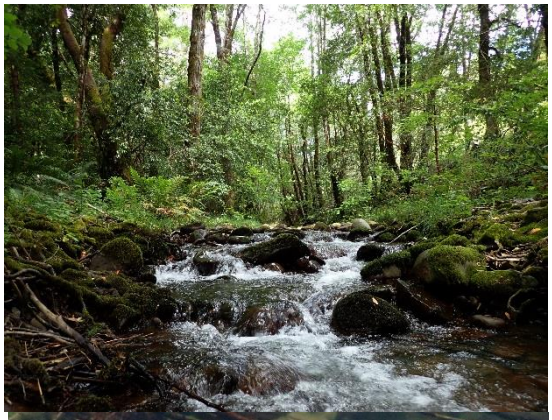
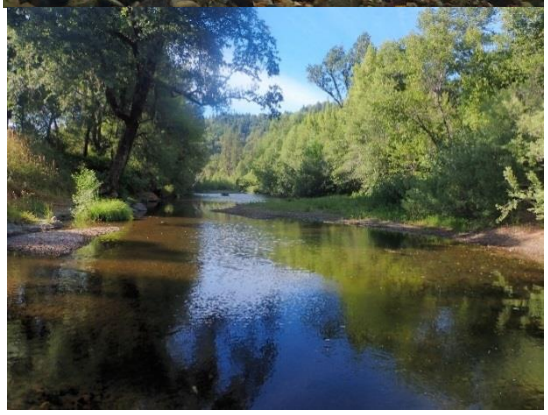
Tenmile Creek Water Temperature, Fish Community and Flow Summary Report Water Years 2020-2021








By Patrick Higgins, Eel River Recovery Project

For the California Coastal Conservancy (Agreement # 20-076)

February 28, 2022

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Acknowledgements

This report was made possible by a California State Coastal Conservancy (SCC) Proposition 1 (Prop 1) grant, which follows a previously performed pilot project funded from the same source. The pilot project resulted in the creation of the *Tenmile Creek Watershed Conservation and Restoration Action Plan* (ERRP 2020) that envisioned the water conservation and erosion control projects funded in what we term SCC Prop 1 Phase II. The Project is expansive in scope and includes work to plan and permit water infrastructure that allows forbearance and stream flow enhancement, erosion control, surface and groundwater budgets and models, flow measurement, and the stream temperature and biological monitoring reported here. An additional element is the use of time-lapse cameras to capture stream flow images that are then made into movies of flow spanning several months.

Our work in Tenmile Creek would not be possible without the permission and support of cooperating landowners that allow us to monitor on their land. Thanks to Bob Vassar, Tony and Liz Varnhagen, Dennis Hogan, Dan and Deb Kvaka, Long Valley Feed and Supply, Triple Creek Ranch, Vernon "Woods" Wilson, Peter Steele, the UC Angelo Reserve, Mare Murphy, Joe Feigon, Black Oak Ranch, and Vic Weaver. ERRP contractor Steve Brown also deserves special recognition for helping deploy probes and cameras. Thomas Gast Associates Environmental Consulting (TGAEC) is also an important part of the project. They collect water temperature data as well as flow data; the temperature date are included in this report.

Mare Murphy

Dennis Hogan

Liz and Tony Varnhagen & Steve Green (l to r).

Coastal Conservancy

Eel River Recovery Project

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Introduction

SCC Prop 1 Phase II includes trend monitoring at locations throughout the Tenmile Creek watershed, many of which had been previously monitored in 2018-2019 as part of the SCC Prop 1 pilot project. Summary of previous temperature and fish community structure by year is available in the *Tenmile Creek Watershed Conservation and Restoration Action Plan* (ERRP 2020). All references in this document to data collected before 2020 are contained in the Action Plan. Despite the fact that monitoring was not fully funded in 2020, due to the end of one SCC grant and the initiation of Phase II, data were collected that are analyzed in this report.

Water Year 2020 (October 1, 2019 to September 30, 2020) was the fifth driest year on record according to the California Department of Water Resources (DWR 2021), and Water Year 2021 was the second driest in history, surpassed only by 1924. There were measurable differences in terms of Tenmile Creek water temperatures, suitability for fish and flow between 2020 and 2021.

Some localized refugia, cold water habitat that supports juvenile steelhead and trout, were maintained in 2020. However, the even more severe drought of 2021 caused most reaches being monitored for temperature and fish to go dry. This was in contrast to Elder Creek, which serves as a control for our Tenmile Creek studies, and the upper South Fork Eel River that was able to support coho salmon juveniles all summer and fall of 2021 (see Conclusion). Thomas Gast Associates Environmental Consultants (TGAEC) operated water flow gauges in 2020 at five locations in main Tenmile Creek and in key tributaries (ERRP 2020), and a sixth site on Mill Creek was added in 2021. While their complete flow results will be reported separately, ERRP also noted disruption of flow at monitoring sites and, therefore, we partially report on flow here. Ten time-lapse cameras were used to record flow conditions, which are discussed below with full movies posted on-line (www.eelriverrecovery.org).

Methods

Sampling methods for temperature data collection in 2020 and 2021 were the same as those used previously in the Tenmile Creek watershed, and by others in basin-wide monitoring (Friedrichsen et al. 1998, Higgins 2014, Asarian et al. 2016). All these studies followed water temperature measurement protocols established by Lewis (1999). ERRP utilizes Onset Instrument HOBO Water Temp Pro v2 automated gauges that are accurate to 0.5C. Before deployment, the gauges are tested in an ice bath and calibrated against a National Institute of Standards and Technology (NIST) traceable thermometer. Sensors not meeting precision and accuracy data quality objectives are not be used.

In streams, the probes are attached to a weight and placed in the current of a well-mixed zone representative of ambient conditions. Locations effected by springs, side channels out of the flow, beaver ponds, or other impoundments are avoided. Probes are also placed out of direct sun to avoid bias due to solar radiation. Sensors are placed with low flows in mind, so that probes remain submerged throughout the summer. ERRP sensors are set to record at half hour intervals, less than the maximum interval recommended by Lewis (1999), which is 1.6 hours or 96 minutes.

After probes are retrieved from the field, files are downloaded to a computer using the Onset- U-D TW-1 HOBO Waterproof Shuttle hard drive. All values prior to placement and after retrieval are removed and the data are checked for quality. Datasets showing a wide range of temperatures beyond those expected are usually as a result of the probe being exposed to the air. In locations where flow was disrupted the date when the temperature amplitude changes indicateds when the stream went dry there. Raw and edited data are archived and shared with the North Coast Regional Water Quality Control Board and other interested parties, including the U.S. Forest Service Climate Research Project in Fort Collins, CO for use in assessment of climate change.

Ecological Conditions of Stream Reaches by Sub-Basin

We divided Tenmile Creek into ten sub-basins for study purposes and a map of these is supplied as Figure 1. Sub-basins will be covered in the following order starting with west-side tributaries Cahto, Mill, Big Rock, Streeter and Peterson creeks. Next will be Lewis Creek, the sole east-side tributary monitored. Mainstem Tenmile Creek reaches will be discussed last, from upstream to downstream in order: Upper Tenmile (upstream of Little Case Creek), Upper Middle Tenmile (Little Case Creek to Wilson), Lower Middle Tenmile (Wilson Creek to Grub Creek), and Lower Tenmile (below Grub Creek).

Tenmile Creek water temperature, fish community, and flow conditions in Water Years 2020 and 2021 are summarized in Figures 2-5. A summary of temperature and fish conditions at monitoring sites for 2020 and 2021are displayed in Figures 2 and 3, respectively, with categories: 1) dry, 2) flowing and supportive of coldwater fish, 3) flowing with warmwater fish, and 4) reaches where flow was disconnected but had isolated pools that supported either warm of coldwater fish. These criteria were changed from previous reports based solely on temperature ranges because so many locations had disrupted flow. Stream flow conditions reported here are based on visual observations, not flow measurements. Figures 4 and 5 represent conditions in 2020 and 2021, respectively. The categories are 1) dry, 2) isolated pools with fish, 3) isolated pools stagnant, 4) perennial flow with warmwater fish, and 5) perennial flow with coldwater fish.

Cahto Creek Sub-Basin

The Cahto Creek sub-basin is 5.6 square miles and has 6.9 miles of anadromous fish habitat (CDFW 2009a). The watershed arises at an elevation of about 3,100 on the shoulders of Cahto Peak and is one of the more productive tributaries for anadromous salmonids in the Tenmile Creek watershed, with frequent use by steelhead and Chinook salmon and occasional use by coho salmon. Rainbow trout are also common in Cahto Creek; they are genetically similar to steelhead but manifest a resident life history. Cahto Creek has excellent spawning gravels and is not over-supplied with sediment. No Chinook salmon were able to access Cahto Creek in 2020 or 2021 because of lack of rainfall during the time of spawning migration, but they successfully spawned in lower Cahto Creek in November 2022. The Cahto Tribe Reservation is within the watershed and the middle reach of Cahto Creek runs through it.

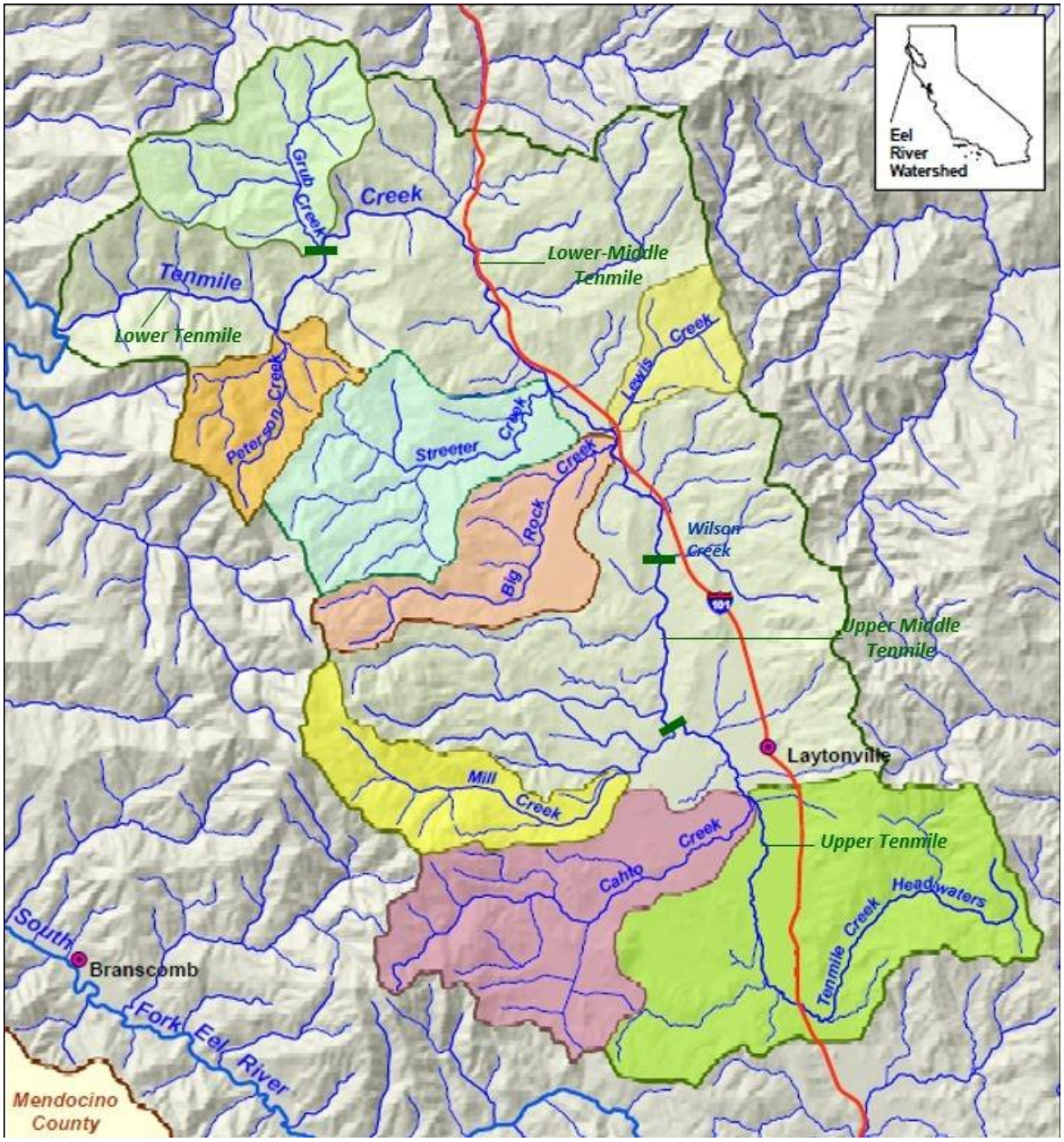

Figure 1. Tenmile Creek subbasins from ERRP (2020). Map by Dr. Paul Trichilo, ERRP.

