



Stream Temperatures in the Eel River Basin 1980-2015

Phase 1: Compilation and Preliminary Analysis



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and Paul Trichilo



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All photos by Patrick Higgins: A. Main Eel at Ft Seward 10/4/15; B. Bear Creek Lower Eel 10/21/15; C. Outlet Creek, 6/21/12; D. Fall Chinook in Fortuna, 10/24/15; E. Lower Eel at High Rock, 9/10/10; F. Bruce Hilbach Barger and Round Valley Indian Tribe EPA staff at mouth of Williams Creek, 7/2/15.

EXECUTIVE SUMMARY

Water temperature has long been identified as primary factor limiting production of salmon and steelhead in the Eel River Basin. There have been some previous analyses evaluating temperature data for the Eel River Basin, but this project compiled by far the most comprehensive dataset. The goal of this study was to 1) acquire, compile, and quality check all available water temperature data for the Eel River Basin, 2) calculate summary metrics for each site and year, 3) rate water temperature conditions according to suitability for coho salmon and steelhead trout, and 4) create tables and maps summarizing results. The results of this analysis will be used to refine monitoring plans and to inform development of future projects to restore aquatic habitat and watersheds within the Eel River.

The compiled dataset spans the years 1980 through 2015. Prior to excluding overlap between datasets, there were 13.4 million individual measurements and 7926 site-years of data. Excluding the overlap, there are a total of 988 sites, 453 reaches, and 5500 unique site-year combinations. Data contributors include the Humboldt County Resource Conservation District, Humboldt State University's Forest Science Project, Pacific Gas and Electric Company, Eel River Recovery Project, Friends of the Van Duzen River, UC Berkeley, Native Fish Society, California State Parks, multiple entities within the U.S. Forest Service (including the Mendocino National Forest, Six Rivers National Forest, and the Rocky Mountain Research Laboratory's NorWeST project), the North Coast Regional Water Quality Control Board, California Department of Fish and Wildlife, U.S Geological Survey, and U.S. Bureau of Land Management. All sites were assigned to reaches in a Geographic Information System (GIS) stream network from the National Stream Internet (NSI). Assigning the Eel River temperature monitoring points to NSI stream reaches will allow the data to be easily integrated into future stream temperature models such as the U.S. Forest Service's Rocky Mountain Research Lab's NorWeST project. In some analyses, we lump all sites within a reach together. We acknowledge that this lumping can mask important differences between sites; however, it makes spatial patterns much easier to visualize on maps at large scales.

During the course of this project, we were forced to confront the enormity of the task of assembling and cleaning such a large dataset, and were not able to do as much analysis as initially envisioned. We hope to conduct a separate future project within the next year to complete quality control on the dataset, acquire and compile additional datasets, and perform a thorough analysis of the stream temperature data which would include relationships with environmental variables such as air temperature and streamflow. We are making the provisional compiled dataset available to the public, but strongly encourage any potential users to contact us to discuss limitations and loose ends in the data. We conducted an intensive screening and trimming process which identified and corrected many errors and inconsistencies in the dataset, but considerable additional review and cleaning are necessary. One of the major issues is that same data were included in multiple compilations, resulting in up to four copies of the same data. We used automated methods in a preliminary attempt to mark much of the obviously duplicated data as overlap, but considerable overlap remains.

We also initiated a process of grouping similar sites together into "standardized" sites to prepare for time series analysis, but we have not had sufficient time to verify the appropriateness of every grouping. We initiated a process of grouping similar sites together into "standardized" sites to prepare for time series analysis. Unfortunately, we did not have sufficient time to verify the appropriateness of every grouping and there are likely instances where we grouped sites together whose temperatures are too dissimilar to warrant grouping. We hope to complete the site standardization in a future project.

