Eel River Recovery Project 2013 Citizen Assisted
Water Temperature and Flow Monitoring






Prepared for: **Eel River Recovery Project**
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Executive Summary

ERRP placed automated water temperature monitoring devices at 58 locations in 2013, including data collected cooperatively by UC Berkeley (Bouma-Gregson 2014). Flow conditions were photo-documented at numerous locations throughout the watershed and observations summarized below.

Eel River water temperatures were the highest ever recorded at some locations in 2013, but several streams did not register all time highs because they are in recovery from past watershed damage and flood events. Bear and Howe creeks on the lower Eel River and Van Duzen tributaries Hely, Cummings, Fox and Yager creeks had higher water temperatures in 1996-1997 (Friedrichsen 1998), and 2013 data confirm a pattern of recovery. However, late 2012 storms caused major aggradation in lower Eel River tributaries Jordan, Price, and Greenlaw creeks. Sediment over-supply in South Fork Eel River tributaries affected by rural development was also evident (i.e. Redwood Creek and Fish Creek), and is a significant factor in surface water availability and the quality and carrying capacity for salmonid juveniles during droughts. The lower Van Duzen River dried up in August 2013, and tends to do so even in non-drought years even though it was historically perennial, because of lingering sediment effects from logging.

Outlet, Ten Mile and Tomki creeks in Mendocino County went dry earlier in 2013 than in 2012 (Higgins 2013a), and Tomki Creek remained dry in December 2013. These are major sub-basins of the Eel River and diversions for domestic and agricultural use are likely factors in dewatering. Similarly, South Fork Eel River tributaries Redwood Creek and Rattlesnake Creek lost surface flow and maintained little carrying capacity for salmonids in 2013. In the upper Eel, Soda Creek and its tributaries Welch and Panther went dry, when they had no history of doing so previously.

Lower Eel River temperatures were unusually warm and reached acutely stressful or lethal range for salmonids as far downstream as Fernbridge until rains in late September. This delayed Chinook salmon and steelhead migration upstream from the estuary and made the lower main Eel optimal for the non-native Sacramento pikeminnow. On a positive note, Eel River tributaries flowing from lesser disturbed or recovering watersheds not only maintained flows during the 2013 drought but also harbored significant standing crops of juvenile salmonids. Examples are the upper South Fork Eel, Steelhead Creek near Alderpoint, Root Creek in the Van Duzen, and the upper East Branch SF Eel. Observations in the Black Butte River and upper Van Duzen River suggested that the warm-adapted, native Sacramento sucker had good juvenile recruitment despite the drought. Lack of scouring flows associated with the drought is also allowing riparian recovery, with gravel bars throughout the basin carpeted in willow, alder and cottonwood seedlings.

Unusual late June 2013 rains cooled tributaries but by late July most of the Eel River was not suitable for recreation because of pervasive swimmer's itch and excessive algae growth. Cyanotoxin monitoring by UC Berkeley at seven locations found measurable levels of neurotoxic anatoxin-A and also the liver toxin microcystin (Bouma-Gregson 2014). The former was prevalent in the middle reaches of the South Fork Eel and the latter was found in the upper South Fork and upper Eel above Outlet Creek. Absence of cyanotoxins at Fernbridge on the lower main Eel River suggests that these compounds break down quickly in transit. Peaks in cyanotoxins occurred from early July to mid-August and varied by site, with measurable levels lingering into September. However, there were no human or animal health effects from algal toxins recorded in 2013.

Background

The Eel River recovery Project's (ERRP) citizen water temperature and flow monitoring project is in response to community needs identified in September 2011 seminal scoping meetings (Higgins 2011) and in subsequent ERRP Action Plans (Smalley & Higgins 2011, Higgins 2012, 2014a). Toxic blue-green algae or cyanobacteria, which is now commonly present in the margins of the lower Eel River, South Fork Eel, and Van Duzen River, is also a major focus of study because it is known to cause dog fatalities and to pose a risk to human health (Hill 2010, Puschner et al. 2008). Long time Eel River residents are also concerned about flow depletion in the watershed as a result of marijuana cultivation after the passage of Proposition 215. Most watershed residents are not trained scientists, so they value the opportunity to assist in scientific inquiry to see if they can verify their observations, which are otherwise treated as "anecdotal" by scientists and agency staff.

ERRP monitoring is aimed at testing two hypotheses:

1) Cyanobacteria blooms are driven by reduced flow and increased nutrient pollution and would not flourish, if the Eel River were closer to its historic range of ecological variability.

2) Stream flow has diminished as a result of increased agricultural diversions and domestic water use since the passage of Prop 215 in 1996.

ERRP's objective is to provide scientific data that documents conditions and trends in the hope that it will provide a foundation for understanding and trust, and help the community get focused on solutions instead of arguing over whether there is a problem.

Water temperature data collected by Kubicek (1977) and the Humboldt County Resource Conservation District (Friedrichsen 1998, HCRCD 2003) from tributaries and mainstem reaches throughout the Eel River watershed can serve as a baseline for gauging trends. Kubicek (1977) deployed 30 temperature recorders in 1973. In1996 the HCRCD collected or acquired data from 216 locations and expanded to 227 locations in 1997. The HCRCD (2003) continued to collect extensive water temperature data from 1999 to 2003 (Attachment #2). ERRP intends to use trend data and new water temperature data collected in 2014 and future years as an indicator of flow depletion, since the volume and transit time of water is reflected in temperature. The desiccation of Eel River tributaries is not subtle in many cases, however, and photopoints with known GPS locations serve as evidence of flow depletion without temperature analysis.

Variability of tributary flow was one factor influencing viability of summer rearing habitat for salmonids, but whether pools were cool and stratified was another. Therefore, pool temperatures were measured in streams with very low surface flow or ones that had lost connectivity. There is also an on-going effort by ERRP to identify refugia that support juvenile salmonid rearing. Although ERRP citizen monitoring of toxic algae began in 2012 (Higgins 2013a), it expanded greatly in 2013 as a result of a partnership with U.C. Berkeley (Bouma-Gregson 2014).

Data produced by ERRP citizen monitoring is also made available to agencies and Tribes so it can be used for all types of trend monitoring (i.e. TMDL implementation) and to help assess effectiveness of restoration.

Methods

In order to collect water temperature data that can reliably be used for trend monitoring and for comparisons that detect changes in flow over time, data collection must strictly follow established protocols (Lewis 1999, Friedrichsen 1998). ERRP deployed 56 water temperature probes in the summer and early fall of 2013. Problems that can arise in probe placement are described by Lewis et al. (2000) such as: 1) exposure of the sensor to the air, 2) improper calibration procedures, 3) improper placement of the sensor in the stream, 4) low battery, 5) inherent malfunctions in the automated probe, and 6) vandalism. Although vandalism is not suspected, four gauges were lost as a result of being improperly secured.

Calibration of Probes: Onset Optic Pro gauges (Figure 1A) were calibrated by Rich Fadness of the NCRWQCB following protocols and he also replaced batteries to insure reliability. ERRP used a National Institute of Standards and Technology (NIST) traceable thermometer and an ice bath to calibrate the older style HoboTemp gauges (Figure 1B) in accordance with Lewis (1999) and replaced batteries as necessary. The University of California Berkeley uses Thermochron iButtons, which are also calibrated with an NIST thermometer. Data from the USGS Elder Creek temperature gauge are also used for analysis and their protocols for quality assurance and quality control are on their website (http://waterdata.usgs.gov/ca/nwis/current/?type=quality).

A) Onset Instrument Optic Pro

B) Onset Hobotemp

C) Thermochron iButton

Figure 1. Automated probe types used in the 2012 ERRP and UCB water temperature monitoring project.

Time Interval for Data Recording: Although the minimum sampling interval recommended by Lewis (1999) is 1.6 hours (96 minutes), ERRP and UCB probes were set to record water temperatures every 30 minutes to enable collection of more detailed data.

Placement of Probes: In the field, sensors were placed in flowing water in locations where the water was well mixed as recommended by Lewis et al. (2000). Exposure of the probe to direct sunlight was prevented by placing the probe where there was riparian shade or an under-cut bank, or by covering it with cobbles. ERRP Volunteer Coordinator Patrick Higgins placed most probes, although volunteers were allowed to place some additional probes after being trained. Where possible, probes were placed at locations previously surveyed (Friedrichsen 1998, HCRCD 2003) to allow for trend monitoring. Plastic twist ties were used to secure gauges to cobbles because of problems with wire breaking or dissolving in 2012 (Higgins 2013a).

Photo Documentation: Each location where a temperature gauge was placed was also photo-documented in an upstream and downstream direction. Photos were also taken where stream reaches went dry in locations formerly known to be perennial. ERRP photopoints are located on properties where land owner permission had been granted or on public easements, such as bridges and stream crossing throughout the watershed. ERRP started the "Is It Swimmable" program in 2013 and photographs were also taken at various popular swimming beaches during summer.

Mid-Season Probe Checks: Due to the limited budget in 2013, probes were not checked during mid-field season as recommended by Lewis (1999). This resulted in loss of data at locations where probes were lost.

Water Temperature Tolerance References for Fish: Water temperature and salmonid tolerances and preferences are well studied. McCullough (1999) is the primary literature source cited for reference values in analysis below, although Welsh et al. (2001) provides the best information for coho salmon temperature tolerance for the northern California region. Pikeminnow water temperature preferences and tolerance are from Bell (1991).

Temperature Analysis: Water temperature data were analyzed using standard methods with the most powerful summary statistic being the floating weekly average water temperature (McCullough 1999, Lewis et al. 2000), which is calculated by averaging the previous three daily average water temperatures with the four days following. The maximum floating weekly average water temperature (MWAT) for the entire year is used to compare recent data with previously collected data at the same locations to assess trends.

Results

Water Temperature: ERRP deployed 56 water temperature probes in the summer and early fall of 2013 and five gauges were lost and 52 data sets collected. Eight stream monitoring sites went dry and temperature data from those locations are useful for determining the date of desiccation. Data were also shared by Keith Bouma-Gregson (2014) of the University of California from seven locations throughout the Eel River watershed where he studied cyanobacteria. A map of all gauge locations is below as Figure 1 and a complete listing of 2013 results, including MWATs, are in Attachment 1.

Maximum floating weekly average water temperatures measured by ERRP in the Eel River basin in 2013 ranged from a high of 82.3^{o} F on the main Eel River above Outlet Creek to a low of 59^{o} F in Hely Creek, a recovering Van Duzen River tributary. The lower Black Butte River (80.1^{o} F), Middle Fork Eel River below Williams Creek (79.4^{o} F), main Eel at Alderpoint (78.1 ^{o} F), and South Fork Eel River at Phillipsville (77.5 ^{o} F) were the next warmest locations, respectively. Maximum floating average temperatures of tributaries were topped by lower Williams Creek (76.7^{o} F, in the Middle Fork drainage, followed by North Fork tributary Hulls Creek (75 ^{o} F).

Comparison of floating weekly averages of the South Fork Eel River in 2013 (Figure 2) show the mainstem above Branscomb Road as the coolest location with sites warming progressively in a downstream direction. The highest floating weekly average temperature was at Phillipsville, while the South Fork at Richardson's Grove and Standish Hickey were next warmest at 76^{o} F and 75.9^{o} F, respectively.

The Van Duzen River did not warm to the same degree as the South Fork Eel (Figure 3) and the maximum mainstem temperature was 74.2^{o} F at Swimmers Delight. The minimum main river MWAT was in the headwaters just below the convergence of the West Fork above Dinsmore (62^{o} F). Van Duzen temperatures remained moderate at South Trinity High School (69.3^{o} F), but were in highly stressful range for salmonids at Bridgeville (73.4^{o} F) and Rainbow Bridge (73.6^{o} F). .

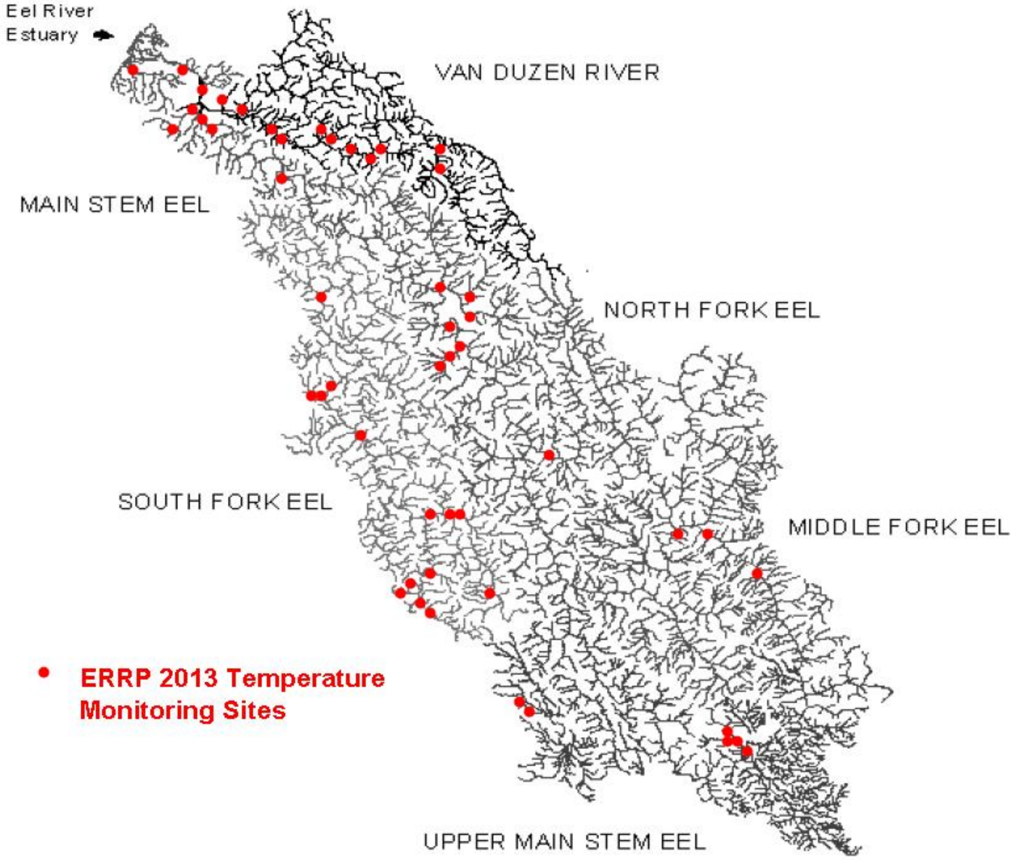

Figure 1. Locations where automated temperature probes were placed in 2013.