Upper Cahto Creek Unnamed Tributary: We have been monitoring and observing conditions since 2018 in this unnamed tributary that joins upper Cahto Creek from the south just below impoundments on what used to be known as the Trout Farm, and is now called Mendocino Magic. This tributary can get steelhead spawning in years with sufficient flows for fish passage, but may also have native trout exhibiting a resident life history. ERRP has access to two parcels, Patricia Kovner's in an upstream reach with moderate gradient (Figure 6) and Darryl Gully's (Figure 7), which is downstream of Kovner's and is very low gradient.

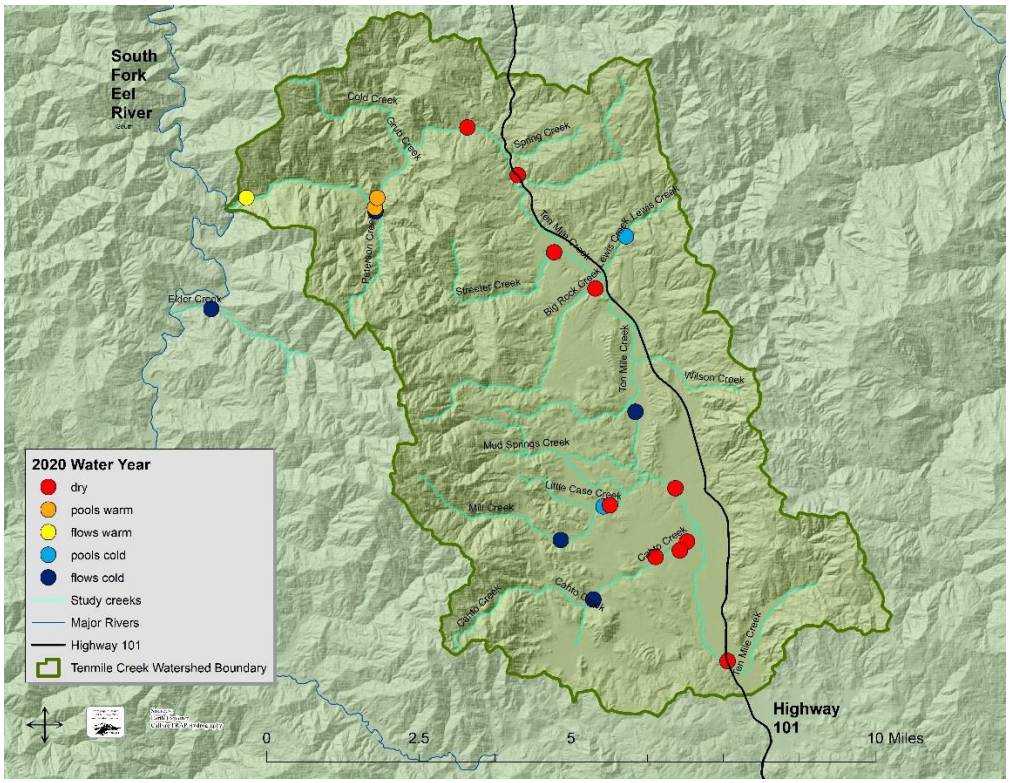

Figure 2. ERRP temperature probe locations with symbols for temperature, flow and fish conditions for the 2020 Water Year. Map by Noel Soucy, Legacy the Landscape Connection.

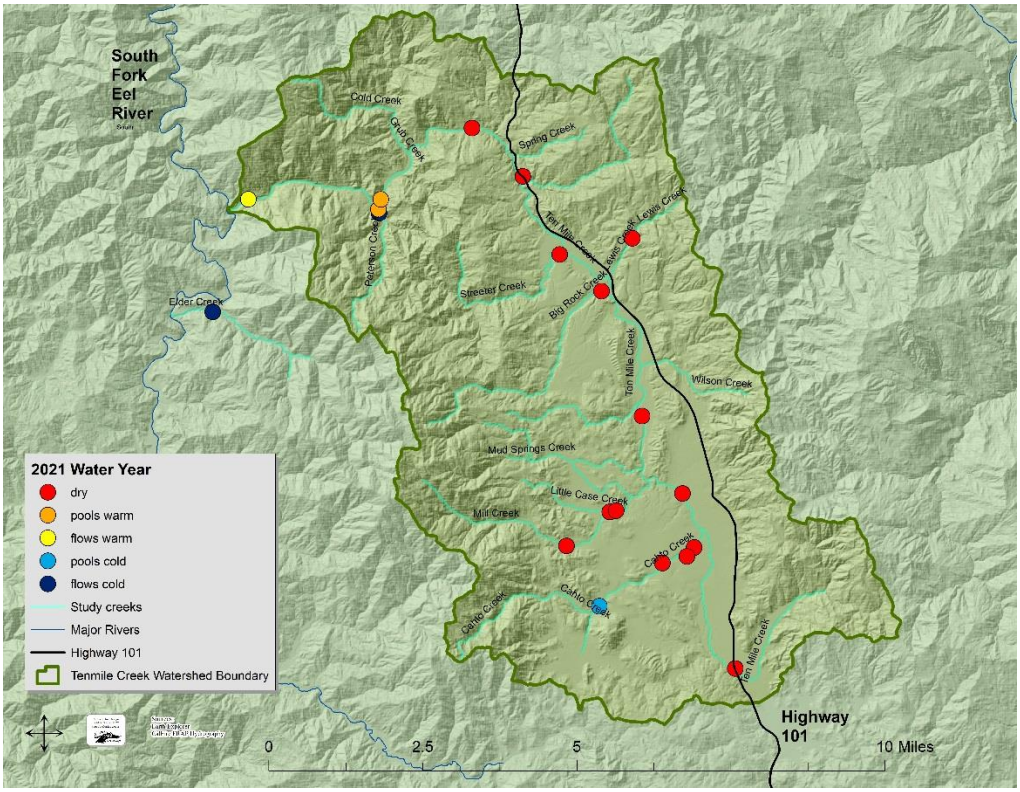

Figure 3. ERRP temperature probe locations with symbols for temperature, flow and fish conditions for the 2021 Water Year. Map by Noel Soucy, Legacy the Landscape Connection.

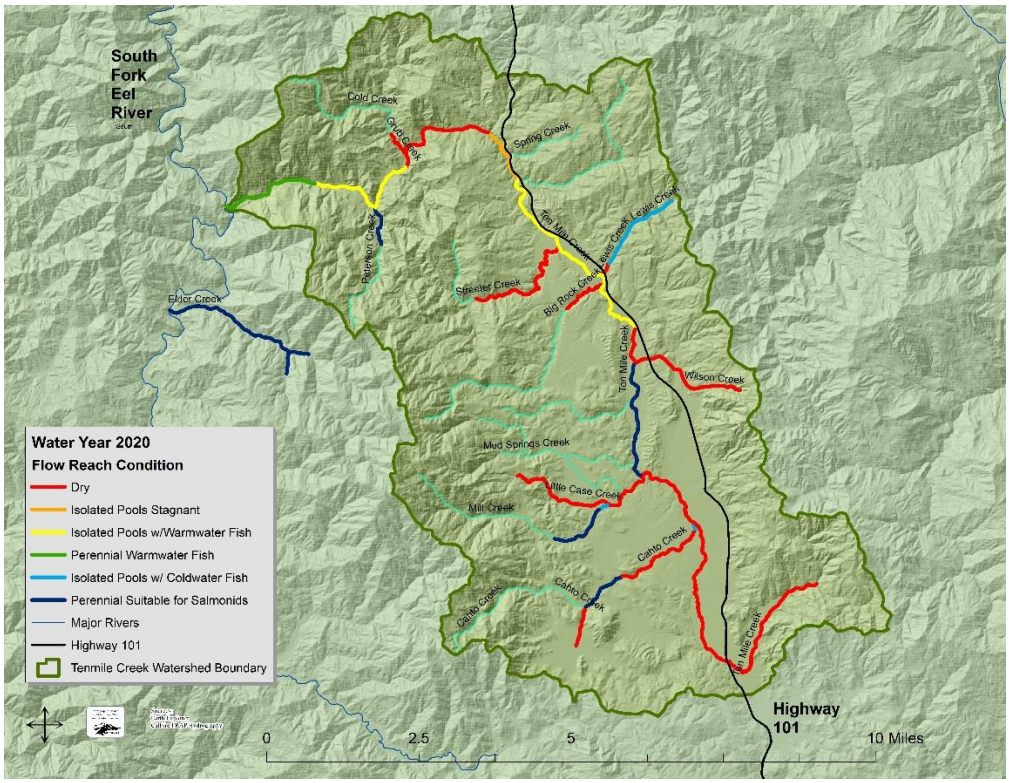

Figure 4. Reaches of Tenmile Creek and tributaries and flow conditions in 2020, with control stream and SF Eel tributary Elder Creek on the Angelo Reserve also included. Map by Noel Soucy, Legacy the Landscape Connection.

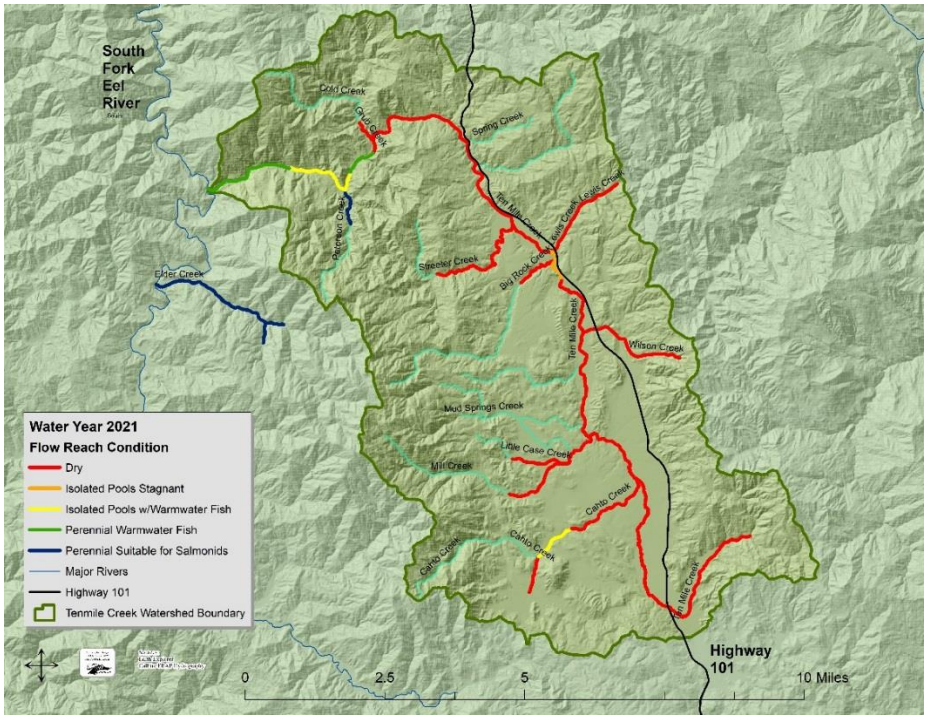

Figure 5. Reaches of Tenmile Creek and tributaries and flow conditions in 2021, with control stream and SF Eel tributary Elder Creek on the Angelo Reserve also included. Map by Noel Soucy, Legacy the Landscape Connection.

Figure 6. Dry bed of unnamed Cahto Creek tributary on Kovner property. 8/25/21.

Figure 7. Darryl Gully in dry creek bed flanked by (l to r) Noah Cornell, Teri Barber (r) and Anna Birkas. 10/11/21.

In 2018, the creek at the top of the Kovner property had perennial flow and temperatures ideal for steelhead juvenile, with a 66.7 F maximum an average of 57.8 F from late July through mid-October (ERRP 2020). No water temperature data were collected in 2019, although flow was maintained at this location, but this reach was dry in late summer and fall in 2020 and 2021.

The same unnamed Cahto Creek tributary on the Gully property just downstream has less than a 1% gradient and its bed is fine textured, indicating excess sediment supply. The creek here tends to lose surface flow annually, but supports trout in wet years in isolated pools fed by cold sub-surface flow. Unfortunately, the pools also dried up late in summer in 2018 and in fall 2019. In 2020 and 2021, surface flow and isolated pools went dry early. Also, desiccation in combination with insufficient winter flows for steelhead migration in 2020 and 2021 contributed to the absence of trout at the Gully property in the last two years.