We calculated daily and seasonal statistics for each site and year. Seasonal statistics included Maximum Daily Maximum Temperature (MDMT), Maximum Weekly Maximum Temperature (MWMT), and Maximum Weekly Average Temperature (MWAT). MWMT is the average daily maximum temperature

during the hottest seven-day period of the year. The four statistics are all highly correlated with each other. All four statistics were calculated and included in report appendices, but for the sake of simplicity the main text and figures in the report focus almost solely on MWMT. For purposes of differentiating categories of stream temperatures in the Eel River Basin and prioritizing areas where it may be feasible to restore coho salmon, MWMT thresholds for salmonid suitability were selected based on a literature review, with upper limits for coho salmon defined as $<18\text{ }^{\circ}\text{C}$ as “likely suitable” and $<20\text{ }^{\circ}\text{C}$ as “possibly suitable”.

Stream temperatures in the Eel River Basin typically peak in July or August. On average, July is slightly warmer than August. There is considerable year-to-year and site-to-site variation in the date that peak temperatures occur.

Many sites were monitored for only a few years, and therefore the available data do not encompass the full range of conditions that occurred during the 1980-2015 period. We applied an approximate index of cool vs. warm years based on the MWMT relative anomaly (i.e., ratio of MWMT for individual years to the mean MWMT calculated from all years), for the years 1994-2015 only. There were not enough sites in 1980-1993 to calculate the index. Based on the MWMT relative anomaly, the four warmest years were 2006, 2004, 1996, and 1997, and the five coolest years were 2002, 2010, 2011, and 2012. Despite having streamflows among the lowest on record and many streams drying up or becoming intermittent, stream temperatures in 2014 and 2015 ranked as cool and moderate, respectively. Analysis of why some years were warmer than others is outside the scope of this analysis, but potential factors include: air temperatures, streamflow, smoke from wildfire, disturbances to stream channels and riparian vegetation (e.g., debris torrents and timber harvest), and recovery from prior disturbance. Many streams were dry in 2014 and 2015 (and to a lesser extent 2013 also) and thus summary statistics could not be calculated due to missing data. It is possible that the large number of dry streams in 2013, 2014, and 2015 could have affected the population of streams that were available to calculate the relative anomaly and therefore biased the classification of cool vs warm years.

For analytical purposes, the Eel River was divided into six study watersheds: Lower Eel River, Middle Eel River, Upper Eel River, Van Duzen River, Lower South Fork Eel River, Upper South Fork Eel River, Middle Fork Eel River, and North Fork Eel River. Each of these watersheds contained sites with a diverse range of temperatures; however, there are differences in the temperature distribution between sub-basins. Temperatures were generally coolest Lower Eel River Subbasin, Van Duzen River sub-basin, and the western half of the Upper South Fork and Lower South Fork.

MWMT temperature is strongly correlated with drainage area, and most streams show the expected pattern of warming as water flows downstream from cold, well-shaded headwaters into wider alluvial channels which are more exposed to solar radiation (Figure ES-1). One exception is the mainstem Eel River which exhibits a more complex pattern where water warms prior to entry into Lake Pillsbury, cool water released from Scott Dam warms rapidly to reach a maximum around the confluence with Outlet Creek and then becomes progressively cooler as it flows downstream towards the Pacific Ocean where summer air temperatures are much lower. MWMT temperatures $<18\text{ }^{\circ}\text{C}$ and $<20\text{ }^{\circ}\text{C}$ occur primarily at sites with drainage areas less than 100 km^2 . For each of the Eel River’s sub-basins, the report presents a map showing site locations, a graph grouped into reaches showing MWMT temperatures for each site and year, and an annual time series of MWMT temperatures at a subset of sites.

Riverbend Sciences also recently performed a water temperature analysis of the South Fork Trinity River for the Watershed Research and Training Center (Asarian 2016), using methods and a report template that are similar to this Eel River analysis. A few charts demonstrating analytical techniques and methods of data display in the methods sections of this Eel River report are examples duplicated from the Asarian (2016) report.