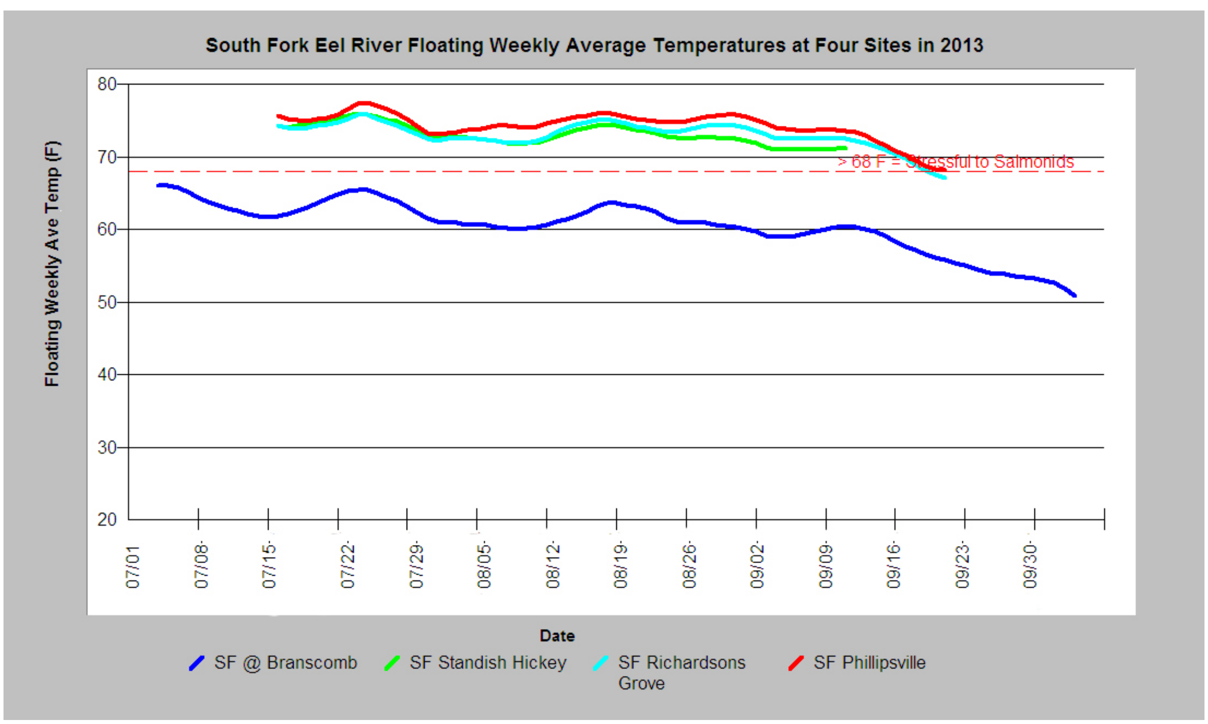

Figure 2. Floating weekly average water temperature of the South Fork Eel River in 2013 at four locations. Reference from McCullough (1999).

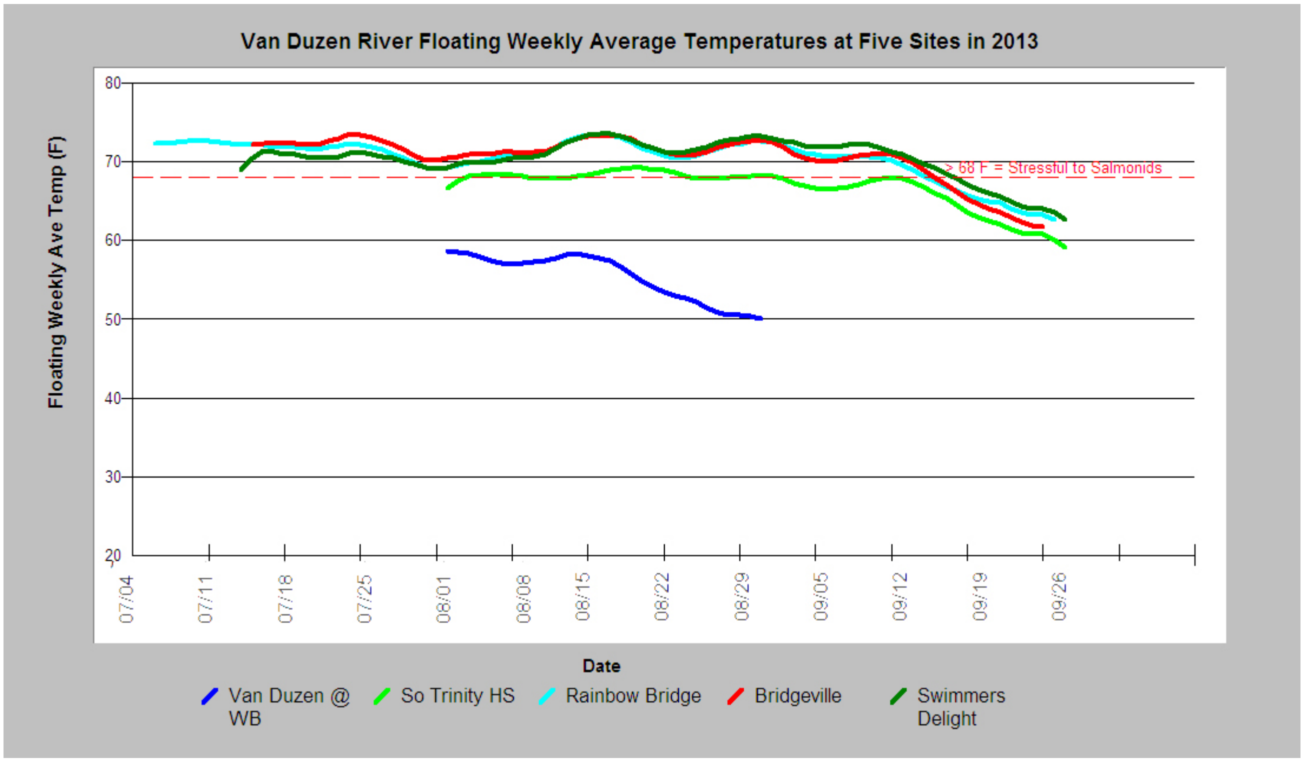

Figure 3. Floating weekly average water temperature of the mainstem Van Duzen River in 2013. So Trinity HS = Southern Trinity High School (upper Van Duzen above Dinsmore). Reference from McCullough (1999).

Van Duzen River tributaries were also on the cooler end of the temperature spectrum (Figure 4) with MWATs ranging from 59° F at Hely Creek to 66.9° F for major tributary Yager Creek. Other Eel tributaries with relatively cold temperatures include Jack of Hearts Creek and Redwood Creek (upper SF), Francis and Bear Creeks (lower Eel), and Sherwood Creek that flows into Outlet Creek in the upper Eel River basin. Pool stratification was variable and is discussed below.

Flow Monitoring: ERRP observed many Eel River tributaries losing surface flow at different times and locations throughout the watershed (Table 1). The limited budget and field schedule did not allow for continual field visits to verify when streams were dewatered, rather the dates are when ERRP confirmed that streams were dry and photo documentation occurred. In some instances where automated probes were installed prior to stream desiccation, dramatic increases in temperature extremes indicated when stream flow was lost.

Some streams became dewatered in only lower reaches where they are aggraded and form deltas through which surface flow becomes submerged. Lower reaches of Chemise, Cummings, Chadd, Bloody Run creeks and the East Brach South Fork are all are known to flow intermittently even in non-drought years. However, upstream reaches within some of these watersheds may maintain optimal conditions for salmonids (i.e. East Branch South Fork). Other streams are being dewatered in most of their reaches for extended periods of time, such as Ten Mile Creek (Figure5), Outlet Creek, and Tomki Creek. ERRP was able to verify that Ten Mile Creek went dry in late July 2013, which is nearly a month earlier than in 2012. The same was likely true of Outlet and Tomki creeks as well, but early season reconnaissance was not possible. Tomki was documented to be dry in early June 2012 (Higgins 2013a) and was dry after light fall rains in December 2013 (Figure 6), indicating that it is remained dry for extended periods even during the winter.

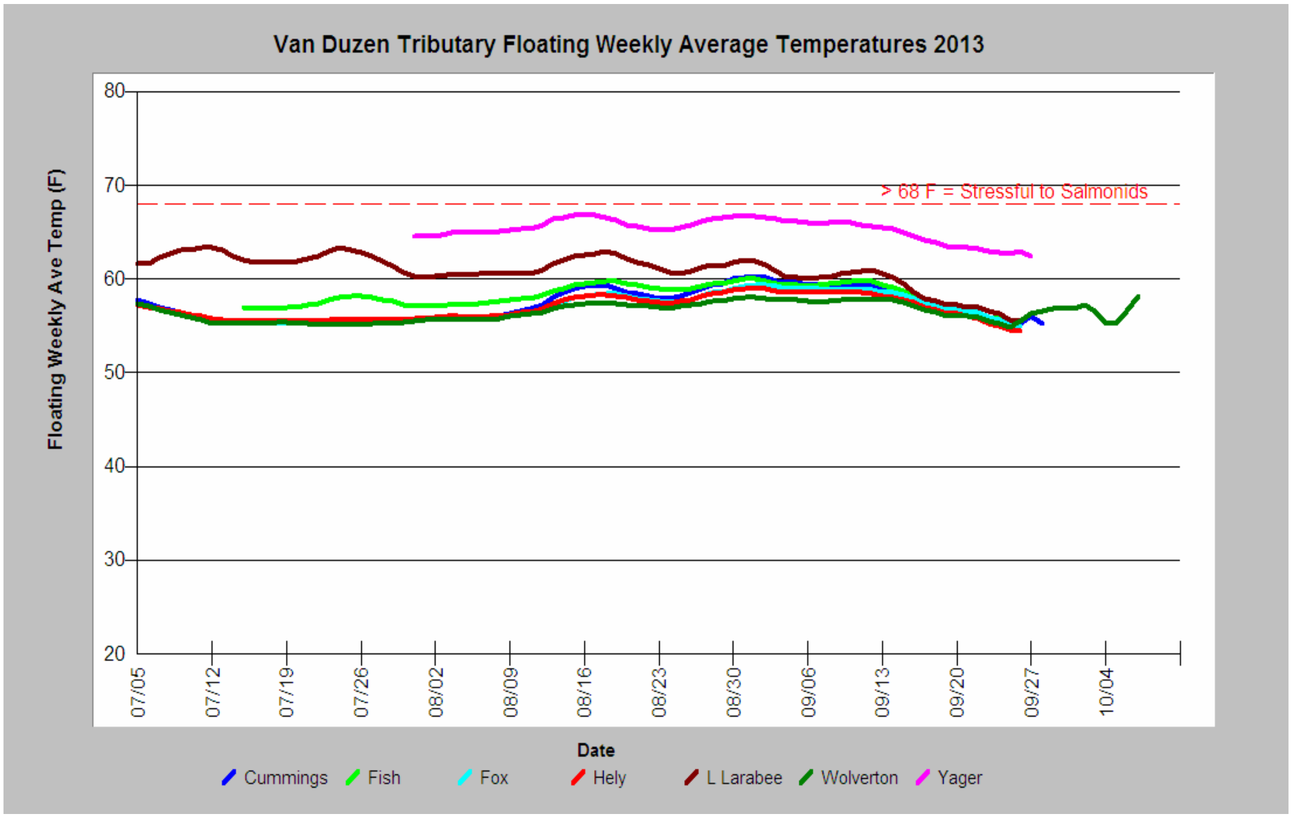

Figure 4. Floating weekly average water temperature of the Van Duzen River tributaries in 2013 showed that most were in the optimal range for salmonids. Reference from McCullough (1999).

Table 1. Stream reaches confirmed as dewatered in 2013 by ERRP, sub-basin locations, date of desiccation and whether a probe was installed.

