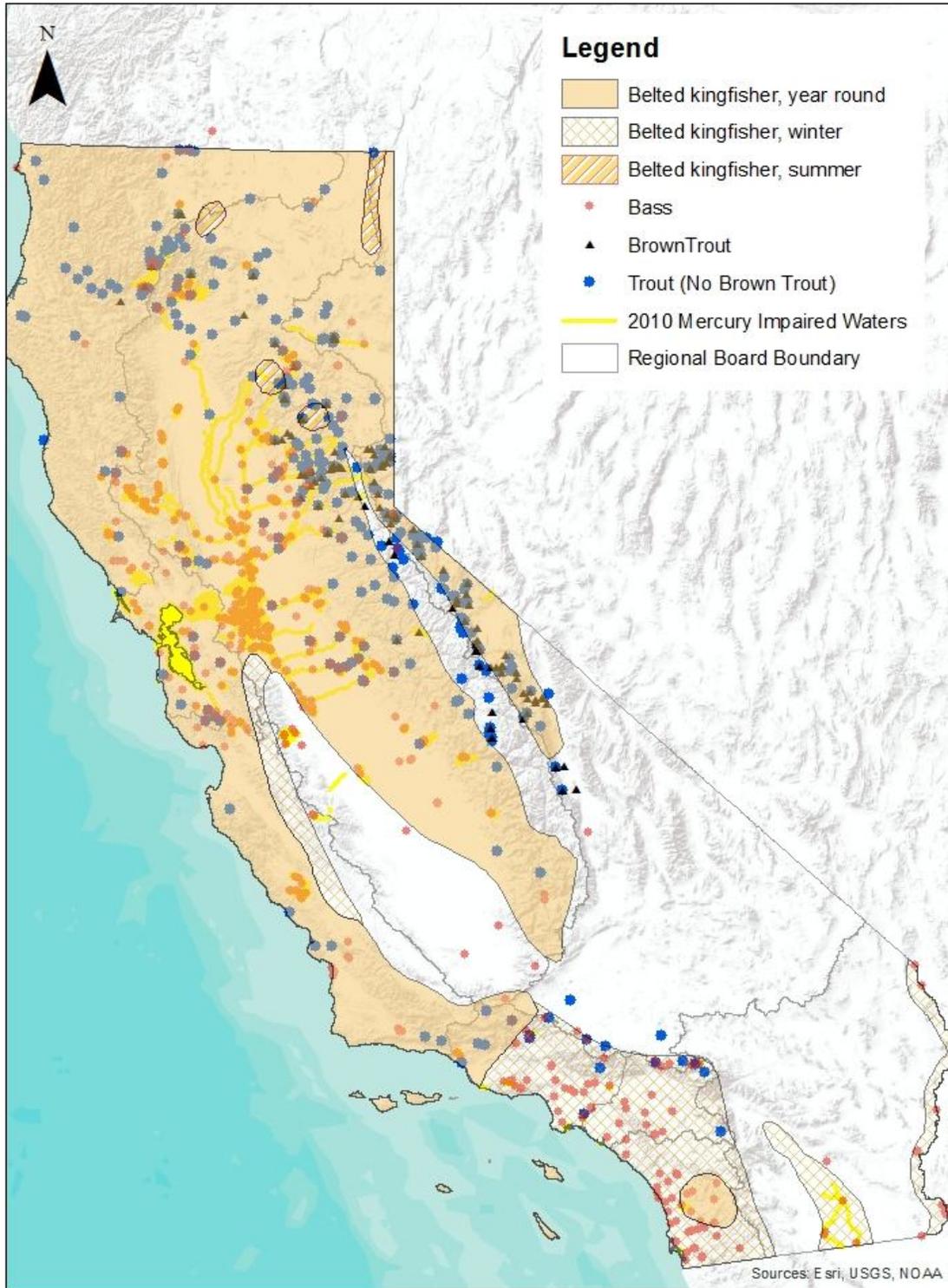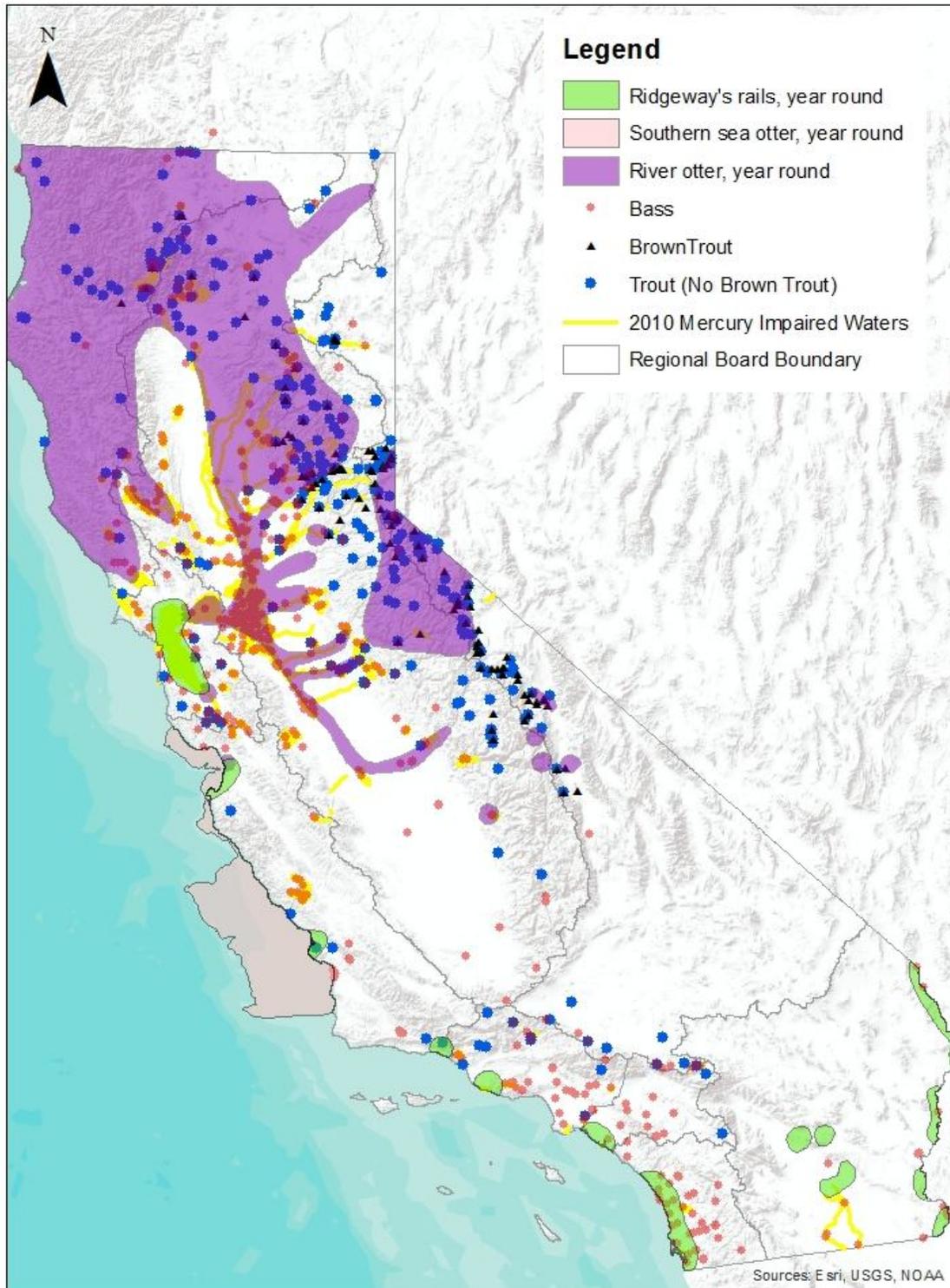
Figure K-4 (continued). Sensitive species habitat ranges that may overlap with trout dominated waters (see Figure K-3). Habitat ranges from California Wildlife Habitat Relationships (GIS shapefiles from www.dfg.ca.gov/biogeodata/cwhr/).