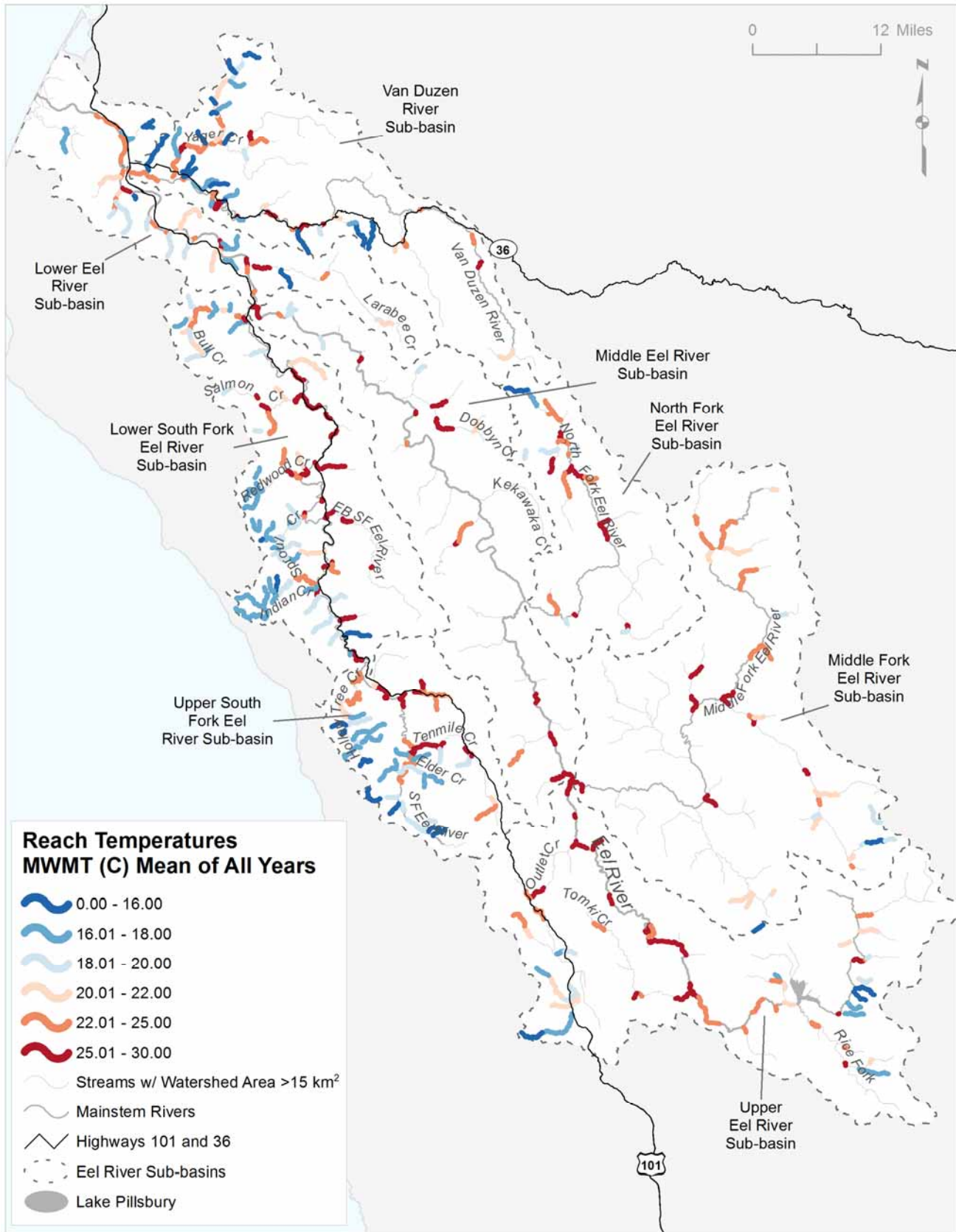


Figure ES-1. Map with all-year reach-level summary of Maximum Weekly Maximum Temperature (MWMT) within the Eel River Basin. MWMT is the average daily temperature during the hottest seven-day period of the year. Mean reach MWMT values were calculated as the mean of all MWMTs across all years (1980-2015) and sites within a reach. Reaches are color-coded according to the MWMT salmonid suitability categories in Table 2 and labeled by stream name.