Data Collector	Creek	Sub-Basin	Date Dry	Probe
Higgins	Soda	UE	8/29/2013	Y
Higgins	Pan	UE	7/27/2013	Y
Higgins	Welch	UE	9/16/2013	Y
Higgins	Outlet	UE/Outlet	9/17/2013	N
Higgins	Bloody Run	UE/Outlet	9/17/13	N
Higgins	Tomki	UE	12/18/2013	N
Mitchell	Streeter	USF/Ten Mile	7/24/2013	Y
Higgins	Upper Ten Mile	USF/Ten Mile	8/15/2013	Y
Higgins	Ten Mile	USF/Ten Mile	7/24/2013	N
Higgins	Rattlesnake	SF	9/17/2013	N
Higgins/Grover	Redwood	SF/Mid	9/6/2013	Y
Higgins	EBSF (Lower)	SF/Mid	8/7/2013	N
Higgins	Fish	SF/Mid	8/7/2013	N
Higgins	Grizzly	VD	9/6/2013	Y
Higgins	Lower Van Duzen	VD	9/15/2013	N
Higgins	Cummings	VD	9/1/2013	Y
Higgins/Weitzman	Salt	NF	10/8/2013	N
Higgins/Weitzman	Hulls Valley Cr	NF	7/3/2013	N
Walker/Higgins	Chemise	ME	7/15/201	Y
Higgins	Chadd	ME	9/7/13	N

a)

b)

Figure 5. At left is Ten Mile Creek drying up on 7/27/13 at the Black Oak Ranch and above is a dead lamprey ammocetes larva that had been living in the cool sediment of the stream bed before desiccation.

Figure 6. Tomki Creek bed looking upstream at its convergence with Rocktree Creek on 12/18/13.

Redwood Creek, a South Fork Eel River tributary west of Redway, lost surface flow by the first week in September 2013 (Figure 7), which resulted in mortality of juvenile steelhead that had been inhabiting the creek. Although pools in lower Redwood Creek maintained water, not all appeared stratified and functional for salmonids, possibly as a result of excess sediment. The Salmonid Restoration Federation monitored flows in Redwood Creek and found that tributaries responded differently to fall and early winter rains (Bill Eastwood, personal communication).

a)

b)

Figure 7. At left Redwood Creek (l) and Seeley Creek (r) are dry above convergence pool. CDFW Redwood Creek steelhead mortalities (above). 9/7/13.

Soda Creek is one of only two anadromous fish bearing tributaries of the upper Eel River within the Potter Valley Project and joins the main Eel River approximately one mile below Scott Dam and Pillsbury Reservoir. It can be an important stream for steelhead spawning and rearing depending on the water year and flows (USFS 1994). Soda Creek is three miles long and is formed by the convergence of Panther and Welch creeks. Baseline data (Friedrichsen 1998) suggest that upper Soda Creek, Panther and Welch were functioning as a cold water refugia, although lower Soda Creek is known to go dry annually (USFS 1999). In 2013, Panther and Welch creeks both dewatered and upper Soda Creek became disconnected, although it supported steelhead juveniles in isolated pools. Since no data were collected during previous droughts, such as 1976-1977, it is not possible to know whether this is a natural fluctuation or due to increased water extraction.

Water Quality Observations, Recreation, and Toxic Algae Development: ERRP published reports on water quality and algae blooms, including photo-documentation (Figure 8), to alert the public about deteriorating conditions (Higgins 2013b, 2013c, 2013d) so they would avoid recreating in areas with visible algal mats or scums. On July 23, the Humboldt County Department of Health and Human Services (2013) issued a public health advisory for potential exposure to toxic blue-green algae, including the South Fork Eel River and Van Duzen River. The public health warning is part of a State wide strategy to help cope with this emerging problem (SWRCB, CDPH & OEHHA 2010). No pet mortalities or human health effects were reported for the Eel River in 2013.

Figure 8. Looking up the South Fork Eel River at Dyerville with profuse algae growth in the margins. ERRP volunteer Sunshine Johnston is at right in the distance. August 7, 2013.

UC Berkeley Ph.D. student Keith Bouma-Gregson (2014) measured blue-green algae toxins at seven locations throughout the Eel River basin with assistance from ERRP volunteers. Resin passive monitoring devices, known as Solid Phase Adsorption Toxin Tracking (SPATT) samplers (Kudela 2011), were used to adsorb algal toxins. Weekly SPATT samples allowed assessment of trends from July through September (Figure 8). The highest concentration of cyanotoxins occurred at Phillipsville on the South Fork Eel River and the substance was anatoxin-A, which is a neurotoxin known to be produced by *Anabaena* (Figure 9) and *Phormidium* (Figure 10).

An unexpected finding was the occurrence of toxins indicative of *Microcystis aeruginosa* in the upper South Fork Eel River on the UC Angelo Reserve and on the upper Eel River above Outlet Creek. Microcystis is known to dominate Klamath River reservoirs and to occur in Big Lagoon in northern Humboldt County, but was not known in the Eel River basin prior to the UC study.

While the cyanotoxin microcystin reached high levels in early July on the upper South Fork, they were not significant on the upper Eel until early August. Anatoxin-A levels at Phillipsville peaked in the first week of August, but showed a significant secondary peak in the third week of August. South Fork Eel River at Standish Hickey anatoxin-A levels peaked in the later half of July and then declined thereafter. The South Fork monitoring station above Richardson's Grove peaked in mid-August, but still had measurable levels in September. No cyanotoxins were measured in the lower Eel River and levels measured in the Van Duzen River in 2013 were also very low. See full report on-line at www.eelriverrecovery.org.

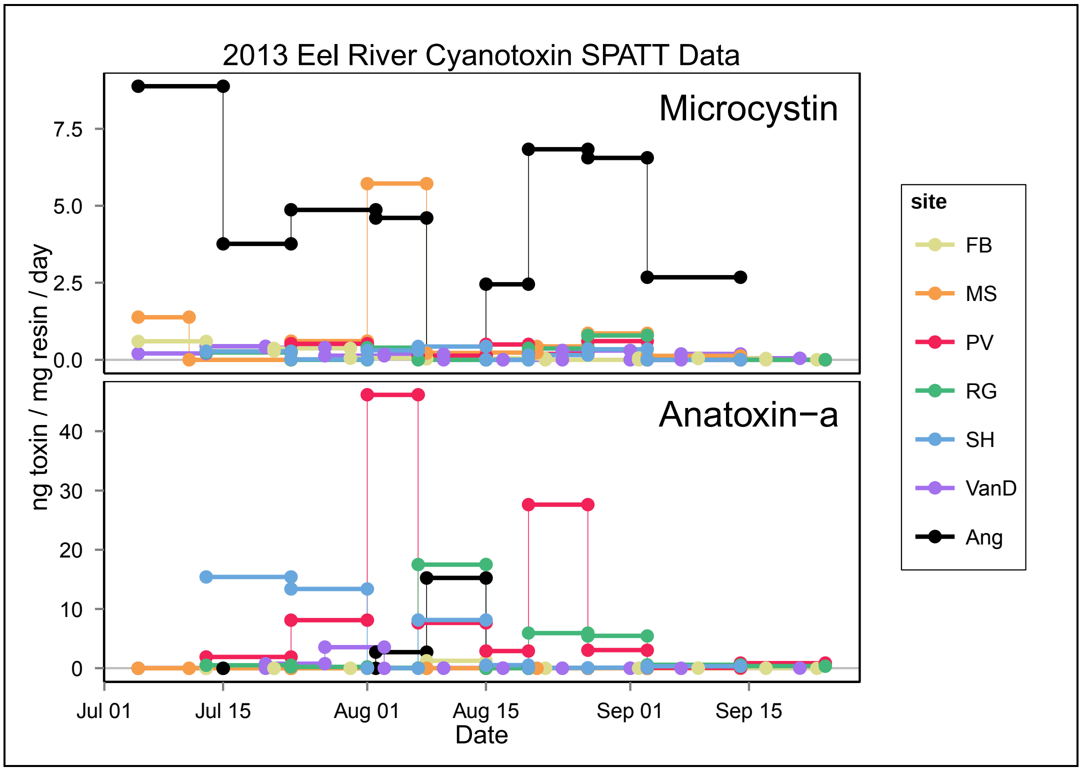

Figure 9. Cyanotoxin concentration data from SPATT samplers with each horizontal bold line between each pair of points representing one sampler. Chart and data from Bouma-Gregson (2014). FB = Eel @ Fernbridge, MS= Main Eel @ Outlet, PV = SF @ Phillipsville, RG = SF @ Richardson's Grove, SH = SF @ Standish Hickey, VanD = Van Duzen @ Swimmers Delight and Ang = SF @ Angelo Reserve.

a)

b)

Figure 10. Above is a photo of Anabaena (dark green) growing in filaments that float to form "fingers" at Phillipsville on the South Fork Eel River. (Blue bar is 15cm or 6" long). At right near the same location is floating algae comprised of mostly cyanobacteria detached from upstream sites.

Figure 11. Phormidium mats on the stream bottom near Phillipsville. Note the orange and brown coloration. From Bouma-Gregson (2014).

Discussion

Impacts of Flow on Temperature: The relationship between flow volume and water temperature is well established (Poole and Berman 2000), so it is not surprising that very low flows in the summer and early fall of 2013 lead to some of the highest water temperatures on record. Flow data for all Eel River flow gauges from late May to late September are displayed as Figure 12. After declining sharply in late June, tributary flow increased and the main Eel flow at Scotia crested at 800 cfs on July 1. This slowed stream desiccation and warming in some but not all tributaries and reaches, as rainfall was not uniform throughout the basin. No such rain event occurred in 2012 (Figure 13) and; consequently, flows were somewhat equivalent for much of summer in 2012 and 2013. Flow of the Eel River at Scotia dropped under 100 cfs on July 29, which promoted warming to above suitability for salmonids and into the optimal range for Sacramento pikeminnow even in the lower Eel River. Large pikeminnow inhabited the Eel River reach below the Van Duzen River in 2013. They were rarely observed there from 2010 to 2012 (Higgins 2011, Higgins 2013b). By September 19, flows were 52 cfs on the mainstem at Scotia, 23 cfs at Ft Seward, 11 cfs in the lower Middle Fork, 4 cfs in the Van Duzen at Bridgeville, 18 cfs in the South Fork at Miranda, and 20 cfs on the upper main Eel at Cape Horn Dam below the Potter Valley Project, and the river was stagnating.

Comparison of 2012 and 2013 Temperatures: A summary of MWAT comparisons at ERRP monitored sites measured in both 2012 and 2013 is displayed as Figure 14 and complete tabular results for 2013 are in Attachment 1. Data shows a pattern of increase at almost all locations between 2012 and 2013. However, Sherwood Creek (Outlet/Middle Eel) water temperatures were almost identical in both years, likely because probe locations are near groundwater sources. Also, warm mainstem locations, such as the South Fork Eel at Phillipsville, Middle Fork Eel below Williams Creek, Van Duzen at Rainbow Bridge, and lower Yager Creek above the Van Duzen all had nearly identical temperatures between the two years. As noted above, very low flows and lack of rain events during summer in 2012 may explain similar mainstem MWATs.

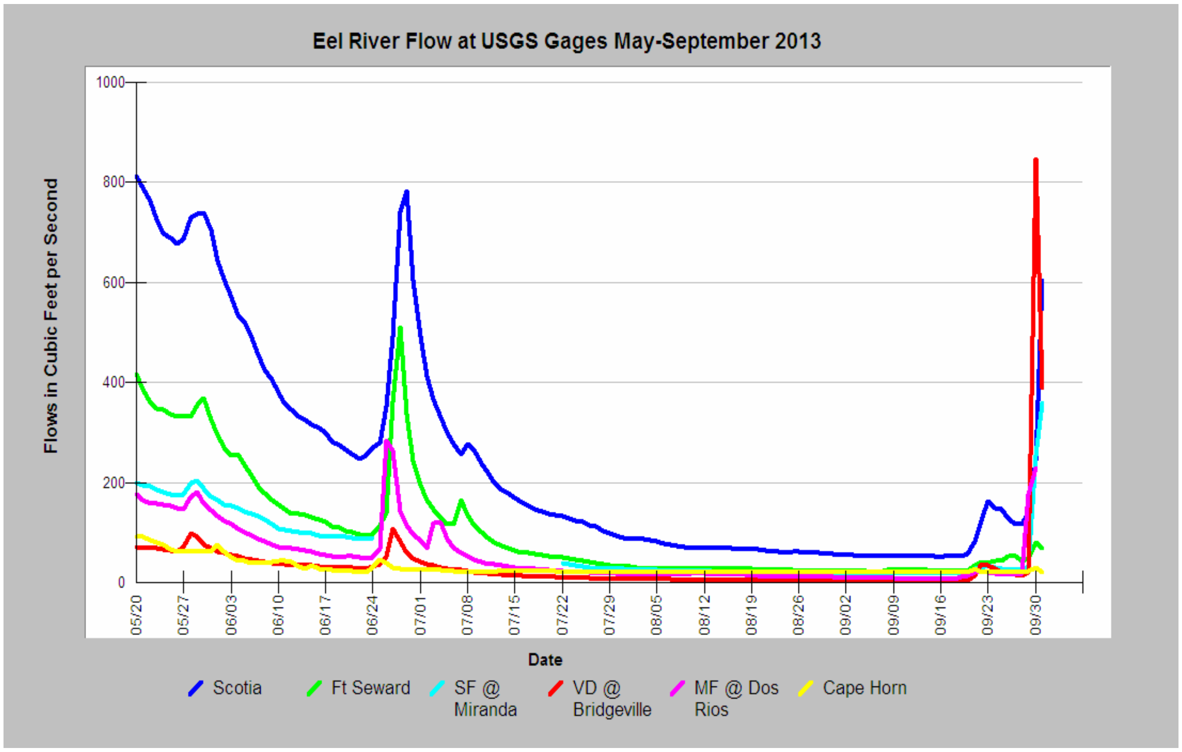

Figure 12. Flow gauge data from USGS gauges at Scotia (lower Eel), Ft Seward (middle Eel), Van Duzen at Bridgeville, Middle Fork at Dos Rios and the South Fork at Miranda. Cape Horn flows from CDEC.