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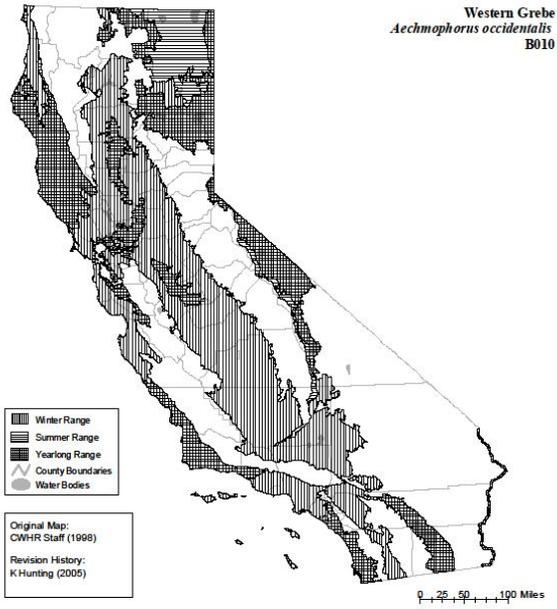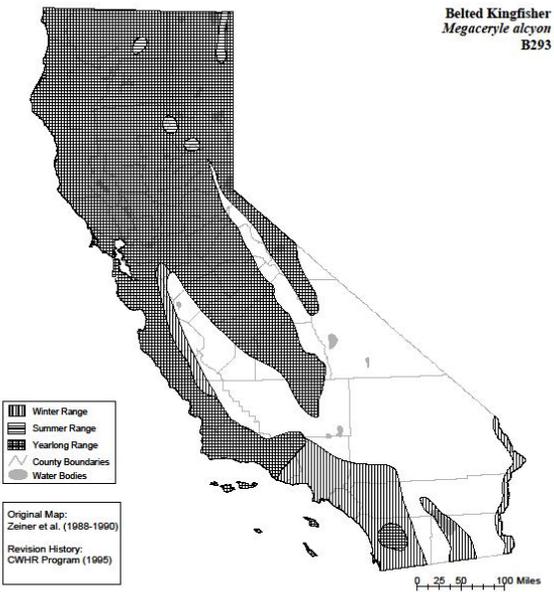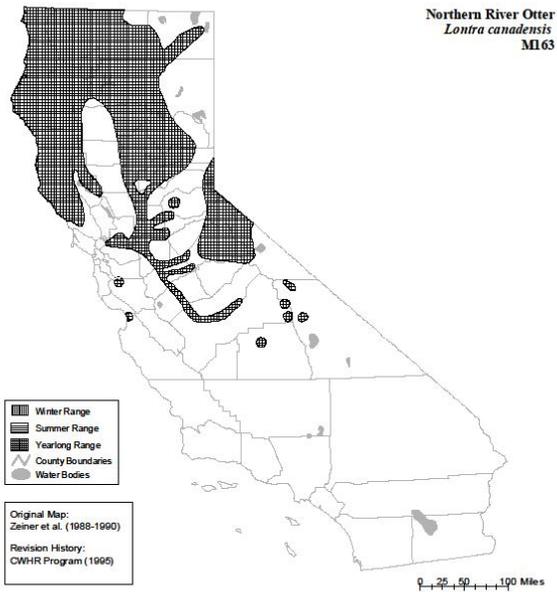