Cahto Creek at Cahto Creek Ranch: This reach of Cahto Creek is on the Varnhagen 1400-acre property immediately upstream of the Cahto Reservation. Cahto Creek tends to maintain surface flow and cold-water temperatures here (Figure 9), even when reaches further downstream dry up. ERRP video documented abundant steelhead and/or rainbow trout juveniles on September 9, 2019 in this reach (https://vimeo.com/358719201).

Although we did not have a water temperature probe in this reach of Cahto Creek in 2020, perennial flow was maintained and steelhead and juvenile resident trout were present. A temperature probe in this reach in summer 2021 found that cool water temperatures were maintained through early September (Figure 8), however, surface flow was lost later in September and only small trout survived in isolated pools. The decrease in temperature in August may reflect reduction in surface flow and increased influence of cold groundwater. The probe was moved September 6, presumably by otters, and air temperatures afterward were edited from the database. It should be noted that this was only one of two locations in the Tenmile Creek watershed that maintained any viable habitat for coldwater fish in 2021.

Figure 8. Cahto Creek on Varnhagen property not far off Branscomb Road. 6/23/21.

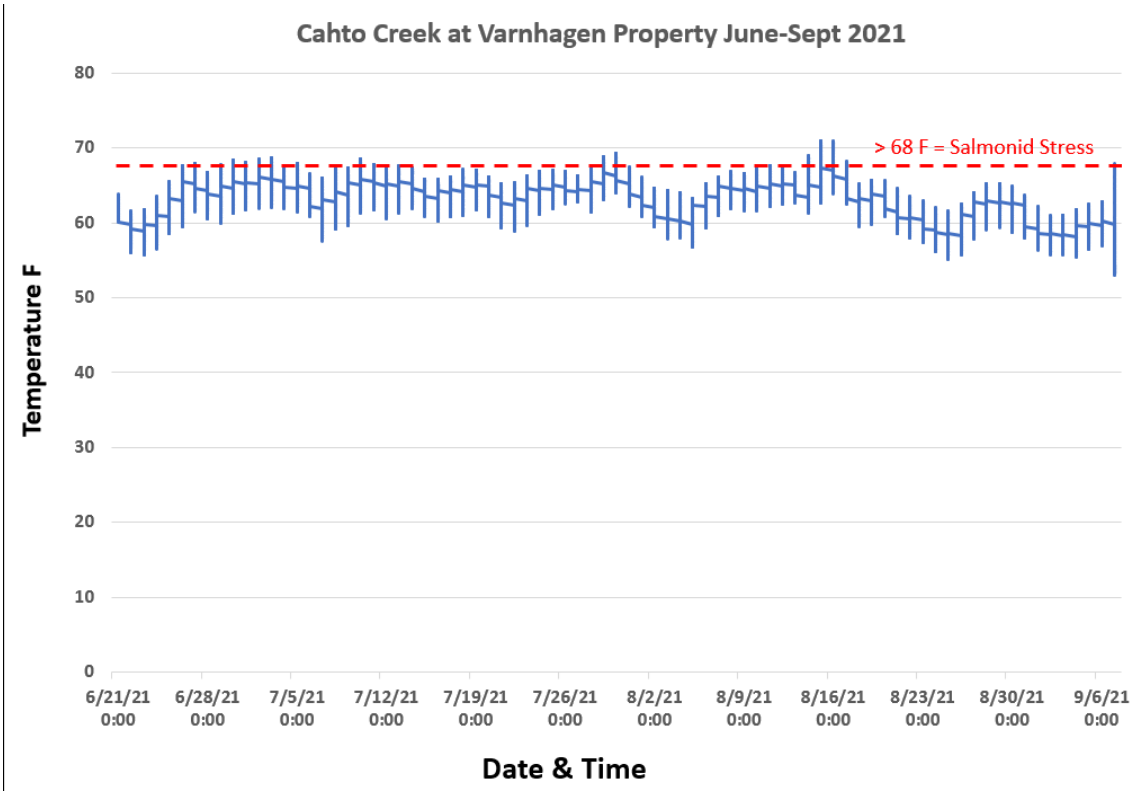

Figure 9. Water temperature of Cahto Creek on Varnhagen property, June – September 2021. Cahto Creek on the Reservation.

Cahto Creek on the Cahto Tribe Reservation: ERRP has been a partner with the Cahto Tribe Natural Resources (NR) Department, monitoring temperature in the creek on the Reservation in 2019, and periodically conducting fish direct observation dives. The reach of Cahto Creek within the Reservation has good habitat for spawning and rearing, when flows allow. The Cahto Tribe has won numerous grants to stabilize stream banks and to promote scour of deeper pools with log structures. ERRP has helped document high densities of juvenile steelhead using these pools in some years. However, juvenile warmwater fish, like green sunfish, may also be abundant, depending on the spill of ponds in spring further up in the watershed. Joe Scriven (personal communication) of the Mendocino County Resource Conservation District found juvenile coho rearing in Cahto Creek on the Reservation in 2010-2012, which were all wet years. The maximum floating weekly average water temperature (MWAT) of Cahto Creek on the Reservation in 2019 was 65 F (ERRP 2020), which was within the suitable range for steelhead rearing. Unfortunately, this reach of Cahto Creek dried up in 2020 (Figure 10) and again in 2021. It is not known why this reach of Cahto Creek dries up when the reach upstream on the Cahto Creek Ranch does not. Hypothesis are variable bed permeability and possibly surface or groundwater extraction.

Figure 10. Cahto Tribe NR staff Fred Simmons in dry bed of Cahto Creek on the Reservation. 10/15/2020.

Cahto Creek at Kvaka Property: This location is off Mulligan Lane about one half mile above the convergence of Cahto Creek and Tenmile Creek. Dan and Deb Kvaka (Figure 11) have assisted with placement of a time-lapse camera, temperature probes are deployed on their property, and dives have identified several fish species holding in their largest pool. Dan Kvaka video recorded an adult Chinook salmon in 2018, but has not noted Chinook salmon spawning or migration since. The fish community in spring and early summer in 2020 and 2021 was diverse and included juvenile steelhead (Figure 12). California roach and native stickleback were noted in June 2020, and the latter species was mating in an eddy in the large pool (Figure 13).

Figure 11. Dan Kvaka at left, Deb at center and Steve Brown in dry bed of Cahto Creek. 8/20/2021.

Figure 12. Juvenile young of the year steelhead or rainbow trout in Cahto Creek at Kvaka's. 5/26/21.

Figure 13. Native stickleback mating in pool at Kvaka's. 6/28/20.

Cahto Creek at Cahto Creek Trail: This location is about a quarter mile upstream of the convergence with Tenmile Creek on the Dennis and Marybeth Hogan property. They are great ERRP partners for stream monitoring, forest health, and riparian restoration. This reach of Cahto Creek is frequently used by Chinook salmon (Figure 14) and steelhead for spawning and rearing, and occasionally by coho salmon. The gravel bed is course and there is good riparian cover for much of the reach on the Hogan property, with the exception of a 160-foot-long section of failing bank adjacent to the Cahto Trail (Figure 15). Bank erosion at this site was active during the storm of October 23, 2021, and a bioengineering project will be implemented in fall 2022 that will stem this source of pollution and create much improved fish habitat.

We found abundant steelhead trout rearing in this reach in 2019 and 2020. Included among them were numerous trout greater than six inches long, which could be older age steelhead juveniles, while some are likely native trout. Steelhead and native rainbow trout are genetically identical and can adopt either anadromous or resident behavior. When surface flow between pools became disconnected in 2019, optimal temperatures for salmonid rearing were maintained because of groundwater connection. In 2020 and 2021, however, the reach dried up completely, including the pools in August and July.

Figure 14. Spawned out female Chinook salmon on lower Cahto Creek at Hogan property. 11/23/21.

Figure 15. Dry bed of Cahto Creek on Hogan property along Cahto Trail that is slated for repair bioengineering. 10/11/21.

Mill Creek Sub-Basin

Mill Creek has its headwaters on the shoulders of Cahto Peak and runs about three miles east to its junction with Little Case Creek. Below their convergence, the USGS topographic map shows the name as Little Case Creek, which runs about a mile further to its junction with Tenmile Creek. Steelhead trout spawn and rear in Mill Creek, and it also likely has native trout, similar to Cahto Creek. Chinook have been seen spawning in Mill Creek above Little Case Creek (Joe Feigon, personal communication), but not in recent years. There are no data on use of Mill Creek by coho salmon in recent years, but the California Department of Fish and Wildlife (Garwood 2012) confirmed historic presence of coho based on a 1968 file report that also reported coho in lower Little Case Creek.

Upper Mill Creek: We have been monitoring upper Mill Creek on the property of Mare Murphy since 2019. The MWAT in 2019 was 62.4 F, which is cold enough for coho salmon (Welsh et al. 2001). In 2020, the stream temperature warmed (Figure 16) but was still optimal for steelhead juvenile rearing. Lack of adequate rainfall in the windows for steelhead spawning over the last few years has resulted in a low standing crop of juvenile steelhead. Only one four-inch specimen was noted in about a ¼ mile survey upstream of the Murphy property in 2020. A time-lapse camera showed that Upper Mill Creek dried up in August in 2021 (Figure 17-18).

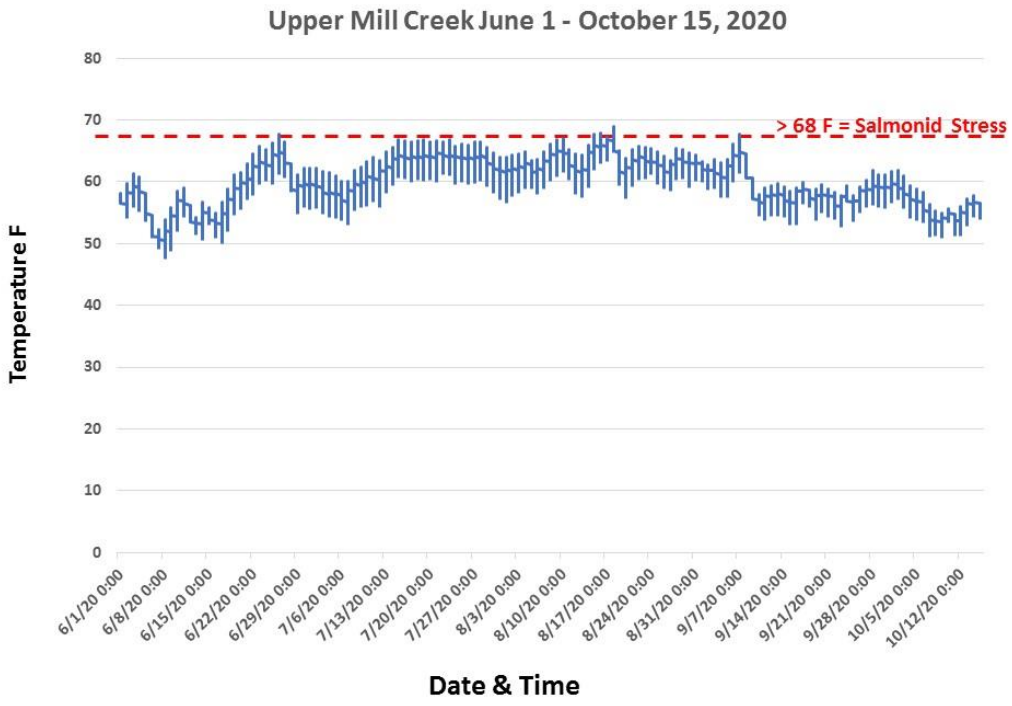

Figure 16. Upper Mill Creek water temperature from June to October 2020.

Figure 17. Upper Mill Creek on property of Mare Murphy looking upstream. 5/26/21.

Figure 18. Upper Mill Creek on property of Mare Murphy dry. 8/20/21

Lower Mill Creek: The reach of lower Mill Creek that ERRP monitors is about 750 feet above its convergence with Little Case Creek on the property of Joe Feigon, where there will also be a 319h funded bank restoration project to stabilize 300 feet of eroding stream bank. Mill Creek at this location maintained surface flows and water temperatures sufficiently cool to sustain steelhead juveniles in 2020 (Figure 19). Juvenile steelhead and/or native trout survived 2020 and there was a fairly high standing crop of juveniles in spring of2021 (Figure 20). Unfortunately, Mill Creek in this reach went completely dry in late July 2021 (Figure 21).