TABLE OF CONTENTS

Executive Summary	i
Table of Contents	iv
List of Electronic Appendices.....	v
List of Figures	vi
List of Tables.....	viii
1 Introduction.....	1
1.1 Description of Study Area.....	1
1.2 Previous Assessments of Stream Temperatures in the Eel River Basin	3
1.3 Study Goals.....	4
2 Methods	4
2.1 Stream Temperature Data Sources Acquired and Compiled.....	4
2.1.1 US Forest Service, Natural Resource Information System Aquatic Surveys	6
2.1.2 Humboldt State University's Forest Science Project	6
2.1.3 Humboldt County Resource Conservation District	6
2.1.4 Pacific Gas and Electric Company	7
2.1.5 Eel River Recovery Project	7
2.1.6 California State Parks	8
2.1.7 NorWeST.....	8
2.1.8 U.S. Forest Service, Redwood Sciences Lab.....	9
2.1.9 Friends of the Van Duzen River	9
2.1.10 Native Fish Society.....	9
2.1.11 U.S. Geological Survey	10
2.1.12 University of California at Berkeley.....	10
2.1.13 U.S. Bureau of Land Management, Arcata Office.....	10
2.1.14 Additional Datasets Not Acquired or Compiled	10
2.2 Quality Control and Cleaning of Stream Temperature Data.....	12
2.3 Assigning Stream Temperature Monitoring Sites to Stream Network GIS Reaches	15
2.4 Standardizing Site Locations.....	16
2.5 Calculation of Daily and Seasonal Summaries	16
2.5.1 Daily Summary Statistics	16
2.5.2 Initial Calculation of Seasonal and Monthly Summary Statistics.....	16
2.5.1 Refining Seasonal Statistics According to Data Completeness	18
2.6 Selecting Temperature Categories for the Eel River Basin Based on Suitability for Salmonids	18
3 Results and Discussion.....	20
3.1 Overall Seasonal Patterns in Stream Temperature and Relationships Between temperature metrics	20
3.2 Inter-Annual Variation in Stream Temperature	23
3.3 Summary of Spatial Patterns in Stream Temperature	25
3.4 Stream Temperature Details by SUB-Basin.....	30
3.4.1 Lower Eel River	30
3.4.1 Middle Eel River	35
3.4.1 Upper Eel River.....	37
3.4.1 Van Duzen River	45
3.4.2 Lower South Fork Eel River.....	48
3.4.1 Upper South Fork Eel River.....	55
3.4.1 Middle Fork Eel River.....	60
3.4.1 North Fork Eel River.....	64
3.5 NorWeST Model Results	66
4 References Cited	68
5 Acknowledgments	73
APPENDIX A: Methods Used for Assigning Stream Temperature Monitoring Sites to the NSI Stream Network.....	A1
APPENDIX B: Sensitivity analysis of MWAT and MWMT Relative Anomalies	B1
APPENDIX C: Map With Years of Temperature Data for Each Reach	C1
APPENDIX D: Explanation of Electronic Appendix 1	D1
APPENDIX E: List of Temperature Monitoring Sites	E1

LIST OF ELECTRONIC APPENDICES

Note: All electronic appendices are available at <http://www.eelriverrecovery.org>

APPENDIX 1: Graphs of provisional site and reach temperatures with Google Earth interface.
See Appendix D for explanation of contents of Electronic Appendix 1

APPENDIX 2: Complete dataset of provisional hourly stream temperature measurements

APPENDIX 3: Complete dataset of provisional daily stream temperature summaries

APPENDIX 4: Complete dataset of provisional annual water temperature summaries

APPENDIX 5: Complete dataset of provisional stream temperature site location attributes