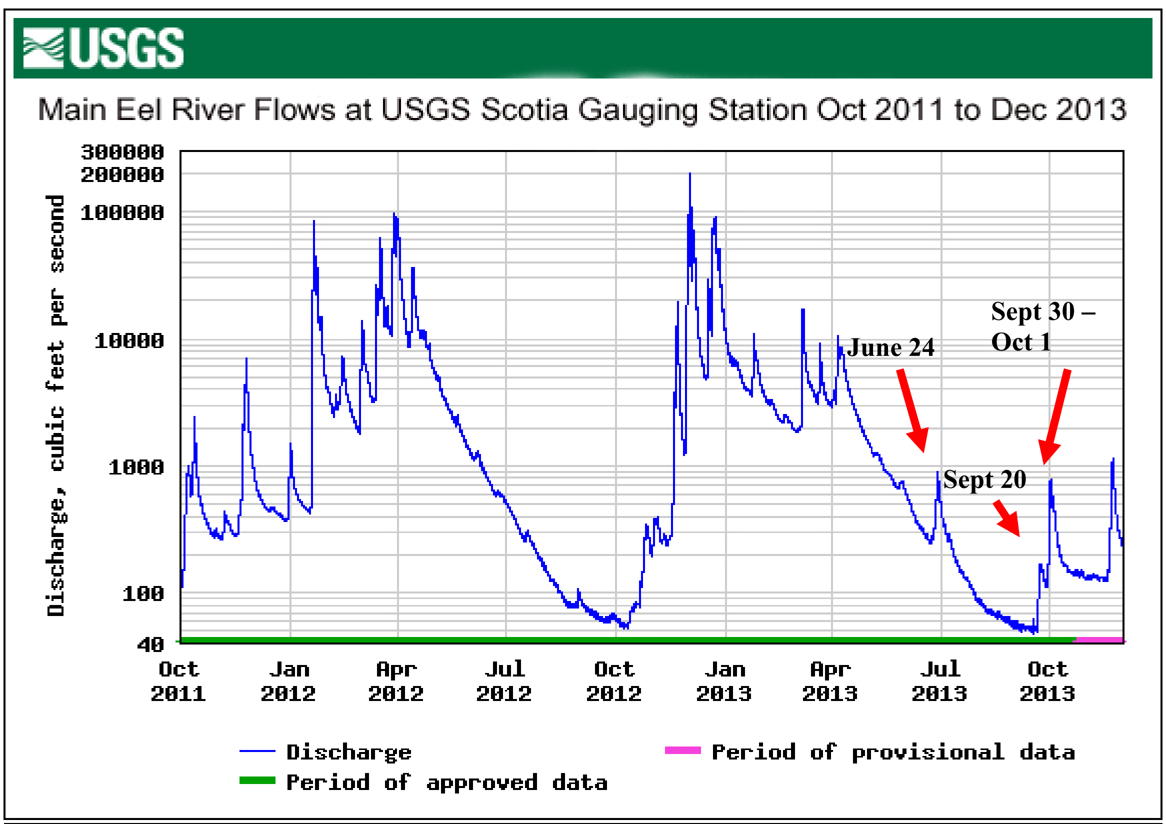

Figure 13. Eel River flow data at Scotia from Oct 2011 to Dec 2013. Unusual rain events in 2013 helped maintain flow, cooled river and tributaries, and allowed fish passage (red arrows). Data from USGS.

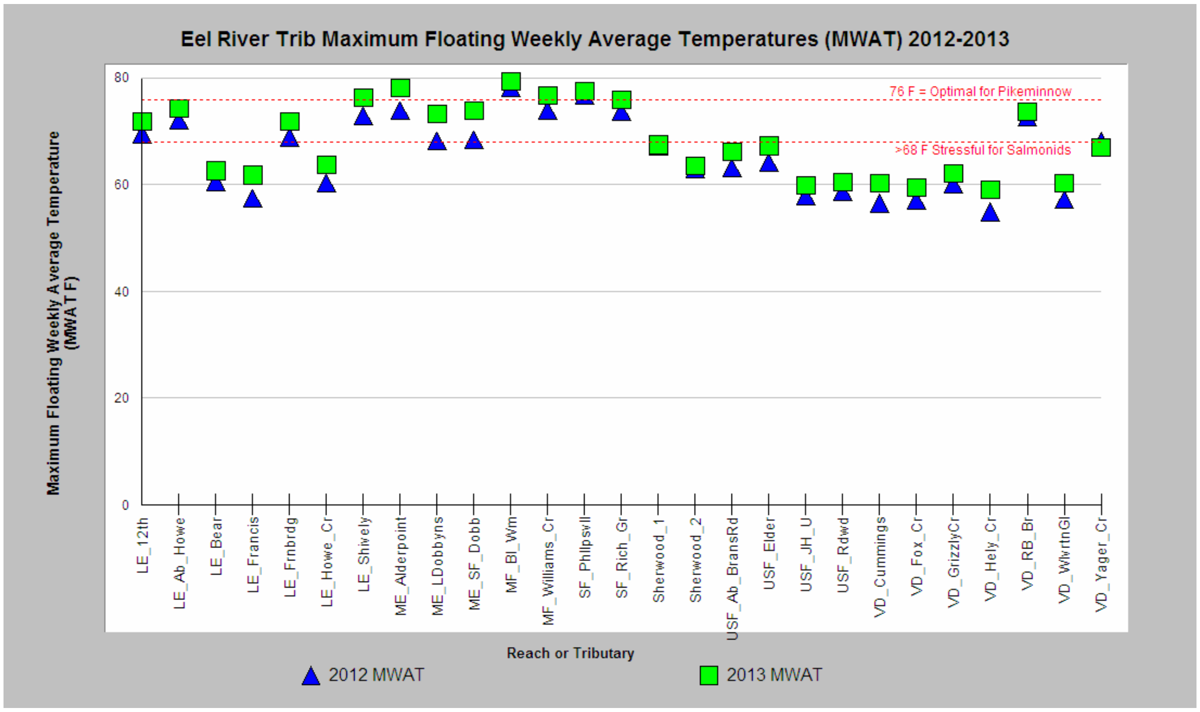

Figure 14. Maximum floating weekly average water temperatures at locations where ERRP collected data in 2012 and 2013. LE = Lower Eel, ME = Middle Eel (Dos Rios to Dyerville), SF = South Fork, USF – Upper South Fork (above Ten Mile Creek), and VD = Van Duzen sub-basin. Temperature references are from McCullough (1999) and Bell (1991).

USGS water temperature data for Elder Creek show that the floating weekly average in 2013 was higher than in 2012 (Figure 15), but that the increase in this undisturbed watershed was modest.

Longer Term Temperature Trend Comparisons: Although water temperatures in 2013 were warmer than in 2012, several values remained down from previous highs recorded by the Humboldt County RCD (Friedrichsen 1998)(Figure 16). Tributaries of the lower Eel River and Van Duzen River had MWAT values still substantially below 1996 and 1997 values, including Bear Creek, Howe Creek, Cummings Creek, Hely Creek and lower Yager Creek. This shows recovery from past sediment impacts (Higgins 2013a) with cooling trends still apparent despite the drought.

Lower River Tributaries Experiencing Set Backs: Late November and early December 2012 rain fall was intense and appears to have triggered sediment remobilization, or new sediment supply, leading to channel aggradation in the lower reaches of Jordan Creek (Figure 17), Greenlaw, and Price creeks. Probes placed in Price Creek were lost due to sediment transport during small, early fall rain events (David Sopjes personal communication). Channel changes are likely causing a slowing of temperature recovery, because aggradation is usually associated with warming, but a more significant effect may be the loss of pool depth and frequency (see Recommendations).

Suitability of the Eel River for Supporting Fish Life in 2013: The most clear disruption of juvenile salmonid rearing capacity was major tributary de-watering, such as in Redwood, Ten Mile, Outlet, and Tomki creeks as discussed above. In the former, as flows diminished and pools became isolated, juvenile steelhead expired before juvenile coho (Scott Bauer personal communication). Coho had hatched earlier and attained larger size and could thus better survive food depravation.

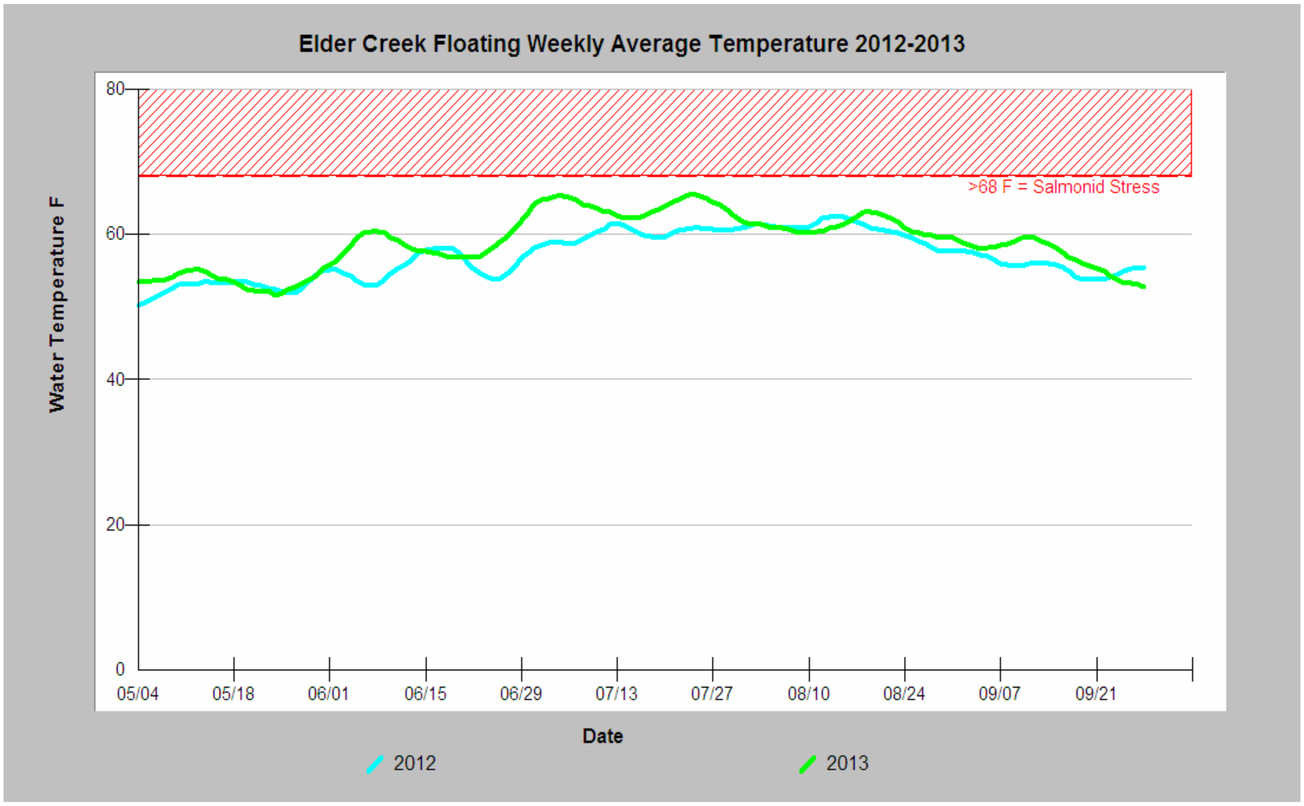

Figure 15. Elder Creek floating weekly average water temperature comparison contrasting 2012 and 2013 data, which shows an increase in the latter year. Data from USGS and references is from McCullough (1999).