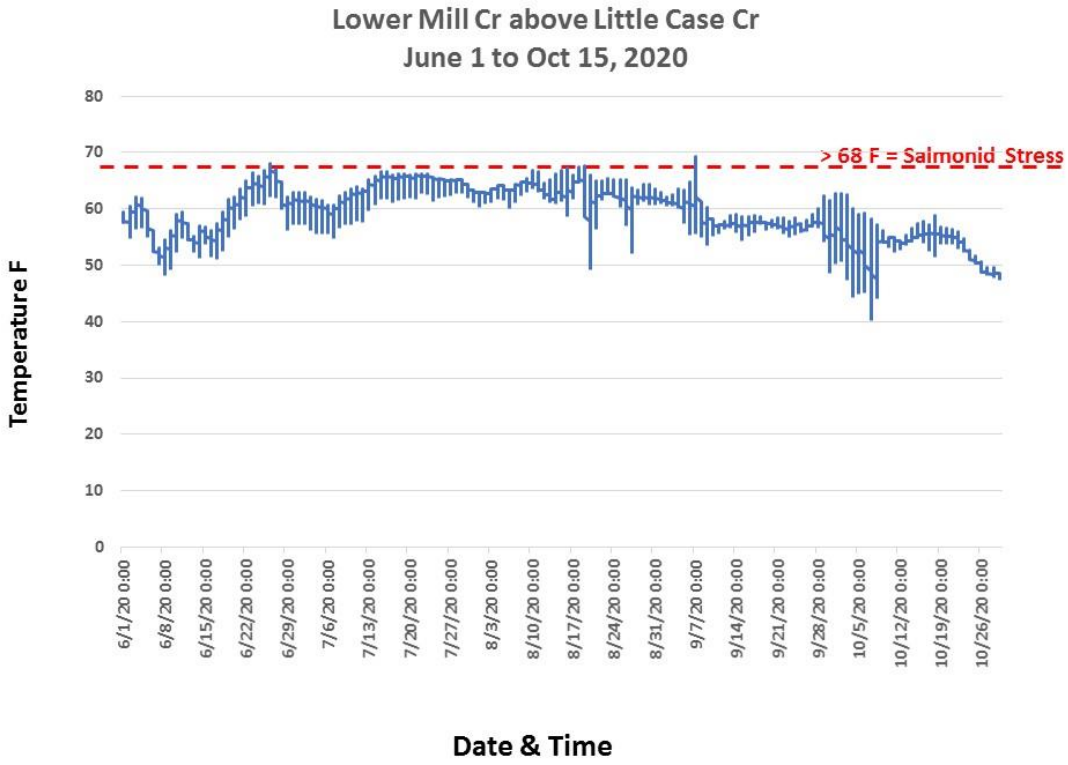

Figure 19. Hourly water temperature of lower Mill Creek from June to October 2020.

Figure 20. Steelhead or native trout juveniles in Mill Creek pool in Feigon property. 5/26/21.

Figure 21. Joe Feigon (l) and Steve Brown in dry bed of lower Mill Creek. 8/20/21.

While ERRP has not monitored Little Case Creek, reconnaissance in 2018 and 2019 established that it typically loses surface flow in summer. This condition was photo-documented just above the convergence with Mill Creek in late October 2021 (Figure 22). The hydrology of Little Case Creek is likely profoundly altered as a result of channelization that occurred to increase agricultural land in the late 19th Century (see Discussion).

Figure 22. Dry bed of Little Case Creek just upstream its convergence with Mill Creek. 10/11/21.

Big Rock Creek Sub-Basin

Big Rock Creek has a watershed area of approximately 3.2 square miles and joins Tenmile Creek from the west, with its headwaters on the shoulders of Cahto Peak at approximately 2,700 feet (CDFW 2009b). ERRP has monitored Big Rock Creek near the mouth and further upstream at a TGAEC flow gauge that has been operating since 2018. We found that Big Rock lost surface flow in 2018, but maintained isolated cold pools that had juvenile steelhead and coho salmon, stickleback, California roach and green sunfish (ERRP 2020). CDFW (Garwood 2012) documented coho presence in Big Rock Creek in three brood years between 1993 and 2002.

In 2019, lower Big Rock Creek maintained surface flow and had a floating weekly average water temperature (MWAT) of 67.4 F, which was suitable for steelhead (McCullough 1999). While Big Rock Creek lost surface flow in mid-August 2020, it went dry even earlier in 2021. No stratified pools with salmonids were noted in reaches further upstream in 2020 or 2021, unlike in 2018. Photos of flow conditions of Big Rock Creek in May and August 2021 are shown in Figures 23 and 24.

Figure 23. Lower Big Rock Creek. 5/26/21.

Figure 24. Lower Big Rock Creek dry. 8/20/21.

Streeter Creek Sub-Basin

Streeter Creek, another major west-side Tenmile Creek tributary, flows from an elevation of about 2,700 feet to it convergence at 1,459 ft. CDFW (2009c) estimated the watershed as 3.2 square miles in size. ERRP has had a working relationship with the Black Oak Ranch, including monitoring lower Streeter Creek near its mouth, since 2012. In 2018, with the inception of the SCC Prop 1 pilot project, when flow monitoring began. Streeter Creek dried up in its lower reaches and failed to maintain habitat for steelhead juveniles in 2018, but flow was perennial in 2019 with temperature data indicating suitability for salmonids (67.5 F MWAT). Numerous steelhead juveniles were video documented in October 2019 (https://vimeo.com/433339215). Streeter Creek, like Big Rock Creek, lost surface flow in mid-August 2020 and it went dry in July in 2021. No pools with salmonids persisted in either 2020 or 2021. Flow conditions in Streeter Creek in May and August 2021 are shown in Figures 27 and 28.

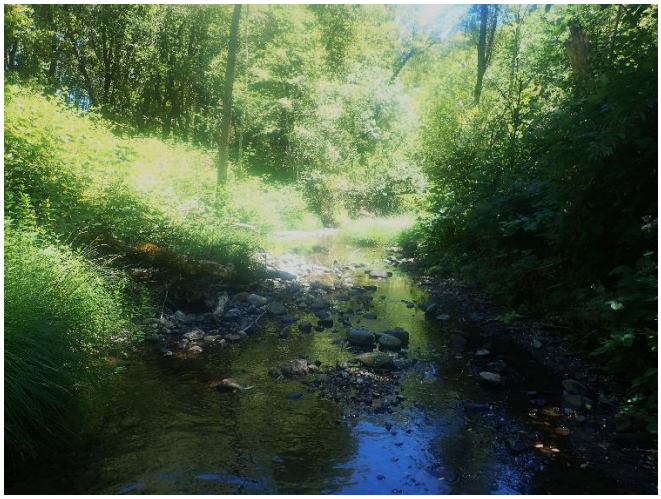

Figure 27. Lower Streeter Creek. 5/26/21.

Figure 28. Lower Streeter Creek dry. 8/20/21.

Peterson Creek Sub-Basin

Peterson Creek is one of the smaller west-side Tenmile Creek tributaries, which joins the mainstem about 2.5 miles upstream of the South Fork Eel River. ERRP has been monitoring it since 2019. From June to October 2019, this creek had the coldest water temperature of any other site within the Tenmile Creek watershed (61.7 F MWAT). It was be cold enough to support coho salmon, although they are not known to have occurred there recently. Landowner Steve Brown (personal communication) observed Chinook salmon in lower Peterson Creek during past very high-water events, and has often seen adult steelhead spawning. ERRP has observed steelhead or native trout juveniles in lower Peterson Creek in all years, including 2021 (Figure 29) when Peterson Creek was one of only two locations supporting salmonids in the entire Tenmile Creek watershed.

Lower Peterson Creek water temperature data for 2020 are shown in (Figure 30) and for 2021 in (Figure 31). Both years had optimal temperature for rearing steelhead, but 2021 appears colder. This is likely owning to very low surface flows, with water temperatures more influenced by cold groundwater. Peterson Creek maintained connectivity above a road crossing low in the watershed, but disconnected closer to the mouth in late summer. On the evening of August 20, 2021, Peterson Creek was underground just above its convergence with Tenmile Creek, but at 10 AM the next morning it was reconnected, likely due to a reduction in tree evapotranspiration overnight (see Discussion).

Figure 28. Trout juveniles in lower Peterson Creek. 6/3/20.

Figure 29. Lower Peterson Creek with surface flow during ERRP field trip. 8/26/20.

Lewis Creek Sub-Basin

We began studying Lewis Creek in 2019, when flow was perennial and water temperatures optimal for juvenile steelhead and/or native trout (66.1 F MWAT), which were observed in moderately high densities (ERRP 2020). The Maacama Fault bisects the Tenmile Creek watershed with sandstone geology to the west and Central Mélange Terrain to the east. West-side vegetation is dominated by coniferous forest and the eastern half of the basin by oak woodlands and grasslands (Figure 32). Soil moisture is greater in sandstone geology than in the mélange (Hahm et al. 2019). Lewis Creek, in the Mélange Terrain, is the only perennial tributary flowing from the eastern Tenmile Creek watershed. In 2020, Lewis Creek maintained surface flow through fall (Figure 33) and temperatures were still cool enough for steelhead (Figure 34), although warmer than 2019. In 2021, Lewis was disconnecting in late June and dry in August. While some pools retained water, no fish life was observed in fall.

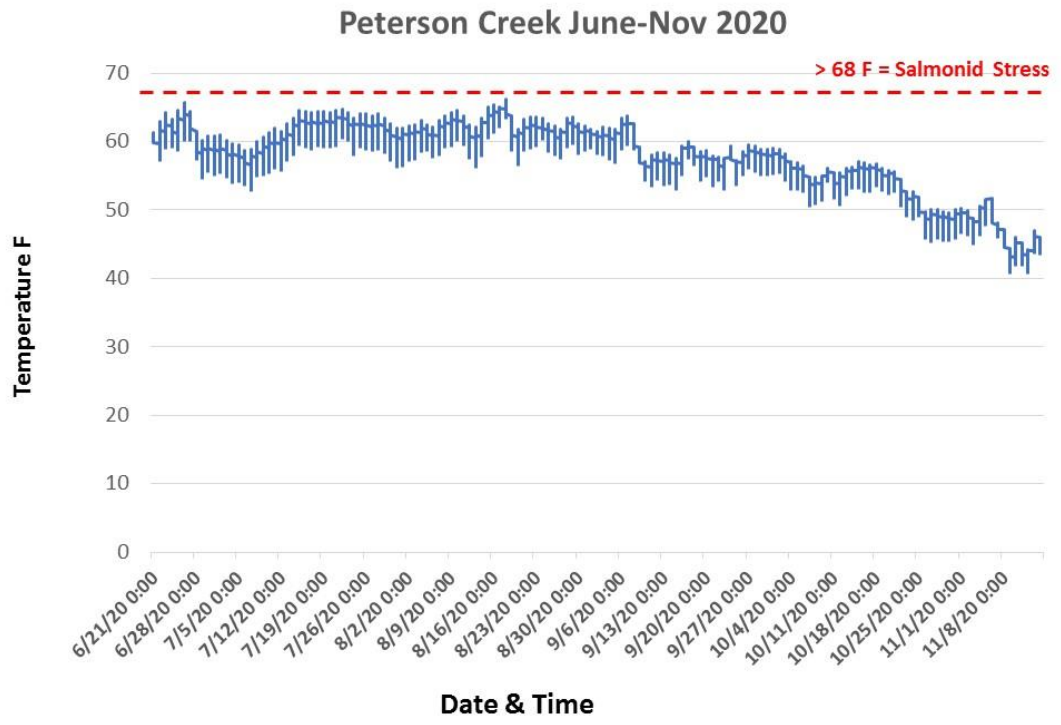

Figure 30. Lower Peterson Creek water temperature June – October 2020.