LIST OF FIGURES

Figure 1. Major sub-basins, rivers, streams, and towns within the Eel River Basin and adjacent areas.	2
Figure 2. Example data quality assessment graph comparing 7-day average of daily maximum water temperatures at all sites monitored by the Eel River Recovery Project in 2012.	13
Figure 3. Example data quality assessment graph comparing hourly water temperature data at a single site (Canoe Creek data collected by California State Parks) (black line) and Alderpoint air temperature (light grey line) across all years. 14	
Figure 4. Example map showing how several water temperature datasets from slightly different locations are assigned to a single NSI/NHD-plus stream reach. Labels for.....	15
Figure 5. Example of range of MWMTs from four temperature monitoring stations on lower Hayfork Creek within the NSI/NHD-plus stream reach COMID 8232510 used as an example in Figure 4 above. From Asarian (2016), which used similar methods to this report.....	16
Figure 6. Daily time series of daily maximum, daily mean, daily minimum, 7-day average of daily mean, and 7-day average of daily maximum, MDMT, MWMT, and MWAT at an example site. MDMT, MWMT, and MWAT are the highest annual values for daily maximum, 7-day average of daily mean, and 7-day average of daily maximum, respectively.	17
Figure 7. Seven-day moving averages of daily maximum temperature (7DADM) for every site and every year in the Eel basin.	20
Figure 8. Date each year 1980-2015 upon which MWMT temperature occurred at sites in the Eel basin.	21
Figure 9. Comparison of mean July stream temperatures with (A) mean June stream temperatures, and (B) mean August stream temperatures, for the entire Eel basin dataset.	21
Figure 10. Correlation matrix comparing maximum weekly maximum temperature (MWMT), maximum weekly average temperature (MWAT), annual single maximum (MDMT), and August mean (Aug_mean) temperatures for the entire Eel basin dataset.....	22
Figure 11. Annual time series of MWMT relative anomaly (i.e., ratio of a site-year’s MWMT to a site’s mean MWMT) for each site and year (black circles).....	24
Figure 12. Mean of MWMT relative anomaly (i.e., mean ratio of a single-year MWMT to a mean MWMT) for each year 1994 to 2015 (there were not enough sites to assess 1980-1993), indicating generalized basinwide cool and warm years.	24
Figure 13. Mean MWMT temperature vs. drainage area (on log scale) for reaches within the Eel basin, excluding the mainstem Eel River.	25
Figure 14. Mean MWMT temperature vs. drainage area (on log scale) for mainstem Eel River reaches only.....	26
Figure 15. Map with all-year reach-level summary of MWMT stream temperatures within the Eel River basin.....	27
Figure 16. Map with cool-year reach-level summary of MWMT stream temperatures within the Eel River basin.....	28
Figure 17. Map with warm-year reach-level summary of MWMT stream temperatures within the Eel River basin.....	29
Figure 18. Map showing stream temperature monitoring sites in the Lower South Fork Eel River sub-basin.	31
Figure 19. Site-level summary of stream temperatures measured within the Lower Eel River sub-basin.	32
Figure 20. Time series of measured stream temperatures for standardized site 1507 at the mouth of Bear Creek.	33
Figure 21. Time series of measured stream temperatures for standardized site 1564 at the mouth of Howe Creek.	33
Figure 22. Time series of measured stream temperatures for standardized site 1607 at the mouth of Price Creek.....	34
Figure 23. Time series of measured stream temperatures for standardized site 8029 at Francis Creek.	34
Figure 24. Map showing stream temperature monitoring sites in the Middle Eel River sub-basin.....	35
Figure 25. Site-level summary of stream temperatures measured within the Middle Eel River sub-basin.	36

Figure 26. Time series of measured stream temperatures for standardized site 1346 at the Eel River upstream of the South Fork Eel River. 36

Figure 27. Time series of measured stream temperatures for standardized site 1550 at the Eel River downstream of the Middle Fork Eel River. 37

Figure 28. Map showing stream temperature monitoring sites in the Upper Eel River sub-basin. 38

Figure 29. Site-level summary of stream temperatures measured at mainstem Eel River sites within the Upper Eel River sub-basin. 39