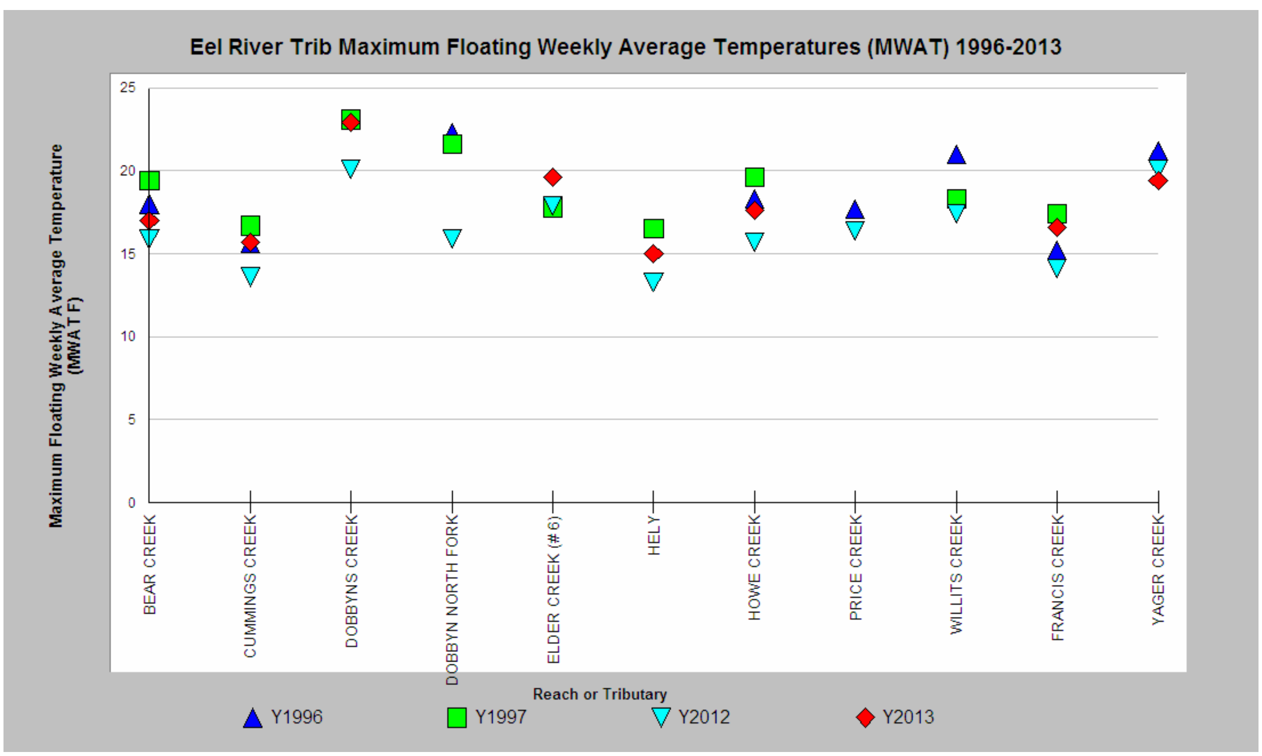

Figure 16. MWAT comparison of recent ERRP data (2012-2013) and Humboldt RCD data (1996-1997) show temperature recovery trends in 2013 at several locations versus those collected earlier despite the drought.

Figure 17. The bed of Jordan Creek is shown here looking downstream from the Highway 101 Bridge with the stream barely flowing on the surface despite rain in the preceding days. November 27, 2013.

Refugia Maintain Function in Drought: At the other end of the spectrum with regard to salmonid rearing capacity were streams like Steelhead Creek near Alderpoint, the upper East Branch South Fork Eel, the upper South Fork Eel, and Root Creek in the Van Duzen River watershed. Steelhead Creek (Figure 18) had a very high standing crop of juvenile steelhead of varying age classes, which suggests carrying capacity was not diminished due to the drought. The water temperature in upper Steelhead Creek on September 9 at the point of entry was 66^{o} F and the temperature declined to 64^{o} F less than a half mile downstream, despite the fact that there had been no tributary inflow. This suggests springs and groundwater or hyporheic connections are helping maintain optimal water temperatures for steelhead similar to the findings of Salve et al. (2014). The East Branch South Fork had a similar water temperature regime (61.4^{o} – 64.3^{o} F) and level of juvenile steelhead abundance and age structure when visited on September 16 on an ERRP field trip with Bureau of Land Management (BLM) staff. While the ambient water temperature of the upper South Fork on the UC Angelo Reserve was somewhat warm for optimal salmonid growth, pools there were stratified at depth, and were harboring two year old steelhead trout.

Coho Salmon Refugia: Juvenile coho salmon standing crops in Root Creek in the Van Duzen were found to be high during a cooperative ERRP and Humboldt Redwood Company survey on August 5, 2013 (Figure 19). The watershed is very steep and the stream has the benefit of topographic shading in much of its length and appears to be in recovery with respect to water temperature, similar to other HRC Van Duzen tributaries as described above. However, pool frequency and depth remain low and addition of large wood jams could help improve carrying capacity and the ability of Root Creek to produce yearling coho (see Recommendations).

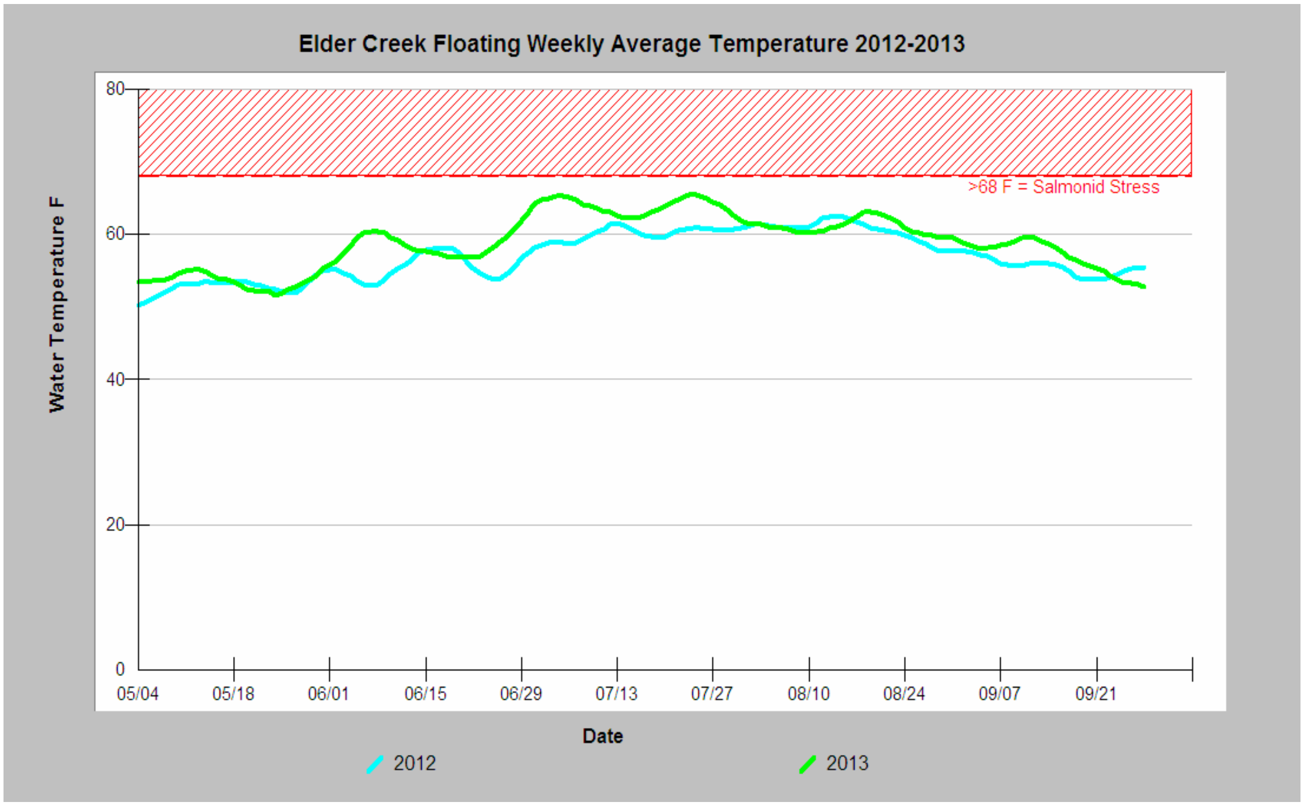

Figure 15. Elder Creek floating weekly average water temperature comparison contrasting 2012 and 2013 data, which shows an increase in the latter year. Data from USGS and references is from McCullough (1999).

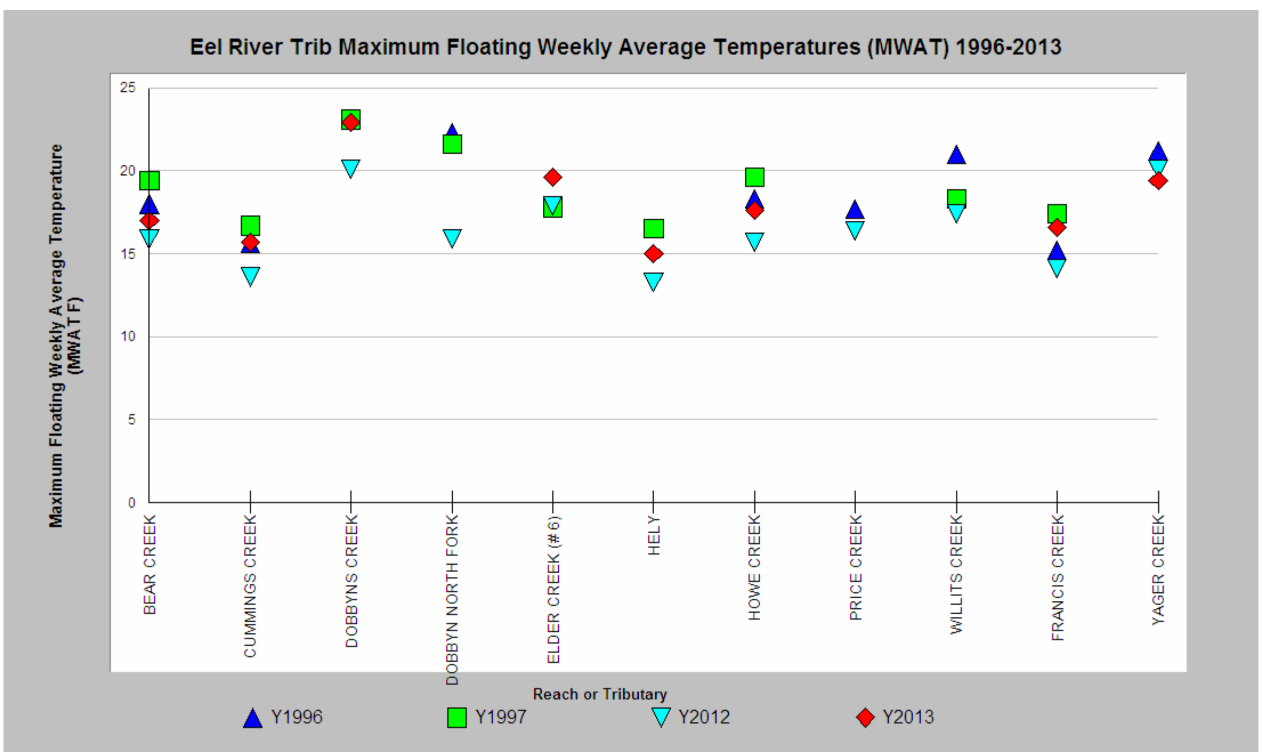

Figure 16. MWAT comparison of recent ERRP data (2012-2013) and Humboldt RCD data (1996-1997) show temperature recovery trends in 2013 at several locations versus those collected earlier despite the drought.

a)

b)

Figure 20. At left ERRP volunteer Proud Savage takes Chemise Creek temperature. Above a young of the year steelhead sits in the middle of diatom covered Cladophora in the pool below. 9/17/13..

Lower Eel Temperature, Flow and Effect on Fall Chinook: Water temperatures in the lower Eel River were also much warmer in 2013 than in 2012 and likely limited migration of Chinook salmon and steelhead half pounders and adults because the floating weekly average remained in the stressful range (Figure 21). Also, lower Eel River pools lacked depth because of sediment deposition in late 2012 (Higgins 2014a) and no stratification was apparent, especially in shallow pools like the Worswick above Fernbridge. As flows dropped in late September, there was no adult holding capacity in the Creamery Pool or Worswick Pool and shallow riffles posed a threat to survival of any Chinook salmon attempting to move up from the estuary (Figure 22). Had early fall rains not occurred, Chinook salmon passage upstream would not have been possible, with potential substantial mortality resulting (Higgins 2011).

Native Warmwater Fishes: On the Black Butte River, a major Middle Fork Eel tributary, water temperatures had already attained lethal levels for juvenile steelhead on July 2. However, a large number of juvenile Sacramento sucker juveniles were present there in mid-September 2013 when temperature probes were retrieved (Figure 23). This species has been depleted by pikeminnow predation and low, warm flows in 2013 appeared to be producing a successful year class. Thousands of sucker juveniles were also spotted in late September during an ERRP upper Van Duzen River reconnaissance dive at Southern Trinity High School above Dinsmore, another indication that this species is drought adapted (Figure 24).

Non-Native Warmwater Fishes: As Ten Mile Creek became disconnected, numerous green-eared sunfish spawned in the margins of isolated pools. Although warm water species escaping from ponds often wash downstream and perish when swept into the ocean, they may persist in stream environments, if there are several extremely dry years in a row. The non-native Sacramento pikeminnow is much better adapted to winter swift water flows and their population also likely increases in drier climatic periods that bring with them warmer temperature regimes. The migration of substantial numbers of large adults into the lower Eel River was opportunistic as waters warmed, but may also have been an instinctual response to diminished carrying capacity in upstream reaches due to the drought and the potential for flow disruption.