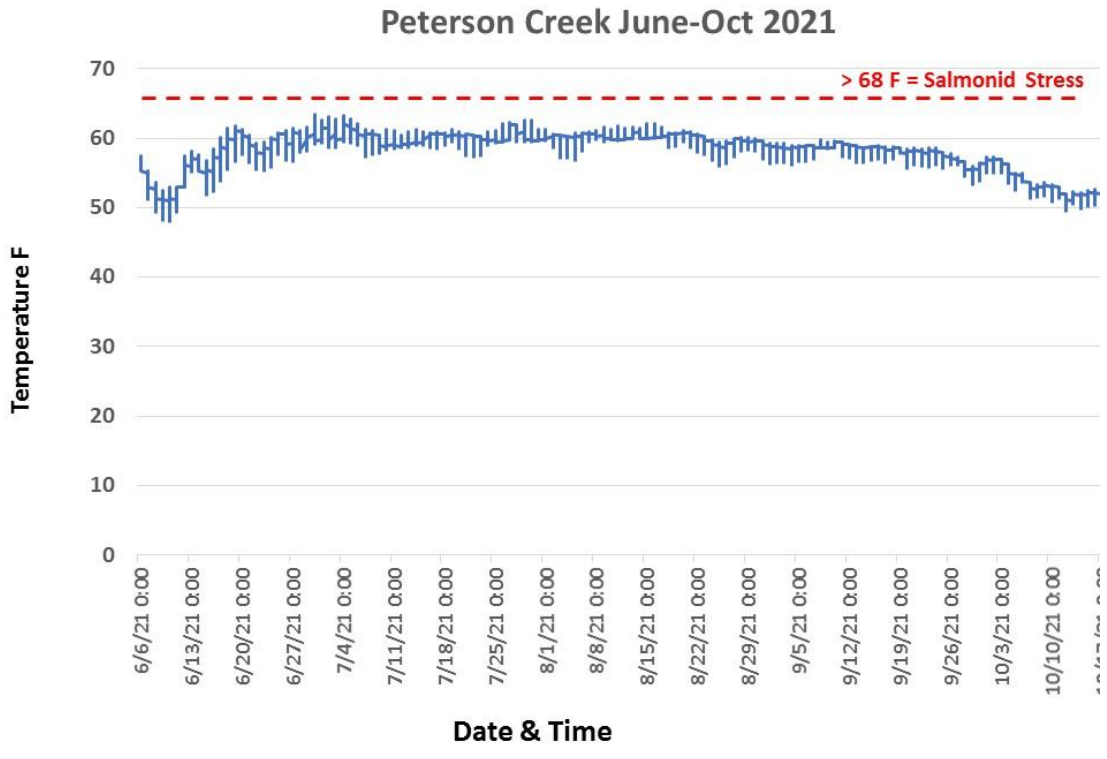

Figure 31. Lower Peterson Creek water temperature June – October 2021.

Figure 32. Looking down Lewis Creek on the Triple Creek Ranch. 6/22/2021.

Figure 33. Lewis Creek on Triple Creek Ranch with flow maintained in 2020. 11/11/2020.

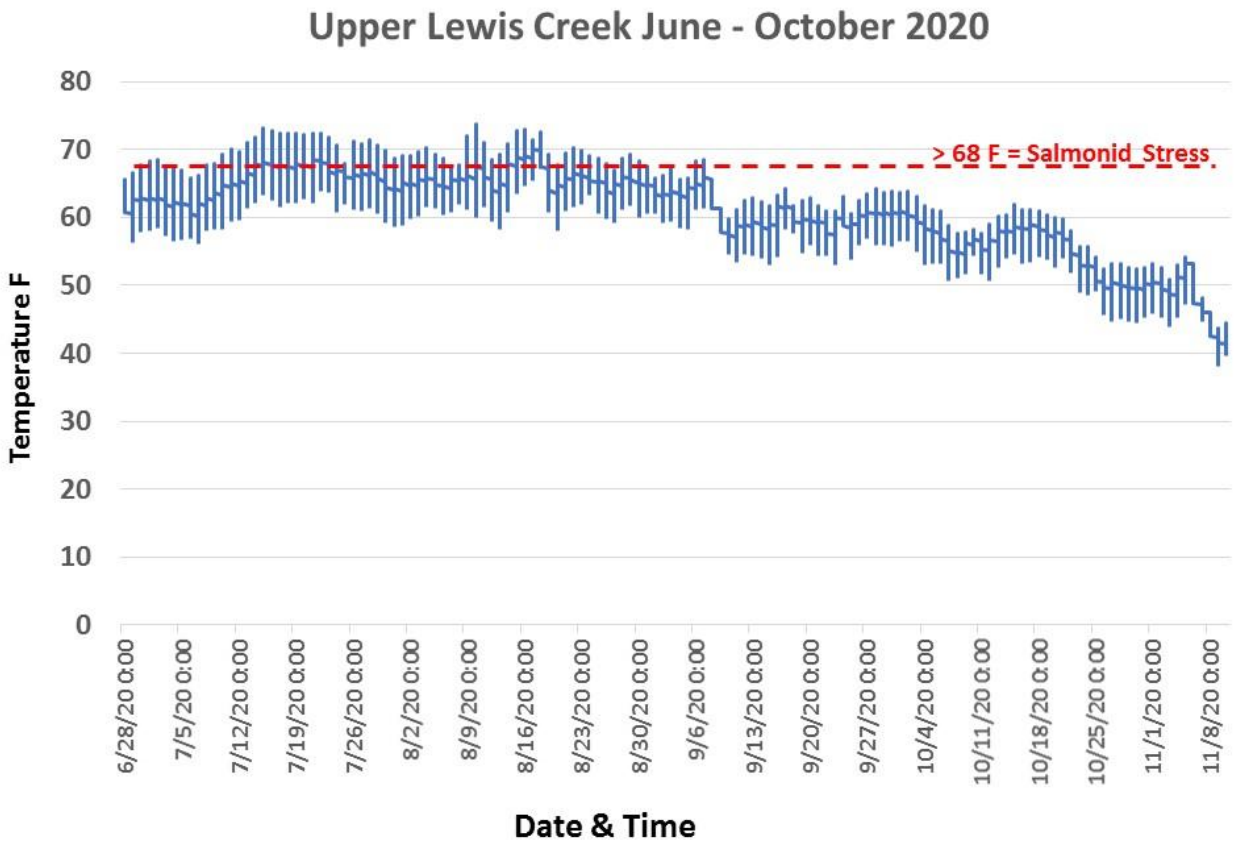

Figure 34. Lewis Creek water temperature from June to October 2020.

Tenmile Creek Mainstem Reaches

Following the convention of the ERRP 2020 Action Plan, main reaches of Tenmile Creek will be discussed from upstream to downstream. The entire Tenmile Creek watershed is approximately 65 square miles. Mainstem reaches are actively used as migration corridors, and also for spawning and rearing (CDFW 2009d). Chinook salmon use the entire length of Tenmile Creek for spawning in years of high abundance when there is sufficient flow for migration from October through January (Higgins 2017). Steelhead trout can migrate into steeper reaches above where Chinook can access, but may also spawn in main Tenmile Creek. Smaller redds have also been observed, indicating native rainbow trout spawning activity. These fish may have an ad-fluvial life history, where they reside in mainstem pools during low flows and then move back into tributaries to feed and spawn during winter and spring. Although coho salmon are rare in Tenmile Creek, it has optimal gradient and substantial potential for recovery if sediment transport can be reduced and cold-water flows restored. Pacific lamprey spawning in Tenmile Creek can also be quite active, as observed from 2015-2017 (ERRP 2020). From 2018 through 2020, at least some mainstem Tenmile reaches remained supportive of salmonids, but not in 2021.

Upper Tenmile Creek (above Little Case Creek): This reach of Tenmile Creek has the most impaired conditions of any other sub-basin. We placed temperature probes in the channel above Highway 101 in 2018 and 2019, but Tenmile Creek went dry at this location in both years. The creek went dry even earlier at this location in 2020 and 2021 (Figure 35). We have also done reconnaissance in the reach at Harwood Park, not far above Cahto Creek, where the bed is comprised of silt and sand, and highly aggraded, with pools filled and spawning gravels silted in. This is indicative of major sediment sources somewhere in this sub-basin. When a stream bed is buried or aggraded, that can contribute to loss of surface flow. The U.S. Geologic Survey (Ferrar1986) noted that groundwater resources in the upper Tenmile Creek sub-basin are very poor, which likely contributes to lack of flow. Also, the headwaters arise on the east side of the Maacama Fault in an area that is less water bearing.

Figure 35. Upper Tenmile Creek bed dry looking downstream towards Highway 101. 8/20/21.

Upper Middle Tenmile Creek (Little Case Creek to Wilson Creek): ERRP has monitored this reach of Tenmile Creek since 2018. It is the only mainstem reach that maintained flows and water temperatures cold water enough to support steelhead and trout throughout the year (ERRP 2020), including in 2020. Despite the drought, steelhead were found successfully rearing in October 2020 above Tenmile Creek Road (Figure 36), but the entire reach dried up in 2021 (Figure 37). This likely had major impacts on the resident rainbow trout population as well as reducing the standing crop of juvenile steelhead (See Discussion).

Figure 36. Trout juveniles in Upper Middle Tenmile Creek above Tenmile Road. 10/21/20.

Figure 37. Tenmile Creek dry below Tenmile Creek Road. 9/17/21. Photo by Margaret Andrews.

Tenmile Creek reaches upstream of Little Case Creek and below Wilson Creek typically lose surface flow or disconnect in moderately dry and dry years. Groundwater contributions are likely a major influence on this reach (Ferrar 1986), although ERRP has not had access to Mud Springs Creek that may also be contributing to surface flow in this reach.

We measured water temperature in this reach at the wet-ford in 2018 and found them suitable for juvenile steelhead and rainbow trout rearing (66 F MWAT). The temperature was somewhat warmer in 2020 (Figure 38) with diurnal temperatures rising above stressful levels for salmonids (68 F). Nocturnal temperatures dropped below this threshold and would have allowed salmonids time to recover.

We have also monitored water temperature further upstream from Tenmile Creek Road and below Mud Springs Creek, on the Raymond property. Water temperature there in 2019 was 66.1 F, within the optimal range for steelhead and trout, and older age steelhead or native trout inhabited a deep pool on the property. In 2020, water temperatures were higher but still suitable for salmonids (Figure 39).