Figure 30. Site-level summary of stream temperatures measured at tributaries within the Upper Eel River sub-basin. 40

Figure 31. Time series of measured stream temperatures for standardized site 1549 at the Eel River upstream of the Middle Fork Eel River. 41

Figure 32. Time series of measured stream temperatures for standardized site 1439 at the Eel River downstream of the Outlet Creek. 41

Figure 33. Time series of measured stream temperatures for standardized site 1403 at the Eel River upstream of the Outlet Creek. 42

Figure 34. Time series of measured stream temperatures for standardized site 8005 at the Eel River at Hearst. 42

Figure 35. Time series of measured stream temperatures for standardized site 1545 at the Eel River upstream of Tomki Creek. 43

Figure 36. Time series of measured stream temperatures for standardized site 1546 at the Eel River below Scott Dam. 43

Figure 37. Time series of measured stream temperatures for standardized site 1602 at the mouth of Outlet Creek. 44

Figure 38. Time series of measured stream temperatures for standardized site 1648 at the mouth of Tomki Creek. 44

Figure 39. Map showing stream temperature monitoring sites in within the Van Duzen River sub-basin. 45

Figure 40. Site-level summary of stream temperatures measured at mainstem Van Duzen River sites within the Van Duzen River sub-basin. 46

Figure 41. Site-level summary of stream temperatures measured at tributaries within the Van Duzen River sub-basin. 47

Figure 42. Time series of measured stream temperatures for standardized site 1465 at the mouth of Grizzly Creek. 48

Figure 43. Time series of measured stream temperatures for standardized site 1573 at the mouth of Little Larabee Creek. ... 48

Figure 44. Map showing stream temperature monitoring sites in the Lower South Fork Eel River sub-basin. 49

Figure 45. Site-level summary of stream temperatures measured within the Lower South Fork Eel River sub-basin (Part 1). 50

Figure 46. Site-level summary of stream temperatures measured within the Lower South Fork Eel River sub-basin (Part 2). 51

Figure 47. Time series of measured stream temperatures for standardized site 1670 at the mouth of Cuneo Creek (tributary to Bull Creek). 52

Figure 48. Time series of measured stream temperatures for standardized site 1305 at the lower Cow Creek (tributary to Bull Creek). 52

Figure 49. Time series of measured stream temperatures for standardized site 1302 at the lower Squaw Creek (tributary to Bull Creek). 53

Figure 50. Time series of measured stream temperatures for standardized site 9853 at the lower North Fork Panther Creek (tributary to Bull Creek). 53

Figure 51. Time series of measured stream temperatures for standardized site 8064 at Bull Creek downstream of Panther Creek. 53

Figure 52. Time series of measured stream temperatures for standardized site 1512 at Bull Creek at the USGS gage. 54

Figure 53. Map showing stream temperature monitoring sites in the Upper South Fork Eel River sub-basin. 55

Figure 54. Site-level summary of stream temperatures measured within the Lower South Fork Eel River sub-basin (Part 1). 56

Figure 55. Site-level summary of stream temperatures measured within the Upper South Fork Eel River sub-basin (Part 2). 57

Figure 56. Time series of measured stream temperatures for standardized site 1566 at the mouth of Jack of Hearts Creek. ... 58

Figure 57. Time series of measured stream temperatures for standardized site 1461 at the mouth of Elder Creek. 58

Figure 58. Time series of measured stream temperatures for standardized site 1534 at the mouth of Dutch Charlie Creek. ... 59

Figure 59. Map showing stream temperature monitoring sites in the Lower South Fork Eel River sub-basin. 60

Figure 60. Site-level summary of stream temperatures measured within the Middle Fork Eel River sub-basin..... 61

Figure 61. Time series of measured stream temperatures for standardized site 1678 at the mouth of the Middle Fork Eel River..... 62

Figure 62. Time series of measured stream temperatures for standardized site 1582 on Middle Fork of the Eel River downstream of the confluence of with the North Fork of Middle Eel River. 62