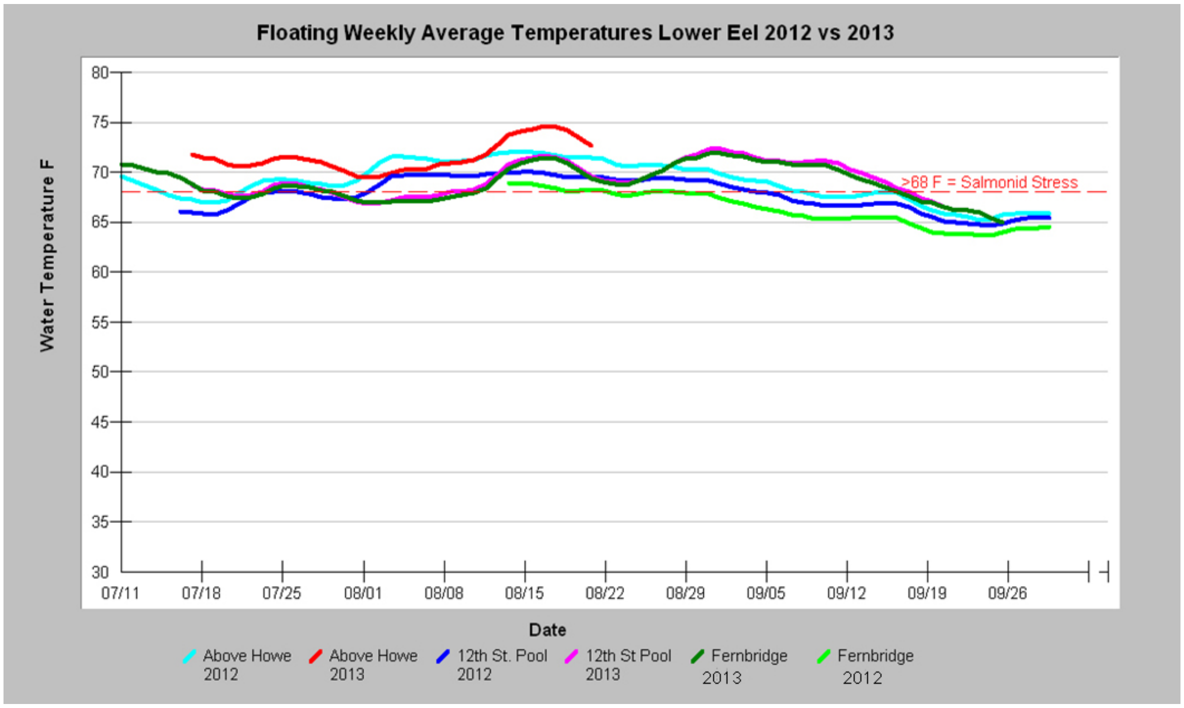

Figure 21. Lower Eel River floating weekly average water temperatures in 2012 and 2013 show much warmer temperatures in 2013 with temperatures in the stressful range for salmonids as far downstream as Fernbridge until the September 20 rain event. Data from ERRP.

Figure 22. Lower Eel River below Fernbridge on September 19, 2013 showing shallow, stagnant conditions with insufficient flows and depth for Chinook salmon passage.

a)

Figure 23. Above Sacramento sucker young of year feed in the lower Black Butte River, which is depicted at right. Note cottonwood starts establishing during the drought. 9/16/13.

b)

Riparian Recovery Allowed By Drought: Main river terraces throughout the Eel River basin are covered with willow, alder, and cottonwood seedlings because there have been no scouring flows since December 2012. Colonization of these terraces may lead to longer term recovery in sub-basins where sediment supply is moderate or low.

Figure 24. Juvenile suckers in a pool near Southern Trinity High School that was showing signs of stratification on the main Van Duzen River above Dinsmore. 9/18/13.

Observations on Algal Bloom Dynamics: Profuse beds of Cladophora, the beneficial green algae that is part of the food web supplying sustenance for juvenile salmonids, developed in early June in the upper South Fork Eel River (Dr. Mary Power, personal communication)(Figure 25). This bloom was not only earlier than normal but also more luxuriant. The June 24 rain event scoured the river bed and caused massive downstream transport of algal biomass, which represents a major nutrient pulse. The nutrients entrained cause what is known as nutrient spiraling, as algae blooms further downstream are subsequently triggered. By mid-July there were profuse blooms on the lower South Fork and lower main Eel River that were then followed by toxic algae development, with *Anabaena* often growing on top of decaying Cladophora (Bouma-Gregson 2014).

Preliminary findings of Bouma-Gregson (2014) indicate anatoxin –a is the most prevalent cyanotoxin present and it is produced by cyanobacteria of the genera *Anabaena* and *Phormidium*. These algae species grow on the stream substrate, with the former preferring quite waters and the latter flowing waters. Cyanobacteria of toxic and non-toxin strains can detach, float, and form rafts, which can pose public and animal health risk. The middle South Fork Eel had the highest levels of anatoxin-a with the greatest concentration values at Phillipsville and Standish Hickey. The suspended toxic cyanobacteria *Microcystis aeruginosa*, which produces liver toxins, is less prevalent and was only found in the upper Eel River and upper South Fork on the UC Angelo Reserve. Since *Microcystis* generally proliferates in still water, its occurrence in the upper South Fork is an anomaly requiring further study. No cyanotoxins of any kind were found at Fernbridge in the lower Eel River, which suggests that toxins are volatile and break down before arrival there.

Figure 23. South Fork Eel River at UC Angelo Reserve with a major Cladophora bed in early June 2014. Photo courtesy of Keith Bouma-Gregson.

Swimmer's Itch: Swimmers, waders, and bathers often contract swimmer's itch when there is a build up of algae in the margins of streams. Flatworm larvae or cercaria of the genus *Schistosomatidae* that reside there burrow into humans and cause the welts characteristic of swimmer's itch (Figure 26a). The cercaria does not survive or reproduce and the welts go away after four days to a week. ERRP has also found that suspended rafts of algae can harbor large numbers of cercaria (Figure 26b). In late July 2013, bathers at Big Bend Lodge on the South Fork Eel above South Leggett came down with mild cases of swimmer's itch, despite no algal growth along stream margins. Bites were small but numerous and all over the body of swimmers, not just on the lower legs. On July 31, a similar case of swimmer's itch was contracted while diving to observe pikeminnow in the pool under the Highway 1 Bridge at Leggett. Again there was no apparent sign of algae in edges of the stream. Therefore, it seems that catching swimmer's itch in very low flow years can happen without thick mats of algae in margins. Since the bites are smaller, it suggests a proliferation of smaller cercaria in the water column.

Loss of Probes: In 2012 (Higgins 2013a), ERRP secured probes to elongate cobbles from the gravel bar with wire, similar to past similar studies (Friedrichsen 1998). However, the quality of wire available seems to have deteriorated and wires dissolved over the course of the summer, resulting in the loss of several temperature probes. Multiple eight-inch long back zip ties fastened automated temperature probes to stream cobble in 2013. Although the instruments were bound tightly, the heating and cooling of the water evidently caused expansion and contraction that loosed the zip ties and resulted in the loss of four probes. New methods of fastening will be used in 2014.

a)

Figure 26. Photo above shows typical swimmer's itch resulting from walking through warm, algae beds in the margins of the lower Eel. At right is a case of swimmers itch contracted by swimming through a raft of suspended algae in the Weymouth Bluff Pool during a 9/28/12 ERRP Chinook salmon dive.

b)

Conclusion

Response of Eel River tributaries and reaches to the 2013 drought was variable depending on watershed condition and hydrology, level of sediment transport, and, of course, human water uses. The Eel River ecosystem co-evolved with a balanced flux of inputs of sediment, large wood and clean, cold water and all of these elements are out of balance.

Despite the drought, tributaries with relatively intact watersheds maintained ample flow and water temperatures cool enough for salmon and steelhead rearing. This suggests that undisturbed hillslope hydrology can supply cold water from deeper rock-water layers that have an inter-annual recharge cycle, similar to the findings of Salve et al. (2014). These intact areas within the Eel River watershed that provide refugia for salmonids need to be protected to prevent extinctions (Bradbury et al. 1995), but also because they are vital for protecting water supply for downstream human use and lower Eel River ecosystem function. ERRP will be working to prudently expand Wilderness Areas to achieve this end, but other measures can be taken to expand habitats functioning as refugia.

Watersheds with high levels of rural development tend to dewater and show variable response in terms of groundwater recharge and surface flow (Bill Eastwood personal communication). Factors known to have a major potential to alter watershed hydrology and water storage capacity are the extent of road networks (Jones and Grant 1996) and forest age (Stubblefield et al. 2012). If hillslope hydrology and the level of sediment were in its normal range of equilibrium, the 2013 drought would have had far less impact. While we work diligently to improve the efficiency of water use to help with water supply issues, we need also to be restoring the sponge-like capacity of forests and watersheds to enhance water supply in the long term.

Roads are impervious surfaces and disrupt groundwater recharge and are also capable of causing catastrophic erosion, if poorly constructed (Hagans et al. 1986). Citizens need to ally to reduce road densities and relocate as many roads as possible to ridges and away from unstable mid-slope locations and especially steep inner gorge areas. Gully erosion on Central Belt mélange prairies can also yield huge amounts of sediment and drop the water table on the hillslopes, thereby reducing water storage. Eel River residents can obtain resources to help with roads and erosion on their lands by working with the Mendocino and Humboldt County RCDs.

Even aged stands of timber resulting from post WWII logging are often dominated by hardwoods and are completely outside the range of historic variability. Recent findings in the nearby Mattole River basin suggest these young forests are using much more water than old growth forests (Stubblefield et al. 2012). Overstocking causes stressed trees that are subject to infestations by insects and pathogens, and will likely have repeated waves of catastrophic fire, if not managed. The Redwood Forest Foundation, Inc. (RFFI) represents a way to advance forest health while maintaining a supply of wood products and jobs. Residents can access fire prevention and fuels management grants as a step to rebuilding forest health, but to succeed there will have to be almost universal cooperation and support in the basin.

Water conservation efforts are already underway in the Eel River with a focus on Redwood Creek lead by the Salmonid Restoration Federation (Camp-Shremmer 2014). Hopefully widespread implementation of water conservation and better coordination of seasonal use there will help maintain surface flows for salmonids in the future, even in years of short supply. Private citizens throughout the watershed are making huge investments in water storage out of necessity during the drought, but also due to concern about the health of the Eel River. A large coming challenge will be to get coordinated use and early season withdrawal so that Eel River tributaries can benefit similar to the upper Mattole River, where Sanctuary Forest has won community cooperation (Camp-Shremmer 2014). Ten Mile Creek will be an ERRP focus for flow restoration beginning in 2014 because it has the most restoration potential using the Bradley et al. (1995) framework: 1) maintains native aquatic species diversity, 2) is adjacent to the last coho salmon refugia in the Eel River basin and the region, and 3) its bed form would create ideal salmonid habitat, if perennial flow were re-established.

The development of toxic blue-green algae blooms is an indicator that the Eel River is trending toward an ecological tipping point. ERRP and UC Berkeley are working together to understand the nature and timing of blooms and to help basin residents, small water districts, and counties to minimize public health risk in 2014. In the longer term, baseline data UCB is collecting can be used to detect whether nutrient pollution reduction and increased flows resulting from restoration efforts can reverse trends.

To some degree, the cold water supply of the Eel River is still there, but it is buried. Lower Eel River and Van Duzen River tributaries on HRC lands are cool enough for salmon and steelhead juvenile rearing, but too shallow. Restoring large wood jams could meter sediment to allow speedier recovery in downstream reaches and would help scour of deeper pools that stratify and are optimal for salmonids. On the mainstem lower Eel River above Fernbridge, bioengineering could be used to scour deep holding pools for Chinook salmon and to improve sediment routing to improve fish passage. Surface flows in the lower Van Duzen below Yager Creek could be also be restored using bioengineering, which would create perennial holding and rearing habitat in an area known to be historically very important (Williams et al. 2002, Higgins 2008).

In 2014, ERRP is scheduled to receive a State Water Resources Control Board contract to educate the community about the critical need to increase water flows and to reduce water pollution and to provide technical assistance to achieve that end. It will also allow expanded citizen-monitoring of water temperature and flow to better define the nature of flow depletion and pollution problems and to serve as trend data for testing whether conditions improve in response to this project and others.

Recommendations

Teach and train watershed residents on how to conserve water and prevent water pollution in 2014 with a special focus on restoring flows in Ten Mile Creek

Promote erosion control as an aspect of water quality and water supply protection and assist the Mendocino County RCD in finding partners for 319 H funding in the South Fork Eel River basin

Work in cooperation with UCB to monitor toxic algae at expanded number of locations, coordinate with county health departments, and provide technical assistance to small water districts

Increase the number of water temperature and flow monitoring sites in the Eel River basin

Fasten probes more securely using weights with hole punched so there is no opportunity for the gauges to wash downstream

Begin deployment of monitoring equipment as early in the 2014 field season as possible because of the chance of exceptionally warm stream temperatures early and also early onset of toxic algae blooms

Expand the "Is It Swimmable" page on the ERRP website and coordinate public postings through social media in summer 2014

Promote discussion of potential large wood projects to accelerate recovery of lower Eel River and Van Duzen River tributaries

Promote forest health to improve watershed hydrology

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Attachment #1- Probe numbers, location and MWAT in Fahrenheit and Celsius.