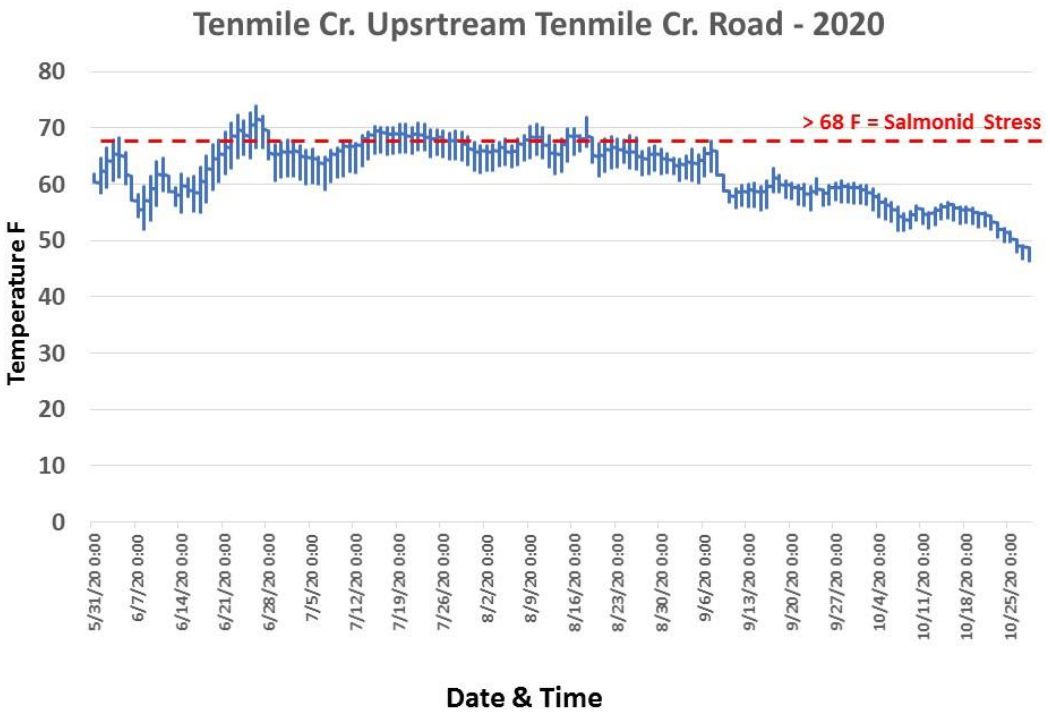

Figure 38. Tenmile Creek upstream Tenmile Creek Road June - October 2020

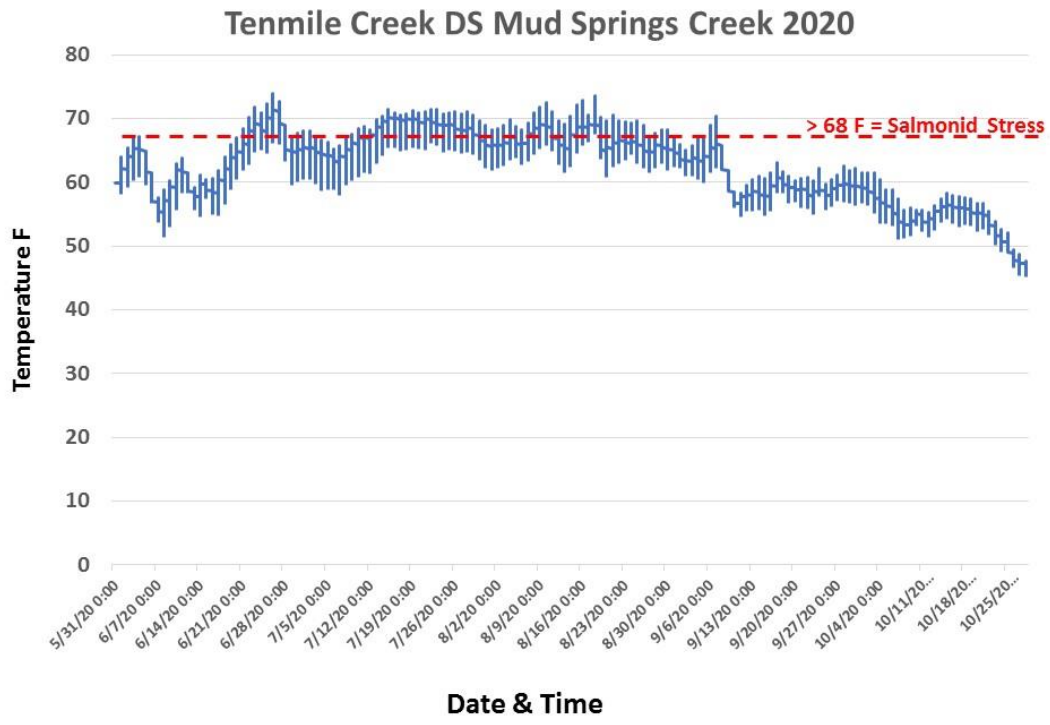

Figure 38. Tenmile Creek downstream Mud Creek, June - October 2020

Lower Middle Tenmile Creek (Wilson Creek to Grub Creek): This reach of Tenmile Creek has fluctuated widely in terms of aquatic ecosystem function since 2018, depending on the amount of precipitation and flow. We have monitored this reach upstream and downstream of Big Rock Creek, on the Black Oak Ranch and on the Vassar property downstream of Highway 101 above Grub Creek. In 2019, this reach of Tenmile Creek maintained surface flow, although the ambient water temperatures were too high for optimal salmonid rearing. The maximum floating weekly average temperatures were 76.6 F at old USGS gauge site upstream of Big Rock Creek, 70.2 F downstream of Steep Gulch, and 76.9 F at the Vassar property. This variability suggests surface or groundwater contributions providing cooling at the location below Steep Gulch. This reach changed profoundly in 2020, due to lack of flow, and almost completely dried up in 2021.

In 2019, hundreds of steelhead juveniles were able to survive in cold water refugia in main Tenmile Creek immediately below Streeter Creek, and resident rainbow trout utilized larger pools despite warm temperatures. In 2020, connecting flow was lost in August and isolated pools that remained strongly favored warmwater fish, such as green sunfish, and bullfrog larvae. Aquatic function deteriorated further in 2021, as pools dried up altogether or were so choked with algae that they were not suitable for fish life (Figure 39). On the Black Oak Ranch above Streeter Creek, the index pool dried up to the point that even bullfrog tadpoles were scarce (Figure 40).

Lower Tenmile Creek at the Vassar property is one of the most closely studied reaches for fish use in the watershed. In an average water year, dives from May to late June find an abundance of juvenile steelhead, then the fish community shifts to warmwater species after July. In dry years, this transition can happen much earlier. On May 10, 2021 ERRP was joined by UCB post-doctoral researchers Phil Georgakakos and Gabe Rossi, and they identified and photographed juvenile Chinook salmon, mixed in with steelhead trout of different ages (Figure 41). What was unusual for early May was the abundance of warmwater species, with numerous California roach and green sunfish also present (Figure 42). After late July in 2021, no fish survived at this site and it almost completely dried up.

Figure 40. Tenmile Creek downstream of Big Rock Creek choked with algae. 8/10/2021.

Figure 41. Tenmile Creek on the Black Oak Ranch with pool almost dried up and fish-less. 8/10/21.

Figure 42. Steelhead juvenile top over Chinook juvenile at Vassar's. Photo by Dr. Phil Georgakakos. 5/10/2021.

Figure 43. California roach in center and foreground with green sunfish at upper left on Tenmile Creek at Vassar place. 5/10/21.

The reach of Tenmile Creek on the Vassar property has optimal spawning substrate for Chinook salmon (Figure 44) and can have some of the highest spawning densities in the Eel River watershed in years of high abundance when flows for migration are adequate (ERRP 2017). However, rains did not come until after Thanksgiving for three years in a row in 2018, 2019 and 2020, and there was little opportunity for Chinook disbursement into tributaries for spawning. Luckily, rains in December 2020 and January 2021 allowed access to Tenmile Creek for spawning upstream at least as far as the Vassar property, as indicated by the presence of Chinook juveniles in spring of 2021.

Early and unseasonably heavy rain in the last week in October 2021, and continuing rainfall in November and December, allowed passage for Chinook salmon to spawning areas throughout the Eel River watershed, including into Tenmile Creek. Dozens of Chinook spawned on the Vassar property and more staged there (Figure 44) and then migrated further upstream.

Figure 44. Chinook habitat on Vassar property that was utilized in fall 2021. 11/15/2021.

Figure 45. School of Chinook holding in main Tenmile Creek on Vassar property. 11/16/2020.

Lower Tenmile Creek (Grub Creek to the South Fork Eel): ERRP has the cooperation of landowners near Peterson Creek and just upstream of the South Fork Eel River, so we have monitored the lower portion of this reach closely. TGAEC has found that lower Tenmile Creek at their gauge site not far upstream of the South Fork maintained surface flow since 2018, although just barely in 2020 and 2021. In 2019, flow was connected in lower Tenmile Creek below Grub Creek, but not in years since. Riffles just downstream of Grub Creek go dry, but pools above (Figure 46) and below Peterson Creek (Figure 47) maintained water and fish life, with California roach the most abundant species and juvenile steelhead intermixed.

Water temperatures in 2019 in lower Tenmile Creek above and below Peterson Creek and at the flow gauge operated by TGAEC indicate cooling temperatures, unlike the lower middle reach (i.e. Vassar property). Above Peterson Creek Tenmile Creek had an MWAT of 71.4 F, below Peterson Creek the MWAT was 71.2 F and at the TGAEC gauge the MWAT was 72.2 F. These temperatures are stressful for salmonids, but there may be cooler places locally due to connection with groundwater (see Discussion). For example, the reach upstream of Peterson Creek had cooler water temperatures in 2020 (Figure 48) and in 2021 (Figure 49) than in 2019. Connecting flows pass through riffles where the stream warms, and when surface flows are lost groundwater temperatures have greater influence, which causes cooling. Downstream of Peterson Creek, the isolated pool temperature in 2021 (Figure 50) did not show hyporheic influence and rose well above the stressful range for salmonids.

Figure 46. Pool upstream of Peterson Creek with good water quality and fish. 8/20/21.

Figure 47. Steve Brown with fish bearing isolated pool on Tenmile Creek downstream of Peterson Creek. 8/20/21.

Water temperature data collected by TGAEC at the lower Tenmile Creek flow gauge do not show signs of hyporheic influence in 2020 (Figure 51) and 2021 (Figure 52). Both years had protracted periods with maximum water temperatures over 80 F, which is potentially lethal for salmonids and would have strongly favored warmwater fish. The 2020 data show a very clear deflection point, with water temperatures dropping around September 8, 2020 due to the flare up of the August Fire. Water temperatures in 2021 followed a more typical cycle, with decreases in mid-September when nights cool and flows increase as tree evapotranspiration drops.

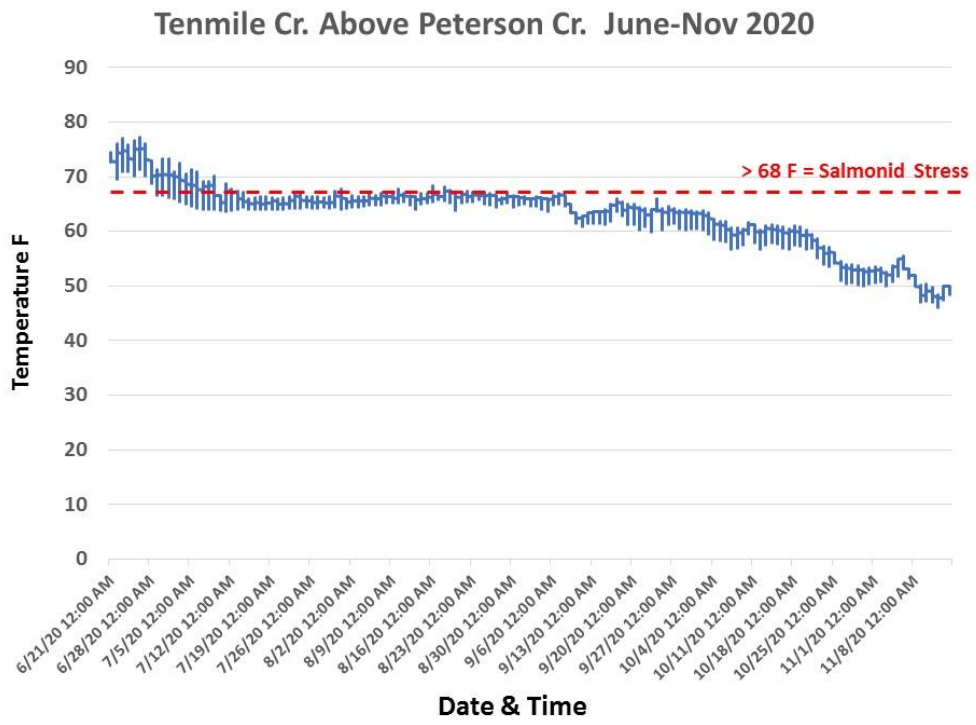

Figure 48. The water temperature of Tenmile Creek above Peterson Creek from June to early November 2020 does not reflect ambient levels, but rather local groundwater influence.

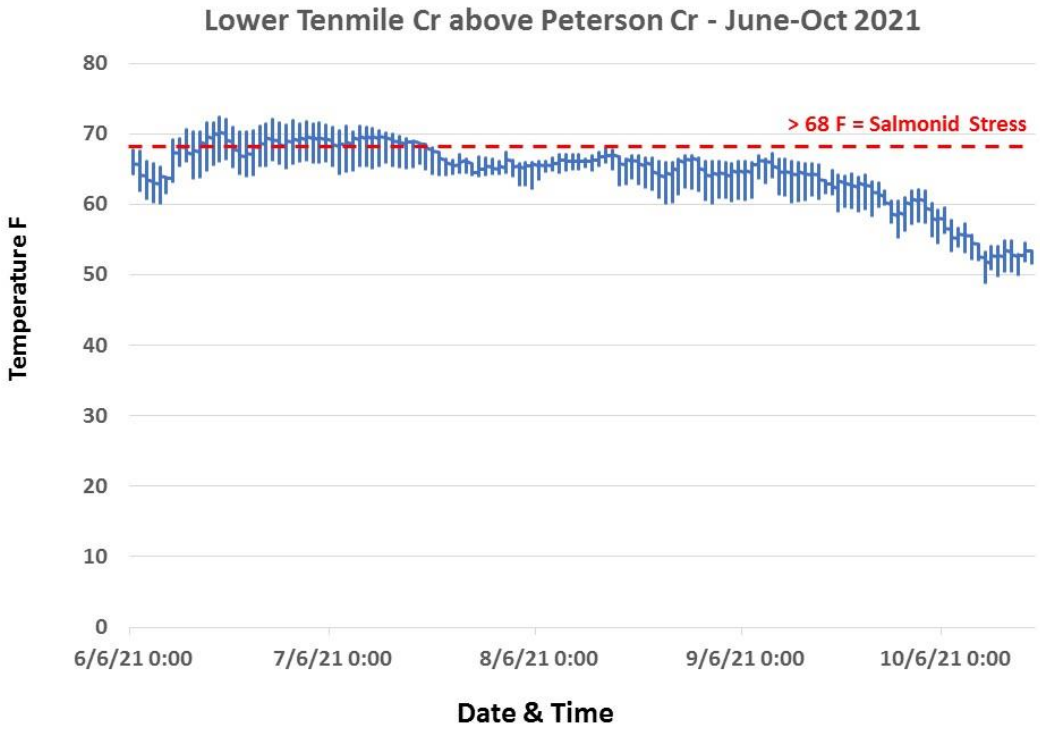

Figure 49. The water temperature of Tenmile Creek above Peterson Creek from June to early October 2021 shows higher fluctuation, then moderation as surface flow diminished.