Figure 63. Time series of measured stream temperatures for standardized site 1505 at the mouth of the Black Butte River... 63

Figure 64. Time series of measured stream temperatures for standardized site 1584 at the Middle Fork of the Eel River downstream of Fly Creek. 63

Figure 65. Map showing stream temperature monitoring sites in the Lower South Fork Eel River sub-basin. 64

Figure 66. Site-level summary of stream temperatures measured within the North Fork Eel River sub-basin..... 65

Figure 67. Comparison of NorWeST spatial stream network model predictions for mean August stream temperature in the Eel River basin for 1993-2013 and a future scenario based on global climate model ensemble averages that represents the A1B warming trajectory for 2080s (2070-2099)..... 67

LIST OF TABLES

Table 1. Summary of the number of stream temperature sites and years monitored by each data source available in the Eel River Basin..... 5

Table 2. Categories for evaluating the suitability of water temperatures for supporting salmonids in streams in the Eel Basin. 20

Table 3. Example calculation of a single site’s mean MWMT and relative MWMT anomaly for each year. The relative MWMT anomaly is the ratio of each year’s MWMT to the mean MWMT..... 23

1 INTRODUCTION

1.1 DESCRIPTION OF STUDY AREA

The Eel River Basin is located on the North Coast of California (Figure 1). The area has a Mediterranean climate with primarily mountainous terrain. Vegetation includes conifer forests, oak woodlands, and grasslands. Precipitation falls primarily as rain except at the highest elevations, which are at the southeastern end the basin in the headwaters of the Middle Fork Eel River and to a lesser extent the mainstem Eel River. Streamflows vary strongly by season, with streamflows during the rainy winter several orders of magnitude higher than during the dry summer and early fall (Power et al. 2015). The basin is home to three species of anadromous salmonid fishes: Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*). Chinook, coho, and steelhead are protected under the federal Endangered Species Act and all have declined greatly from historical levels (Yoshiyama and Moyle 2010). The lower-gradient valleys have the highest intrinsic potential for coho salmon (NMFS 2014).

The only significant dams in the Eel River Basin are Scott Dam and Cape Horn Dam on the upper mainstem, which are part of the Potter Valley Project and form Lake Pillsbury and Van Arsdale Reservoir, respectively (NMFS 2014). The largest water diversion in the Basin is from Van Arsdale Reservoir through a tunnel into the adjacent Russian River Basin (NMFS 2002). There are many smaller surface water diversions and groundwater wells associated with rural residences and marijuana cultivation sites throughout the Basin (Bauer et al. 2015, Power et al. 2015); pastures and forage crops in the Eel River Delta (Ferndale/Loleta), Little Lake Valley (Willits), Round Valley (Covelo), Long Valley (Laytonville); and municipal water systems including the communities of Willits, Scotia, Fortuna, Loleta, Ferndale, Laytonville, Redway, and Garberville.

Since California legalized medical marijuana in 1995, marijuana cultivation has expanded dramatically in the Basin, with associated increases in water diversions (Bauer et al. 2015). Inadequate summer streamflow has been identified as a primary contributor to declining populations of coho salmon in the Basin (NMFS 2014, Bauer et al. 2015).

For analytical purposes, the Eel River was divided into six study watersheds: Lower Eel River, Middle Eel River, Upper Eel River, Van Duzen River, Lower South Fork Eel River, Upper South Fork Eel River, Middle Fork Eel River, and North Fork Eel River (Figure 1). These sub-basins do not match a single level of the U.S. Geological Survey Hydrologic Unit Code (HUC) system, but rather were created by aggregating sub-watersheds together.

Additional information about the Eel River Basin can be found in California Fish and Wildlife watershed assessments (Downie et al. 2005, CDFG 2010, CDFG 2012, Kajtaniak 2014), the NMFS (2014) coho salmon recovery plan, and Yoshiyama and Moyle (2010).