Probe_Num	ERRP	Basin	Location	MWAT_F	MWAT_C
4612	Higgin	LE	Eel 12th St	71.9	22.2
17955	Higgins	LE	Eel at Howe	74.3	23.5
18629	Higgins	UE	Soda	DRY	DRY
18630	Mitchell	TM	Street/Camp Pool	DRY	DRY
18637	Higgins	UE	Soda (Project Top)	Dry	Dry
18642	Johnston/Higgins	LE	Eel at Shively	76.3	24.6
18650	Stephano-Davis	ME	Eel at Alderpoint	78.1	25.6
18653	Higgins	UE	Welch	61.9	16.6
545276	Johnston/Higgins	LE	Bear (Shively)	62.6	17
823452	Higgins	UE	Panther	DRY	DRY
823453	Mitchell	TM	Street/ Rest Pool	61.3	16.3
2024404	Steinberg/Trichilo	VD	Wolverton	60.3	15.7
2024408	Steinberg/Trichilo	VD	YagerGrange	66.9	19.4
2024410	Steinberg/Trichilo	VD	CummingsCreek	60.2	15.7
2024416	Steinberg/Trichilo	VD	Fox Creek	59.4	15.2
2024420	Steinberg/Trichilo	VD	VanDuzenWeare	71.9	22.2
2024422	Steinberg/Trichilo	VD	VanDuzenChapman	72.3	22.4
2024423	Steinberg/Trichilo	VD	Hely Creek	59	15
2024428	Steinberg/Trichilo	VD	Grizzly Creek	62.1	16.8
2024432	Steinberg/Trichilo	VD	Fish Creek	60.0	15.6
2024437	Steinberg/Trichilo	VD	Little Larabee	63.3	17.4
2024438	Steinberg/Trichilo	VD	VD_RainbowBr	73.6	23.1
2024439	Stephano-Davis	ME	Dobbyns	73.2	22.9
2024442	Higgins	ME	NF Dobbyns	LOST	LOST
2024445	Steinberg/Trichilo	VD	VDSuntanGlen	71.4	21.9
2024447	Stephano-Davis	ME	SF Dobbyns	73.8	23.2
2024450	Steinberg/Trichilo	VD	VD_Bridgeville	73.5	23.1
2024460	Steinberg/Trichilo	VD	VD_at_SFVD	62	16.7
2024468	Steinberg/Trichilo	VD	VD_STHigh	69.3	20.7
2024483	Steinberg/Trichilo	VD	VD_Runburg	73.9	23.3
2024491	Sopjes	LE	Howe Cr	63.7	17.6
2024497	Sopjes	LE	Lower Price	LOST	LOST
2024499	Sopjes	LE	Francis Cr	61.8	16.6
2024500	Sopjes	LE	Upper Price	LOST	LOST
2298315	Higgins	USF	Redwood Branscomb	60.5	15.8
2298317	Higgins	USF	SF Ab Branscomb Rd	66.1	18.9
2298318	Higgins	TM	TM Ab Branscomb Rd	DRY	DRY
2298325	Hilbach	MF	MF Below Williams	79.4	26.3
2298326	Hilbach	MF	L Black Butte	80.1	26.7
2298328	Downing	MF	Williams AB MF	76.7 24	.8
2298332	Grover	SF	Rdwd Park Pool	64.3*	17.9*
2298334	Dane Downing	MF	Black Butte River (upper)	80.2	26.8
2298335	Savage/Higgins	ME	Chemise Pool (Late)	64.1*	17.8*
2298337	Higgins	USF	SF bl Elder	LOST	LOST
2298347	Grover	SF	Rdwd ab Seely	DRY	DRY
2298354	Grover	SF	Rdwd bl Dinner	62.6	17
2298355	Weitzman	NF	NF at Mina Br	LOST	LOST

Probe_Num	ERRP	Basin	Location	MWAT_F	MWAT_C
2298356	Weitzman	NF	Hulls Creek	75	23.9
2298359	Savage	ME	Chemise Riffle Proud	70.4	21.3
2298362	Wise	ME	Lower Chemise	DRY	DRY
2298375	Grover	SF	Rdwd Park	DRY	DRY
2298390	Harris	UE	Sherwood_1	67.5	19.7
2298391	Harris	UE	Sherwood_2	63.5	17.5
2298398	Edell	USF	Jack Hearts Low	63.1	17.3
2298403	Walsh	USF	Dark Canyon	59.7	15.4
2298407	Steinberg/Trichilo	VD	VD_Swimmers	73.6	23.1
2298411	Walsh	USF	Upper JH	59.9	15.5
Internet	USGS	USF	Elder	67.3	19.6
Tidbits	UCB	LE	Fernbridge	71.9	22.2
Tidbits	UCB	SF	Phillipsville	77.5	25.3
Tidbits	UCB	SF	Richardsons_Gr_SF	75.9	24.4
Tidbits	UCB	SF	Standish_Hick_SF	76	24.4
Tidbits	UCB	ME	Eel at Outlet	82.3	27.9
Tidbits	UCB	VD	Van Duzen	74.2	23.4
Tidbits	UCB	USF	Upper SF Angelo	73.9	23.3

Attachment 2. Humboldt County RCD Baseline MWAT Data 1999-2003

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
1501	ASBILL CREEK	North Fork Eel	16.0	16.4	16.5		17.2
9648	Atwell Creek	Lower Eel River			15.7	15.4	16.6
1514	BALM OF GILEAD CREEK	Middle Fork	18.5	19.6	19.2		
8046	BARNWELL CREEK	South Fork Eel				16.3	
1289	BEAR CREEK	Lower Eel River		19.2	18.8		
9654	BEAR CREEK	Lower Eel River				17.4	18.6
1839	BEAR CREEK	South Fork Eel	14.1				
8062	Bear Creek	South Fork Eel					15.2
1776	BEAR PEN CREEK	South Fork Eel	16.8				
1520	BEAVER CREEK	Middle Fork	17.1	18.8	18.4	19.3	19.2
1519	BECHTEL CREEK	Upper Main Eel		18.2	18.1	17.4	20.2
1521	BENMORE CREEK	Upper Main Eel	18.9	20.7	20.8	20.2	20.7
1654	BLACK BUTTE (UPPER)	Middle Fork		20.8	20.2	19.5	20.1
1505	BLACK BUTTE CRK (LOWER)	Middle Fork	23.9	24.6	25.0	25.4	26.3
9642	Blanton Creek	Van Duzen			14.8	14.4	15.1
4070	BLUFF CREEK (MIDDLE)	North Fork Eel				17.3	
4069	BLUFF CREEK (UPPER)	North Fork Eel				16.4	
8037	BOGUS CREEK	South Fork Eel			17.0	23.1	
2150	BOND CREEK	South Fork Eel	15.2				
1362	BOOTHS RUN	Van Duzen			14.9	15.0	15.8
1517	BROADDUS CREEK	Upper Main Eel	19.8	19.0	17.3	17.6	19.6
8001	BUCK GULCH	South Fork Eel	15.8	15.9	15.3	15.6	17.1
1515	BUCKNEL CREEK	Upper Main Eel	19.2	19.9	19.8	19.7	
8064	Bull Ck abv Kemp	South Fork Eel					19.2
1417	BULL CREEK	South Fork Eel					19.8
1512	BULL CREEK	South Fork Eel	20.0	15.4	17.7	20.2	20.8
1668	BULL CREEK	South Fork Eel	18.4	19.2	14.3		
8047	BULL CREEK	South Fork Eel					20.6
1509	BURGER CREEK	Upper Main Eel	22.5	23.3	22.4	23.5	24.1
1424	BURNS CREEK	South Fork Eel	19.0	19.3			
1432	BUTTE CREEK	Van Duzen	18.0	18.5	18.4	19.0	19.9
1303	CANOE CR*	South Fork Eel	16.4				
9622	CANOE CRK	South Fork Eel		16.8	17.2	17.1	
1523	CHADD CREEK	Lower Eel River	16.1	16.1	15.8	15.2	16.2
1527	CHAMISE CREEK (UPPER)	Upper Main Eel	23.5			22.0	24.1
1525	CHINA CREEK	South Fork Eel	16.3			14.9	15.3
9643	Cooper Mill Creek	Van Duzen			15.7	14.9	16.2
1529	CORBIN CREEK	Upper Main Eel	21.5	22.2	21.7	22.5	22.6
1288	CORNER CR	Van Duzen		13.6	13.5	13.4	14.0
9608	CORNER CREEK	Van Duzen	13.9				
1305	COW CR*	South Fork Eel	16.2				
1532	COW CREEK	South Fork Eel	15.8	15.7	15.7	15.6	16.1
9623	COW CREEK	South Fork Eel		15.8	15.6	15.7	16.2
1410	COX CREEK	North Fork Eel	15.4	16.5	16.2		18.7
4071	COX CREEK	North Fork Eel				19.0	
1308	CUMMINGS	Van Duzen			15.5	14.3	15.6
1530	CUMMINGS CREEK	Van Duzen	16.0	15.8	15.5	14.8	15.8

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
8048	CUNEO CREEK	South Fork Eel				18.7	16.6
1444	CUNEO CREEK	South Fork Eel				16.6	
1670	CUNEO CREEK	South Fork Eel	19.9	20.1			
8065	Decker Ck	South Fork Eel					16.0
8002	DINNER CREEK	South Fork Eel	15.3				
8003	DINNER CREEK	South Fork Eel	15.0	14.9	14.8	15.0	16.7
1595	DOBBYN NORTH FORK	Upper Main Eel	21.0	21.5	22.1	21.7	21.5
1437	DOBBYNS CREEK	Upper Main Eel	22.2	21.7	23.6	23.4	23.5
1534	DUTCH CHARLIE CK	South Fork Eel	16.8	16.9	16.5	16.4	
1780	DUTCH CHARLIE CREEK	South Fork Eel	13.2				
8049	EAST BRANCH	South Fork Eel				23.5	24.0
1546	EEL @ CABLEXING SCOTT DAM	Upper Main Eel	20.7	18.6	20.0	21.4	17.8
8005	EEL @ EMANDEL	Upper Main Eel	25.8	26.8	26.5	26.9	27.7
1547	EEL @ MONKEY ROCK	Upper Main Eel	20.6	18.1	19.8	21.4	19.0
8010	EEL @ POOL ABV TOMKI	Upper Main Eel	21.9	24.4		23.7	23.6
8008	EEL @ POOL BEL TOMKI	Upper Main Eel	24.0	24.9		23.8	25.6
8009	EEL @ RIFFLE ABV TOMKI	Upper Main Eel	23.7	23.2		25.1	25.0
8007	EEL @ RIFFLE BEL TOMKI	Upper Main Eel	22.0			25.3	24.0
8011	EEL @ VAN ARSDALE	Upper Main Eel	20.6	20.7	21.2		20.9
1544	EEL @INLET OF LK PILSBURY	Upper Main Eel	21.9	22.5	23.3	23.1	22.9
1550	EEL DOWNSTRM OF MF	Upper Main Eel	25.0	25.4	25.0	26.0	27.0
202	EEL RIVER	Lower Eel River	20.6				
221	EEL RIVER	Lower Eel River	19.8				
225	EEL RIVER	Lower Eel River	20.8				
229	EEL RIVER	Lower Eel River	20.4				
9639	EEL RIVER	Lower Eel River		23.1			
9640	EEL RIVER	Lower Eel River		22.4			
9641	EEL RIVER	Lower Eel River		22.1			
9628	EEL RIVER	Lower Eel River		22.6			
9629	EEL RIVER	Lower Eel River		21.9			
9630	EEL RIVER	Lower Eel River		22.3			
9631	EEL RIVER	Lower Eel River		22.0			
9632	EEL RIVER	Lower Eel River		22.1			
9634	EEL RIVER	Lower Eel River		21.6			
9635	EEL RIVER	Lower Eel River		20.7			
239	EEL RIVER	Lower Eel River	24.8				
8020	EEL RIVER	Upper Main Eel	26.1		26.6		26.8
8025	EEL RIVER	Upper Main Eel			24.2		25.9
1452	EEL RIVER (ABOVE OUTLET)	Upper Main Eel	26.1	27.1	26.3	26.9	28.0
1439	EEL RIVER (BEL OUTLET)	Upper Main Eel		26.4			
1555	EEL RIVER @ DYERVILE BRIDGE	Lower Eel River		23.8	22.1	22.1	23.3
1554	EEL RIVER @ EEL ROCK	Upper Main Eel	24.1	25.4	23.3		25.4
8030	EEL RIVER @ EMANDAL,POOL	Upper Main Eel		24.4	25.3		26.1
1548	EEL RIVER ABV VANARSDALE	Upper Main Eel	20.7	20.0	20.0		
1455	EEL RIVER@BLOODY ROCK	Upper Main Eel	20.0	20.5	21.3	18.9	21.3
1549	EEL UPSTRM OF MF	Upper Main Eel	24.7	26.1	25.1	26.1	
1461	ELDER CREEK (# 6)	South Fork Eel	16.9	17.8	17.5	17.9	18.8
8050	ELDER CREEK U/P BRIDGE	South Fork Eel				17.9	
8004	ELK CREEK	South Fork Eel	16.7	19.7		16.7	17.7