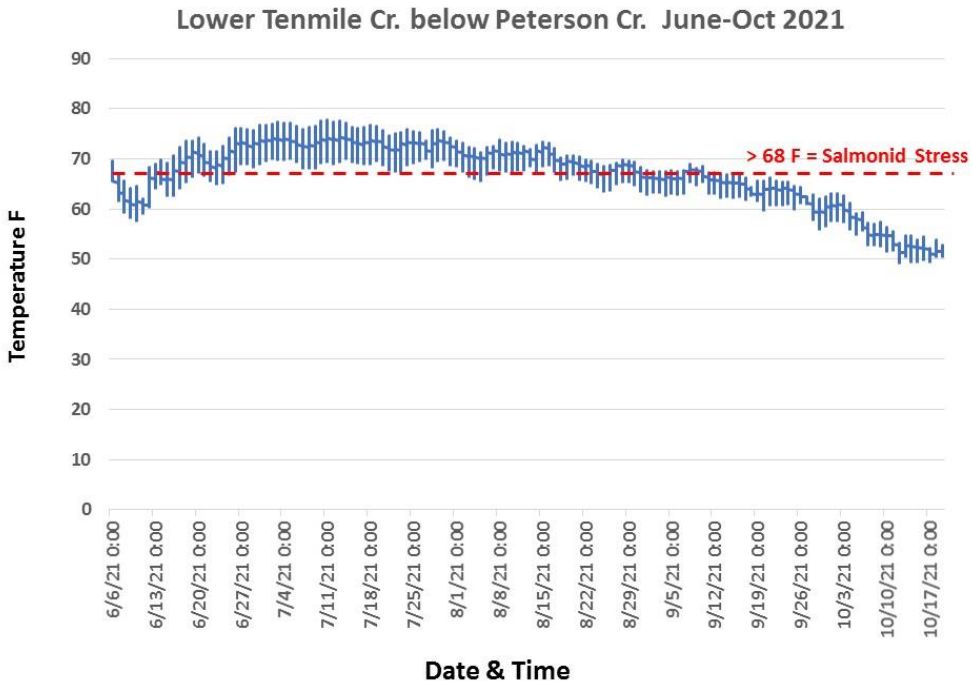

Figure 50. Lower Tenmile Creek downstream of Peterson Creek from June to October 2021.

Elder Creek

Elder Creek, which is a tributary to the South Fork Eel River on the Angelo Reserve, serves as a control for comparison with Tenmile Creek tributaries. USGS measures the flow and temperature of Elder Creek and water temperature data for 2020 and 2021 were downloaded from their website. As noted above, Elder Creek maintained surface flow in both 2020 and 2021, but water temperatures in the latter year were elevated substantially (Figure 53). While 2020 water temperatures rarely exceeded the stress level for salmonids, the maximum daily water temperature exceeded 68 F for most of July and August in 2021, attaining a maximum water temperature of 72.1 F. This unusually high, and is connected to near record low flow and water volumes. However, nocturnal temperatures dropped below 68 F, which would allow steelhead and trout to recover from warmer diurnal temperatures. Coho salmon adults were noted migrating in Elder Creek in December 2020 (Peter Steele personal communication), but juvenile coho would have been acutely stressed by summer 2021 temperatures, unless they could find local refugia in stratified pools near zones of upwelling with hyporheic connection.

The August Fire and Temperature Data

The period of the August Fire blow up after September 8, 2020, when it moved into dead and dying oak woodlands in the North Fork Eel River watershed, created an interesting pattern in water temperatures with a universal decline after that date as a result of smoke (Figure 54).

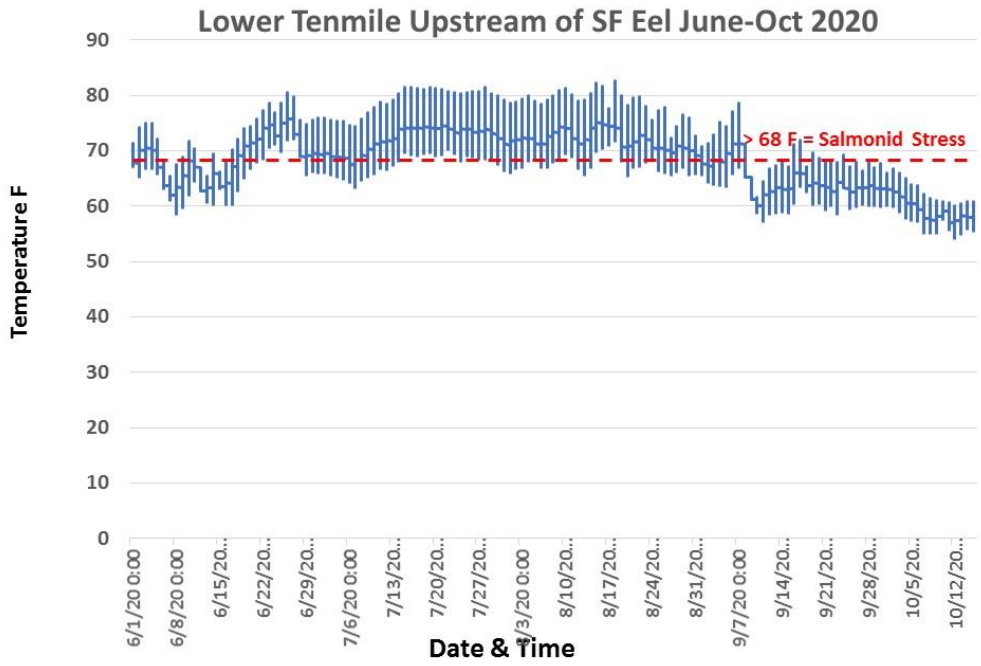

Figure 51. Water temperature of the lower Tenmile Creek above the South Fork Eel in 2020 at ERRP flow monitoring site. Data from TGAEC.

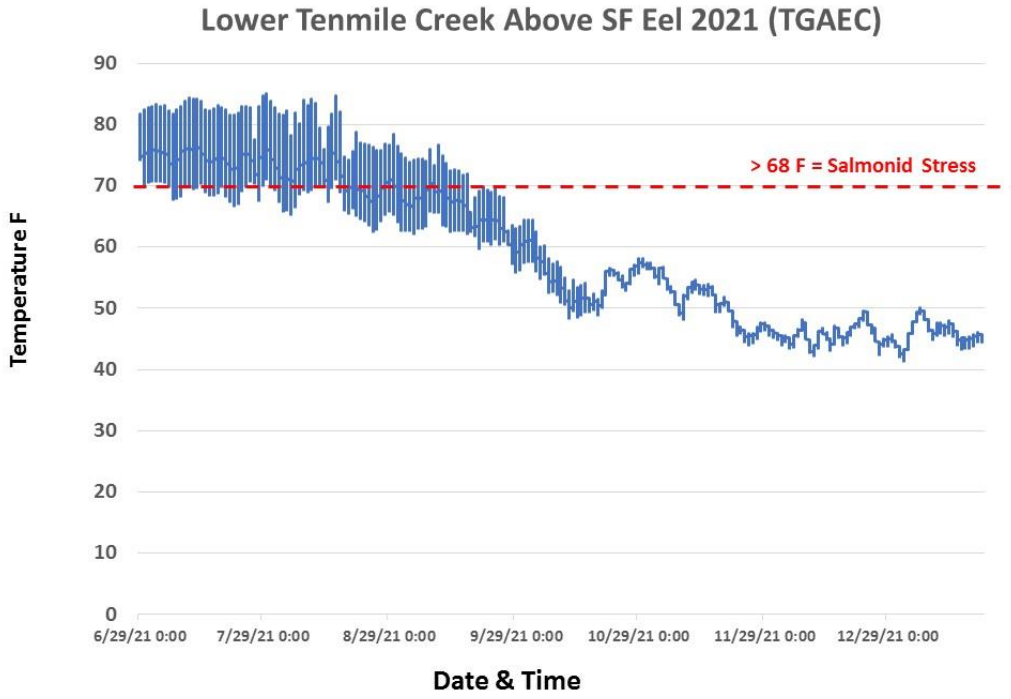

Figure 52. The water temperature of Tenmile Creek above the South Fork Eel River from June to the end of December 2021. Data from TGAEC.

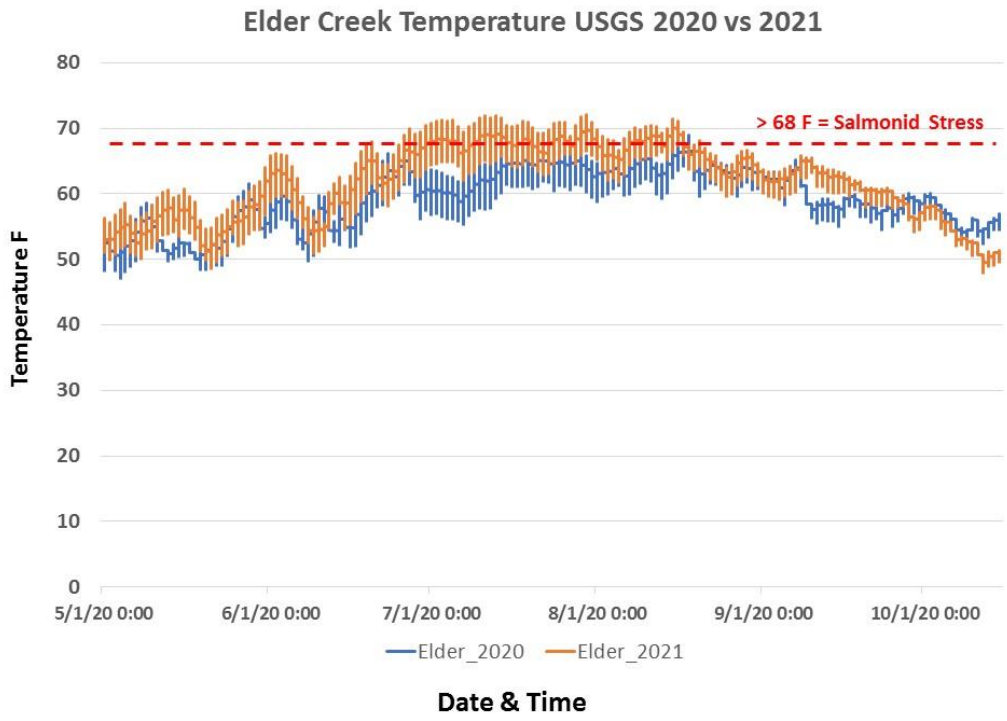

Figure 53. Water temperatures of control stream Elder Creek remained mostly below stressful for salmonids in 2020, but exceeded 68 F frequently in 2021. Data from USGS.

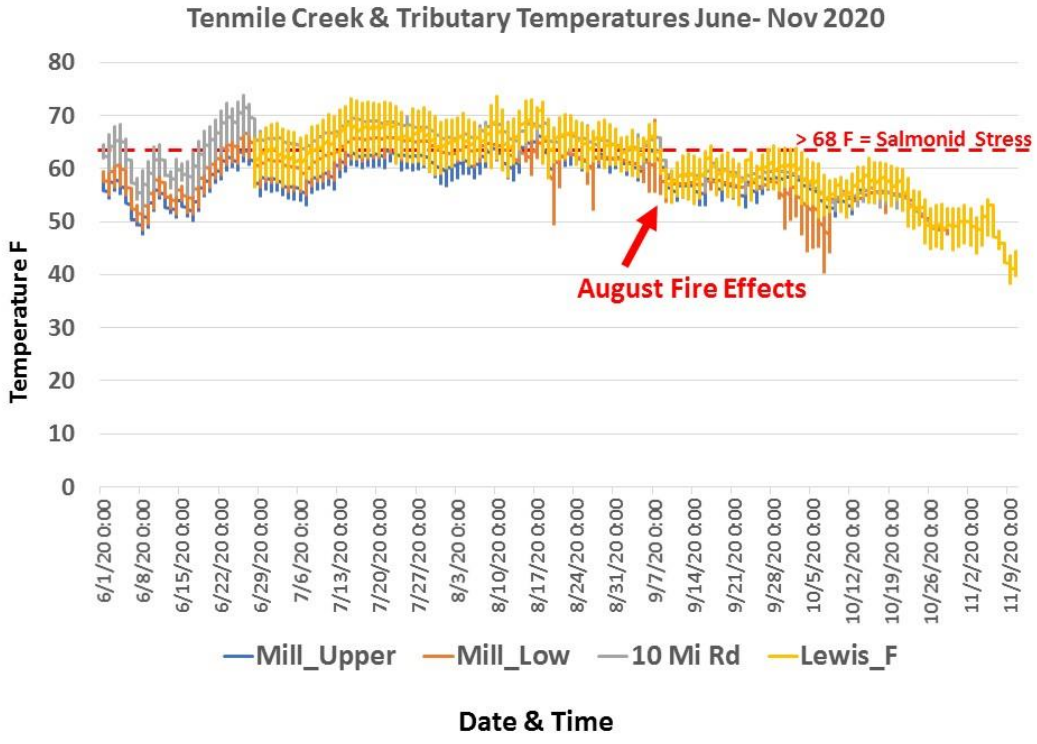

Figure 54. Water temperature of Tenmile Creek and tributaries cooled due to smoke from the August Fire.