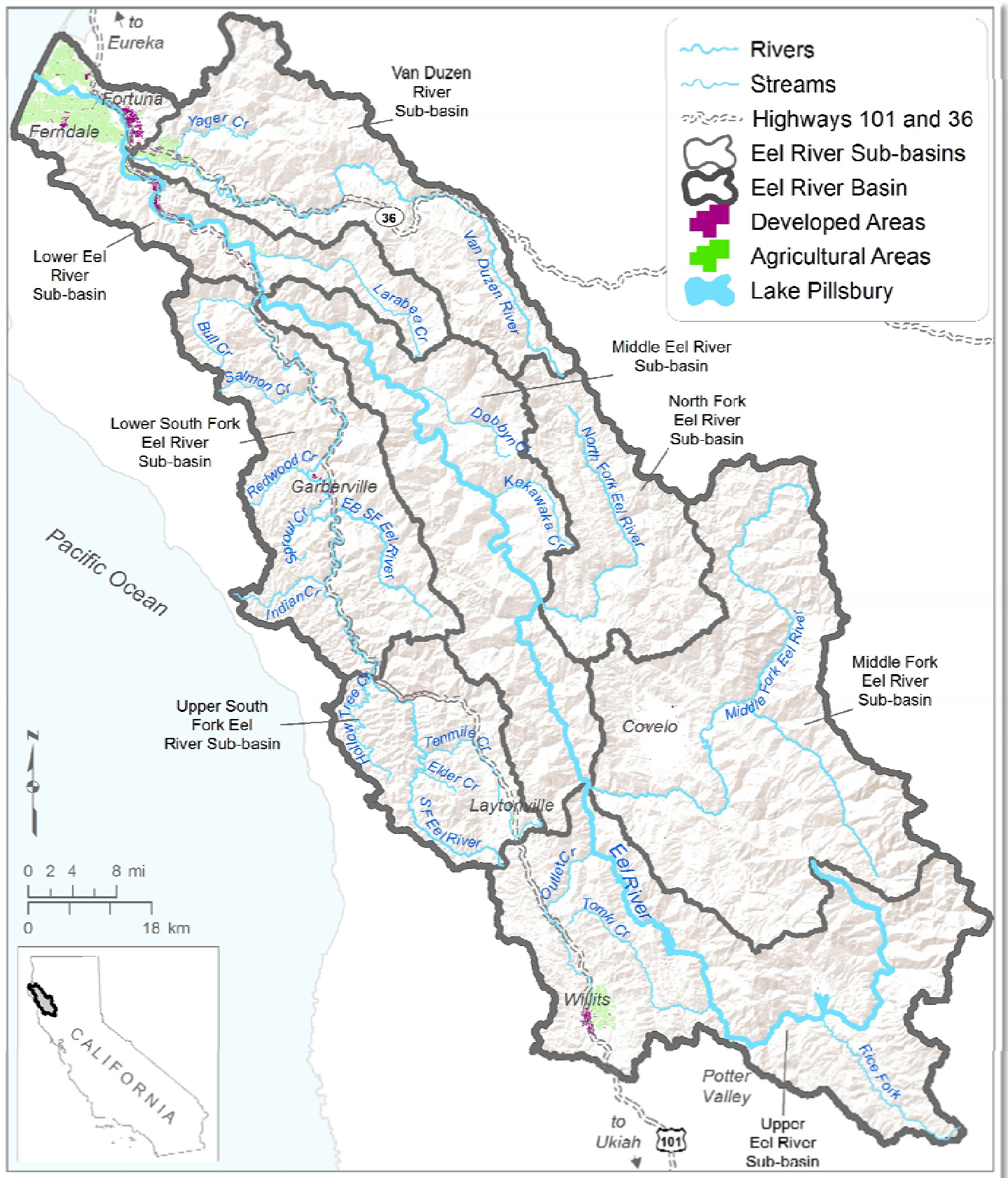


Figure 1. Major sub-basins, rivers, streams, and towns within the Eel River Basin and adjacent areas.