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
1542	ELK CREEK (RATTLESNAKE)	South Fork Eel				19.5	
1543	ELK CREEK, MF	Middle Fork	24.8	25.9	22.8		
9619	FISH CREEK	Van Duzen		12.9	13.6		12.9
8052	FOX CREEK @ WILDERNESS	South Fork Eel				16.7	
1559	FRANCES CREEK	Lower Eel River		15.1		14.4	
8029	FRANCIS CREEK	Lower Eel River			14.8		
1311	GRIZZLEY CREEK	Van Duzen		17.5	17.7	17.8	18.5
1465	GRIZZLEY CREEK	Van Duzen	16.6	17.1	16.6	17.1	17.7
1467	HARPER CREEK	South Fork Eel				16.0	
1312	HELY	Van Duzen		14.7	14.7	14.0	15.2
8069	Hoagland Ck	Van Duzen					18.0
8063	Hollow Tree	South Fork Eel					18.1
2029	HOLLOW TREE (LOWER)	South Fork Eel	19.1				
2142	HOLLOW TREE (MIDDLE)	South Fork Eel	16.5				
2036	HOLLOW TREE (UPPER)	South Fork Eel	12.6				
1778	HOLLOW TREE CREEK	South Fork Eel	20.8				
1324	HOWE CREEK	Lower Eel River		18.6		17.1	19.1
1564	HOWE CREEK	Lower Eel River	18.5	18.8	18.5	17.6	19.7
9614	HOWE CREEK	Lower Eel River	18.2				
9647	Howe Creek	Lower Eel River			17.7		18.5
8022	HOWE HACKETT RANCH	Lower Eel River			15.6		
2037	HUCKLEBERRY CREEK	South Fork Eel	13.0				
1770	INDIAN CREEK	South Fork Eel	15.1				
1786	INDIAN CREEK	South Fork Eel	16.8				
8060	JACK OF HEARTS CREEK	South Fork Eel				17.3	
1566	JACK OF HEARTS CREEK	South Fork Eel	16.2	17.1	16.3	16.9	17.7
9646	Jordan Creek	Lower Eel River			16.1	15.2	16.9
9644	Kapple Creek	Lower Eel River			16.5		
9651	KAPPLE CREEK	Lower Eel River				15.6	16.7
1569	KETTENPOM CREEK	North Fork Eel					21.7
8036	KINSEY CREEK	South Fork Eel			19.3		21.1
1106	LADOO	South Fork Eel	15.3	15.3	14.6		
9621	LARABEE	Lower Eel River		20.8	22.4	22.1	19.1
9605	LARABEE CREEK	Lower Eel River	20.6				
1571	LARABEE CREEK (UPPER)	Lower Eel River	17.3			17.4	18.0
9607	LAWERNCE CREEK	Van Duzen	18.6				
1209	LAWRENCE	Van Duzen			18.3	18.4	19.1
1247	LAWRENCE	Van Duzen			15.4	15.5	
1355	LAWRENCE	Van Duzen				17.2	
9618	LAWRENCE CREEK	Van Duzen		18.4	19.0	18.2	18.7
8034	LEGGET CREEK	South Fork Eel			15.9		
8035	LEGGET CREEK	South Fork Eel			16.9		
1572	LEGGETT CREEK (UPPER)	South Fork Eel		18.3	16.7	17.6	19.3
8021	LEGGETT CREEK 2	South Fork Eel		18.9	18.6	18.7	19.3
1126	LITTLE LARABEE	Van Duzen	14.8	14.6			
1127	LITTLE LARABEE	Van Duzen	13.8	13.6	13.3		
1128	LITTLE LARABEE	Van Duzen	13.5	13.2			
1573	LITTLE LARABEE CREEK	Van Duzen	17.8	18.4	18.1	17.8	19.1
1477	LITTLE SPROUL CREEK	South Fork Eel				16.5	17.8

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
1406	LITTLE VAN DUZEN/S.F. VDR	Van Duzen	20.4	21.2	20.5	21.2	22.3
8041	LOM LONG	South Fork Eel			13.9		
1574	LONG VALLEY	Upper Main Eel	21.2	22.1		21.2	
8038	LOSTMAN	South Fork Eel			15.7		
1576	MCCOY CREEK	South Fork Eel		16.9		16.1	17.2
8019	MF EEL	Middle Fork	24.9	25.8	25.6	26.3	26.9
1581	MF EEL @ FERN PT POOL	Middle Fork	16.8	19.4	18.9	19.5	
1583	MF EEL @ OSBORN POOL	Middle Fork	20.4	22.2	21.9	22.8	23.0
1584	MF EEL @ OSBORN RIFFLE	Middle Fork		21.9	22.3	23.1	23.0
1587	MF EEL @ Wrights Vl bel falls	Middle Fork	17.6	19.0	19.6		20.6
1578	MF EEL ABOVE BLACK BUTTE.	Middle Fork	23.1	24.9	24.7	24.4	25.5
1580	MF EEL ABOVE THATCHER CRK	Middle Fork	25.5	23.4			
1588	MF EEL abv Wrights vl	Middle Fork	15.6				
1585	MF EEL, NORTH FORK	Middle Fork	18.5	19.7	19.3	20.4	
1589	MF,NF@ WILLOW CK	Middle Fork	18.1	19.1			
2152	MICHAELS CREEK	South Fork Eel	15.3				
1678	Middle Fork @ Dos Rios	Middle Fork	25.3	26.1	25.5	26.4	26.2
1590	MILL CREEK	South Fork Eel			19.1		
8033	MILL CREEK	South Fork Eel			17.5	17.6	17.7
1662	MILL CREEK	Upper Main Eel	17.3	18.1		17.4	19.7
8012	MILLER CREEK	South Fork Eel	15.8	15.0	14.1	14.3	
8014	MILLER CREEK	South Fork Eel	15.8				
8032	MILLER CREEK	South Fork Eel			14.2		17.6
1480	MISERY CREEK (ELDER CRK)	South Fork Eel				16.0	
9611	MONUMENT CREEK	Lower Eel River	15.8				
9620	MONUMENT CREEK	Lower Eel River		16.1	15.8	15.1	16.7
1577	MUD CREEK	South Fork Eel	16.5	16.9	16.0	17.1	
8028	MUD CREEK (DOWN)	Middle Fork			18.2		
8026	MUD CREEK UPPER	Middle Fork			17.8		
1838	MUDDY GULCH	South Fork Eel	12.6				
9612	NEWMAN CREEK	Lower Eel River	16.5				
9625	NEWMAN CRK	Lower Eel River		16.2	16.3	16.0	16.6
1485	NF EEL @ MINA BRIDGE	North Fork Eel	25.3	26.3			
4077	NF EEL @ WILBURN RANCH	North Fork Eel				25.2	
4051	NF EEL ABV KETTENPOM	North Fork Eel	22.0	23.1		23.2	24.2
4045	NF EEL BEL KETTENPOM	North Fork Eel	21.2	21.4		21.8	23.1
4046	NF EEL BEL SALT	North Fork Eel	24.1			25.5	26.4
1656	NF EEL BEL SALT CREEK	North Fork Eel	23.6	24.3	24.4	24.6	25.9
4043	NF EEL EAST FORK	North Fork Eel				16.4	
4062	NF EEL EAST FORK	North Fork Eel		21.9			
4042	NF EEL WEST FORK	North Fork Eel		20.5		20.2	21.1
9616	NF YAGER CREEK	Van Duzen		20.7			
8068	North Fork Eel	North Fork Eel					21.5
9649	North Fork Yager Creek	Van Duzen			20.4	21.1	21.7
1602	OUTLET (LOWER)	Upper Main Eel	25.2	26.5	25.9		26.7
1603	OUTLET (MIDDLE)	Upper Main Eel	22.8	24.2	23.8	24.0	24.5
8066	Panther Ck/Bull	South Fork Eel					19.1
4073	PANTHER CREEK	North Fork Eel				14.7	
1605	PANTHER CREEK	Upper Main Eel	19.6	20.1	19.9	20.3	20.6

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
1673	PETERSON CREEK	South Fork Eel	16.4	15.9			
8016	PETERSON CREEK	South Fork Eel	16.6	16.1			
1606	PIERCY CREEK	South Fork Eel		16.1			17.2
1772	PIERCY CREEK	South Fork Eel	16.0				
1412	POLLOCK CREEK	South Fork Eel	16.1	16.4		14.5	
8031	PREACHER GULCH	South Fork Eel			17.2		17.1
1607	PRICE CREEK	Lower Eel River	18.0	19.2	18.4	18.4	19.4
8054	RATTLESNAKE @ ELK	South Fork Eel				20.9	
1610	RATTLESNAKE CREEK	South Fork Eel	21.9				
1611	RATTLESNAKE CREEK	South Fork Eel	18.4	19.6		17.4	19.6
1623	RATTLESNAKE CREEK,MF	Middle Fork	18.5	20.4	20.6	21.4	21.2
1624	RATTLESNAKE POOL	Middle Fork	19.4	20.7	19.1		21.4
1625	RATTLESNAKE RIFFLE	Middle Fork	20.2	22.1	20.7	23.0	22.9
1621	RED MOUNTAIN CREEK	South Fork Eel	20.9			20.7	20.0
4074	RED MT.CREEK	North Fork Eel				22.9	
1779	REDWOOD CREEK	South Fork Eel	12.7				
1619	RICE CRK (UPPER SITE)	Upper Main Eel	21.2	21.5	22.3	22.4	20.7
1618	RICE CRK(LOWER)	Upper Main Eel	21.2	21.5	21.4	21.5	22.6
1203	ROOT CR	Van Duzen	15.2	14.7	15.1	14.3	15.7
1404	ROOT CREEK	Van Duzen	14.3	15.0	14.3	13.8	15.8
1627	RYAN CREEK	Upper Main Eel	15.9	16.6	15.8	16.3	17.8
1684	SALT CREEK @ MOUTH	North Fork Eel		25.1	22.2	22.6	23.8
4075	SALT CREEK @ MOUTH	North Fork Eel				26.1	
8067	Salt Creek at Mo	North Fork Eel					26.1
1299	SCOTT CR	Lower Eel River	13.3		13.9	13.8	14.2
1633	SF EEL @ DYERVILE BRIDGE	Lower Eel River	22.1	23.9	22.5	22.7	
1268	SF YAGER	Van Duzen	16.9				
9617	SF YARGER	Van Duzen		17.0	16.6	16.1	20.8
1240	SHAW	Van Duzen		15.0	14.8	14.5	15.4
9613	SHIVELY CREEK	Lower Eel River	16.7				
9624	SHIVELY CRK	Lower Eel River		15.7	16.5	14.9	15.9
1631	SODA CREEK	Upper Main Eel	18.3	19.2	18.3	17.6	19.6
1640	SONOMA CREEK	Middle Fork	16.0				
1641	SPANISH CREEK	Middle Fork	17.9	19.0	18.6	19.5	19.8
1137	SPROUL	South Fork Eel	20.4	20.9			
1407	SPROUL	South Fork Eel	16.7	17.4		16.4	17.7
1408	SPROUL	South Fork Eel	18.8	19.3	13.7		18.8
1409	SPROUL (WEST FORK)	South Fork Eel	17.1	17.3			
1302	SQUAW CR*	South Fork Eel	16.3	15.9	15.9	15.8	17.1
9626	STITZ CRK	Lower Eel River		16.7			17.4
1363	Strawberry Creek	Van Duzen			14.3		
9657	STRONGS CREEK	Lower Eel River				14.3	15.2
9658	STRONGS CREEK (NF)	Lower Eel River				14.0	15.2
1840	TAYLOR CREEK	South Fork Eel	14.6				
1675	TEN MILE @ PETERSON CREEK	South Fork Eel	22.0	21.3			
1646	TEN MILE CK (LAYTONVILLE)	South Fork Eel	18.7	19.2	16.6	18.3	20.6
1647	TEN MILE CK (NEAR SF)	South Fork Eel	23.6	24.7	24.6	24.7	24.7
1643	THATCHER CREEK	Middle Fork	22.6	24.3			
9650	Thompson Creek	Lower Eel River			17.0	16.4	17.1

SITE_ID	STREAM_NAME	Basin	1999	2000	2001	2002	2003
8058	TOM AND JERRY CREEK	South Fork Eel				17.7	
8057	TOM LONG CREEK	South Fork Eel				16.9	
1649	TOMKI CREEK	Upper Main Eel	19.8				
8017	TOMKI CREEK	Upper Main Eel	21.2				
1648	TOMKI CREEK (LOWER)	Upper Main Eel	23.6	25.2	19.3	25.0	24.8
8039	TOSTIN CREEK	South Fork Eel			18.5	19.0	19.7
9645	Upper Larabee Creek	Lower Eel River			21.5	21.4	22.3
209	VAN DUZEN	Lower Eel River	20.0				
219	VAN DUZEN	Van Duzen	20.6				
220	VAN DUZEN	Van Duzen	20.3				
231	VAN DUZEN	Van Duzen	19.8				
1405	VAN DUZEN @ ROOTCREEK	Van Duzen	21.4	22.2	22.7		22.3
8070	VDR @ Dinsmore	Van Duzen					20.5
1651	WELSH CREEK	Upper Main Eel	16.2	17.2	17.4	16.9	17.0
1599	WEST FORK OF NORTH FORK	North Fork Eel	19.3				
1107	WEST FORK SPROUL	South Fork Eel	14.4				
1108	WEST FORK SPROUL	South Fork Eel	14.9				
1109	WEST FORK SPROUL	South Fork Eel	15.0				
1773	WILDCAT CREEK	South Fork Eel	16.7				
8040	WILDCAT--TRIB. TO LOM LONG	South Fork Eel			20.5		
1663	WILLITS CREEK	Upper Main Eel	19.1	19.3	19.8	17.9	19.7
1664	WILLITS CREEK	Upper Main Eel	15.5	16.5		15.3	17.6
8018	WILLITS CREEK	Upper Main Eel	18.4	19.8		19.3	20.8
1438	WILSON CREEK	North Fork Eel	20.5	21.5	21.8		
9615	YAGER CREEK	Van Duzen		22.3	23.1		
9655	YAGER CREEK	Van Duzen				21.4	21.7
9656	YAGER CREEK	Van Duzen				20.6	
9659	YAGER CREEK (NORTH FORK)	Van Duzen				18.4	
9653	YAGER/TRIB	Van Duzen				13.9	15.1
1653	YELLOW JACKET CREEK	North Fork Eel	21.8	22.1	25.1	22.2	24.0