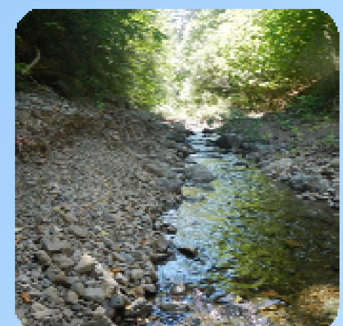

Stream Temperatures in the Eel River Basin 1980-2015

Phase 1: Compilation and Preliminary Analysis

J. Eli Asarian

Riverbend Sciences

Patrick Higgins
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Funded by:
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Photo credits for cover page (clockwise from top):

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 °C as “likely suitable” and <20 °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 °C and <20 °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.

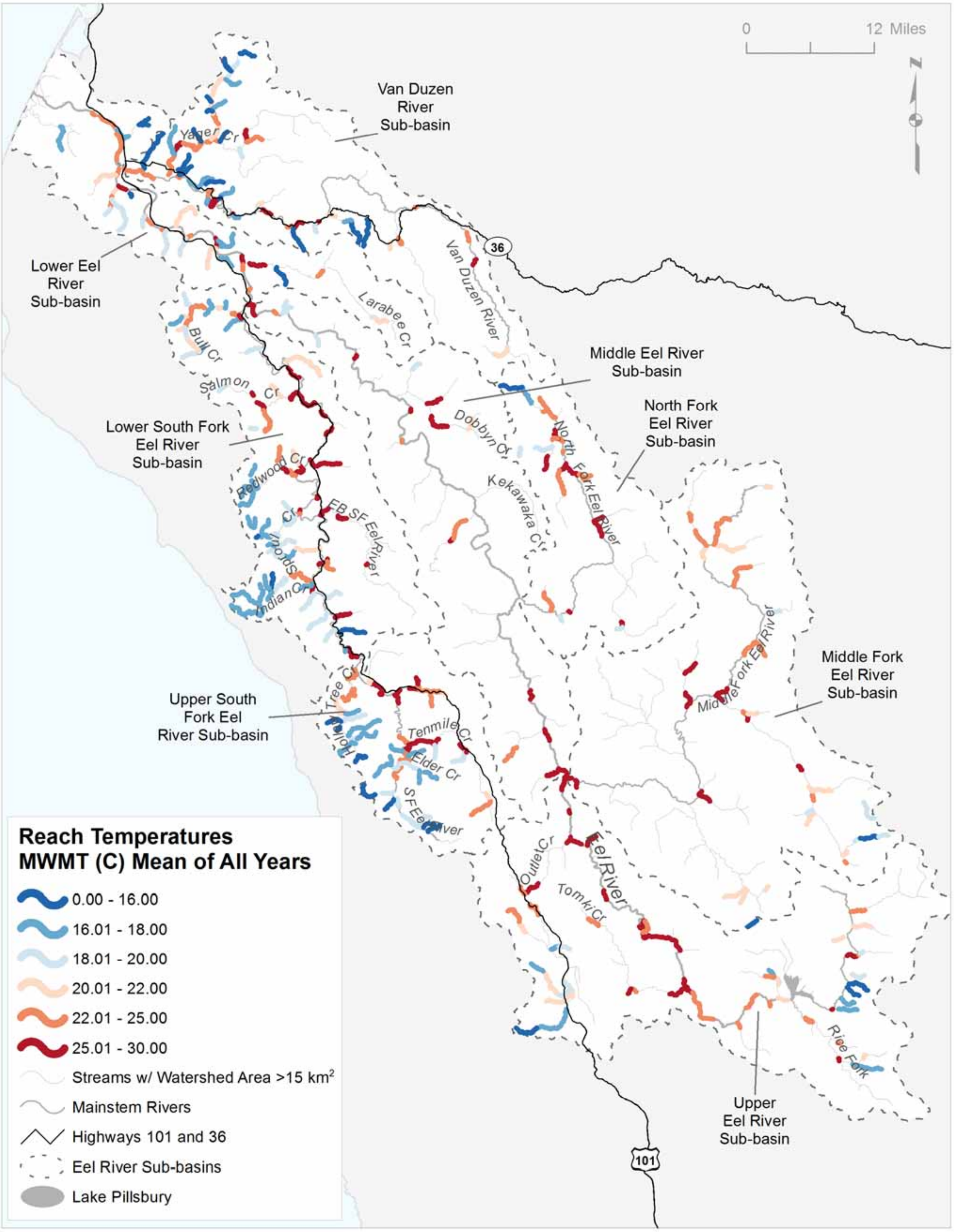

Figure ES-1. Map with all-year reach-level summary of Maximum Weekly Maximum Temperature (MWMT) within the Eel River Basin. MWMT is the average daily temperature during the hottest seven-day period of the year. Mean reach MWMT values were calculated as the mean of all MWMTs across all years (1980-2015)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

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APPENDIX 2: Complete dataset of provisional hourly stream temperature measurements

APPENDIX 3: Complete dataset of provisional daily stream temperature summaries

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

South Fork Eel River near Branscomb
Photo: Patrick Higgins

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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 though 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).