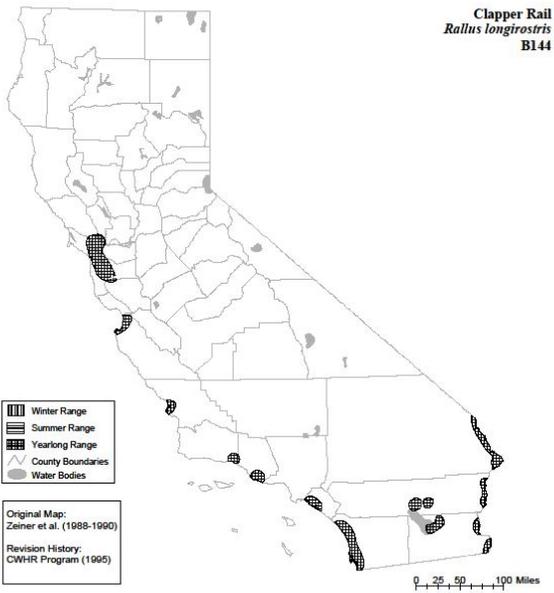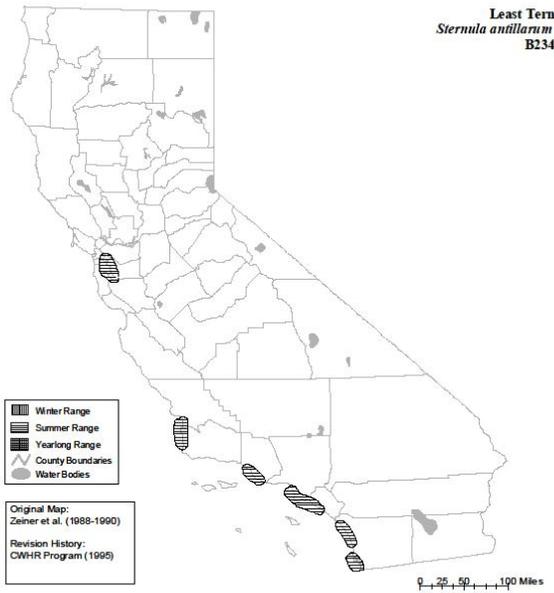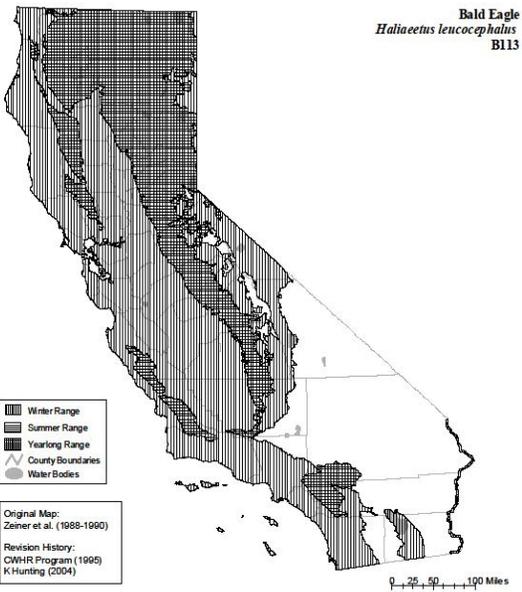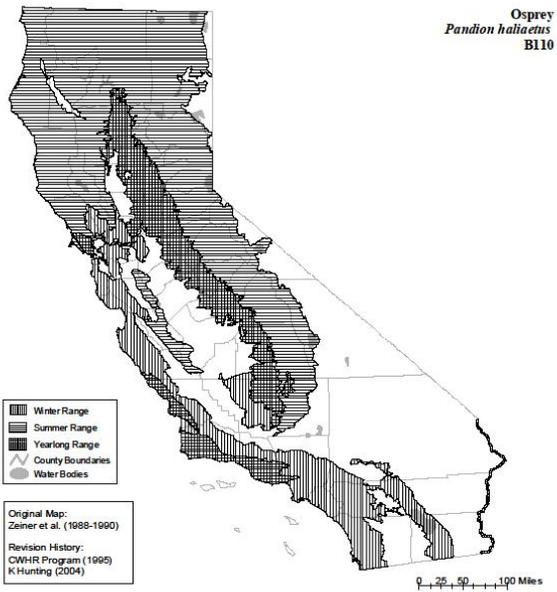
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