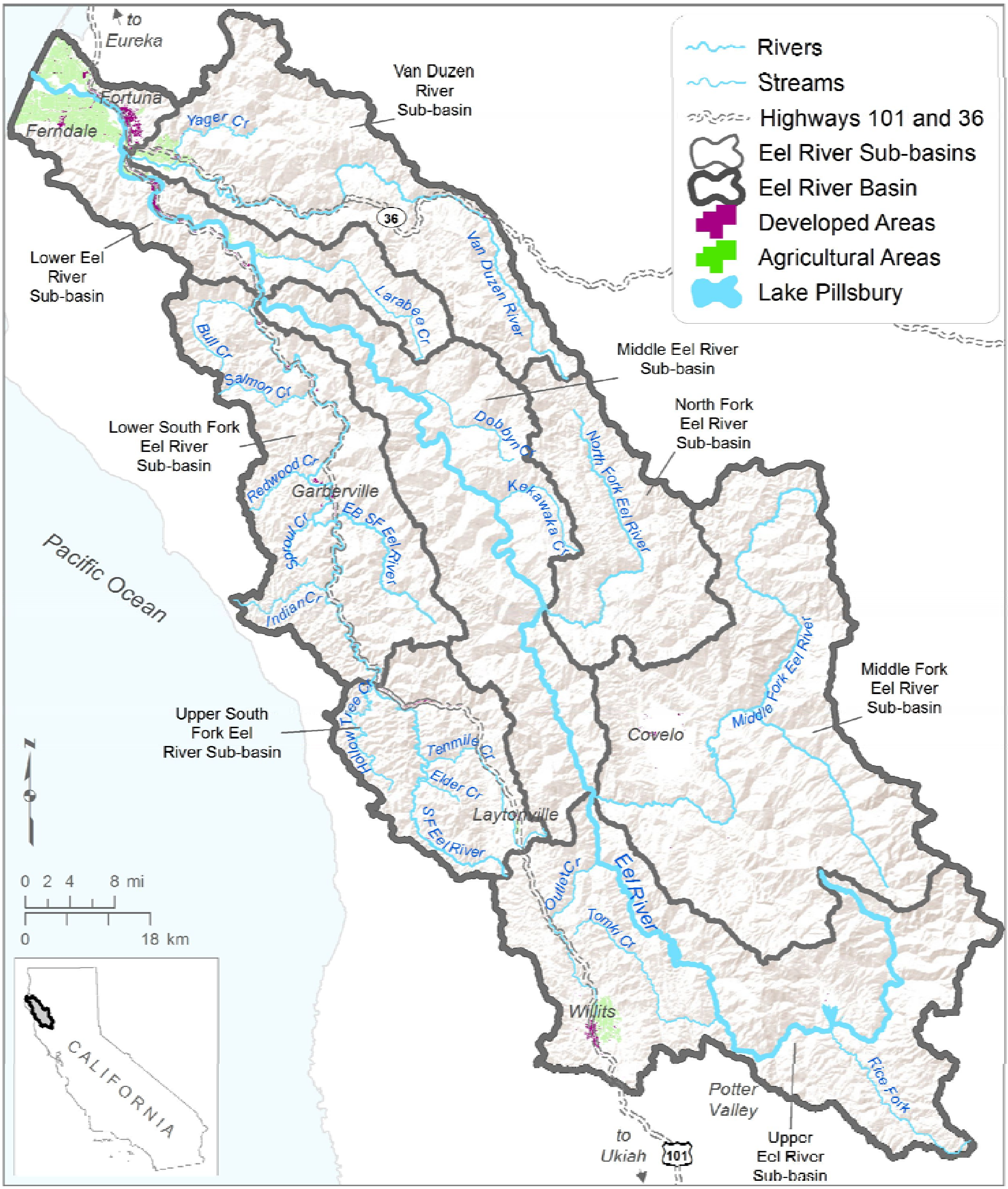

Figure 1. Major sub-basins, rivers, streams, and towns within the Eel River Basin and adjacent areas.