Time-lapse Cameras

ERRP has operated time-lapse cameras in the Tenmile Creek watershed and Elder Creek since 2018. The main Tenmile Creek time-lapse camera above Big Rock Creek is no longer maintained, but in 2021 Peterson Creek was added to make a total of ten locations (Figure 55). Photos taken every 30 minutes are blended into time-lapse movies of flow that are instructive and dramatic. Still photos may also be useful. Figure 56 shows upper Mill Creek maintaining surface flow on 08/20/20 while Figure 57 shows the same location dry on 8/20/21. The Vassar time-lapse camera on lower Tenmile Creek captured flows that likely enabled successful Chinook migration on 1/04/21 (Figure 58). The same location was dry on 8/20/20 (Figure 59). Videos are posted at https://vimeo.com/eelriverrecoveryproject. Time-lapse cameras all over the Tenmile Creek watershed and everywhere else in the Eel River watershed captured images that went from orange to dark red, and then black for hours on September 8 and 9, 2020 due to smoke.

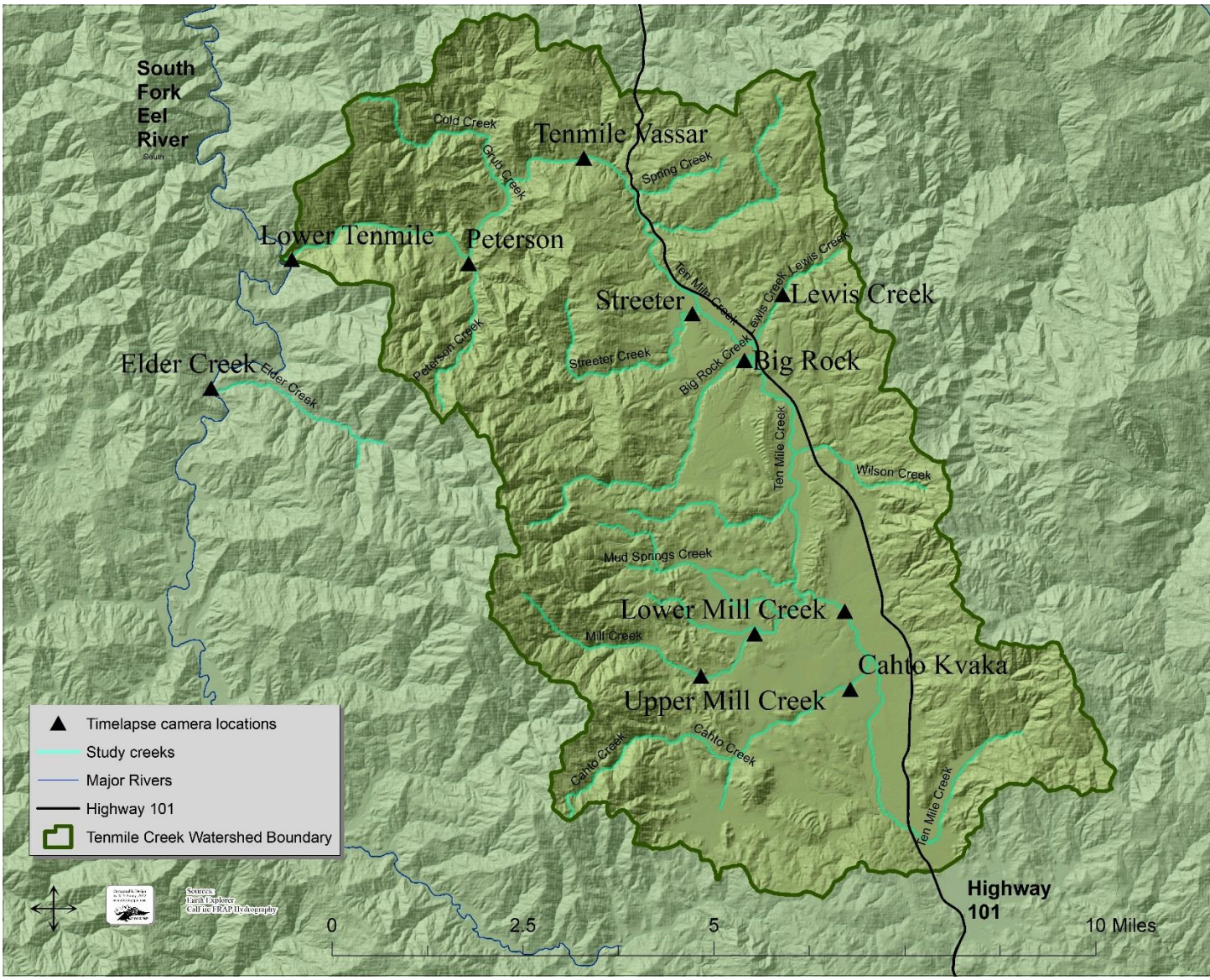

Figure 55. Locations of ERRP time-lapse cameras in 2021. Map by Noel Soucy, Legacy the Landscape Connection.

Figure 56. Upper Mill Creek flowing. 8/20/20.

Figure 57. Upper Mill Creek dry. 8/20/21.

Figure 58. Lower Tenmile Creek at Vassar property. 01/04/21.

Figure 59. Lower Tenmile Creek dry. 08/20/20.

Discussion

The report *Water Year 2021: An Extreme Year* by the California Department of Water Resources (DWR 2021) indicates that 2020 was the fifth driest year on record in the State, and that WY 2021 ranked second behind 1924. The fact that these years followed one another in succession created a cumulative effect. A parched landscape and low groundwater reserves set up by 2020, combined with low WY 2021 rainfall, led to the worst Tenmile Creek aquatic conditions in recent history.

Tenmile Creek compared favorably to nearby Eel River tributary, Outlet Creek, in May 2021. Algae growth was already advanced in Outlet Creek and steelhead juveniles we only located at two monitoring stations out of ten. At the same time, Tenmile Creek maintained good conditions, with more retarded algae growth and juvenile steelhead and native trout widespread and abundant. Many of the trout fry were very small, and there were small redds, indicating spawning by native trout. The most unfortunate occurrence during WY 2021 was the loss of flow in a critical mainstem reach between Little Case Creek and Wilson Creek that has been a summer refugia for trout. Local interests reported that new agricultural diversions in this reach may have contributed to flow problems in WY 2021. While steelhead trout will re-seed the watershed, and some of their progeny may manifest a resident life history, it will likely be a while before standing crops of native trout rebound.

Chronic drought may be the new normal, so Tenmile Creek watershed planning should emphasize water conservation and activities that can help restore hydrology. Residents can't affect how much precipitation falls, but they can affect how much is stored in the landscape and how much runs off, when it does rain.

Reducing Forest Evapotranspiration

ERRP was assisted by the hydrologic firm TGAEC that ran the VELMA (Visualizing Ecosystem Land Management Assessments) model created by the U.S. EPA (McKane et al. 2014). Results indicated that flow patterns in Streeter and Big Rock creeks were driven by forest evapotranspiration, similar to the findings of Stubblefield et al. (2012) in the upper Mattole River and Moore et al (2004) in the Cascades of Oregon. Therefore, over-stocked Douglas fir forests resulting from post-WW II logging need to be thinned and firs competing with oak trees also need to be removed. Hahm et al. (2018) found that oaks use far less water than conifers in summer. Both activities will increase base-flows and reduce the risk of catastrophic fire. ERRP is working cooperatively with the Tenmile Creek Watershed Council and the Cahto Tribe to get grant funding for more forest health planning and implementation.

Restoring Meadow Hydrology

The Tenmile Creek watershed has magnificent grasslands, especially in the eastern half that is underlain by Central Belt Franciscan Mélange geology. Historic over-grazing, introduction of non-native grass species and plants, and associated gully erosion have degraded meadow habitat and led to loss of water storage that these areas once had. We are planning to use woody material from forest health projects to heal gullies, to raise the water table, and to reintroduce native grasses and other plant species to stabilize these areas. The result will be more productive meadow areas for wildlife, an increase in stream baseflow at least seasonally, reduced erosion, and diminished fire risk as lush perennial native grasses replace more flammable non-native species. These activities could be carried out under forest health projects that ERRP and TCWC are working on.

Restoring Wetlands

The Cahto Tribe created impoundments and lakes all over the Tenmile Creek valley floor, creating a huge water bank that would have led to abundant, perennial, cold water flows. European settlers breached impoundments, channelized creeks into a straight line and dug trenches to systematically drain wetlands. We have identified one such large trench on the Cahto Creek Ranch and intends to seek permits to fill it with woody debris and organic material from forest health implementation. Restoring sheet flow to the nearby meadow would likely help significantly to recharge underlying groundwater that might be released over time via hyporheic connection to Tenmile Creek. In other cases, historic logging and associated equipment operation compacted areas all over the watershed, including wetlands or uplands adjacent to wetlands. While forests may grow vigorously after logging, compaction of roads and landings may be long-lasting, effecting runoff for decades (Haynes et al. 1996). Road densities greater than four miles of road per square mile effectively double the stream network and peak flood discharges, and deplete infiltration into the watershed's water storage system (Jones and Grant

1996). Steps to improve hydrology could include 1) reducing road networks by putting roads to bed (Harr and Nichols 1993), 2) recontouring roads that will remain in use by outsloping onto vegetated slopes ((Weaver et al. 2015) , and 3) ripping old roads and landings and 4) interring wood derived from forest health projects. Burying woody debris can help increase soil moisture storage capacity and soil fertility, while also helping in a big way with carbon sequestration (Zeng 2008).

Restoring Headwater Streams

Many headwater channels of Tenmile Creek have lasting hydrologic impairment as a result of past logging activities, including yarding and skidding logs up and down creek beds and sometimes completely re-routing streams. Historically headwater tributaries would have had a series of very large wood jams that would meter sediment, provide complex habitat for salmon and steelhead, and also constitute a water bank (Sedell et al. 1988). Skidding logs down channels caused a complete removal of large wood, sedimentation of the stream bed and downcutting that causes nearby hillslope instability. In aggregate, these changes have compromised water storage and water supply in affected tributaries. Large woody debris from forest health projects could be used to restore headwater stream channels and water storage capacity. ERRP recently completed a Forest Health Management Plan for the Kovner property on the unnamed tributary of upper Cahto Creek. The channel is down-cut (Figure 60) and ERRP recommends that large wood be used from subsequent forest health projects to create stair-steps to meter sediment, sort spawning gravels and rebuild the water table. This is similar in concept to the Sanctuary Forest large wood installations on upper Mattole tributaries that were shown to have benefit for nearby groundwater storage (Formosa 2013). These projects would need separate permitting and planning apart from forest health implementation, but the timing of the two projects would be closely coordinated.

Increasing Water Storage and Forbearance

The WY 2021 led to a widespread domestic water shortage in the Tenmile Creek watershed, as well as major flow problems for Tenmile Creek. As noted in the *Action Plan* (ERRP 2020), groundwater supply for homesteads on the west side of the Tenmile Creek basin is very poor and mostly insufficient to meet needs in dry years. This leaves residents with little alternative than to pump already stressed surface water sources, which hastens the desiccation of streams. In 2020 and 2021, many people had to purchase trucked water, a prohibitive expense for those of least means. The specter of continuing drought means that the community must think outside the box on water storage. ERRP believes the solution involves a major increase in tank water storage with a major component of the supply from rainwater catchment.

SCC Prop 1 Phase II is promoting water conservation on the west side of the Tenmile Creek basin, with an emphasis on the Cahto and Mill Creek watersheds. The idea is to get subsidized water storage for landowners in exchange for forbearance of water extraction from surface water or connected groundwater from May through November, similar to the upper Mattole (McKee 2004, Camp-Schramer 2014).

Figure 60. Unnamed tributary of Cahto Creek on Kovner property with good steelhead spawning gravels, but with channel down-cut five to six feet lessening nearby groundwater storage. 8/20/20.

Conclusion

An unusual rain event on October 24, 2021 set records in many areas of northern California. Amounts of six to nine inches in 24 hours were reported around the Tenmile Creek watershed. A question we should all consider is how much water ran off rapidly and how much percolated into the ground from this storm event, versus how much of the water would have infiltrated into groundwater in 1840. A concerted effort to restore watershed hydrology could make a critical difference in maintaining ecological function, even in the face of climate change.

The resilience of Tenmile Creek must also be considered in the context of the entire Eel River watershed, because of connectivity with refuge areas (Bradbury et al. 1995). The upper South Fork Eel River upstream of Tenmile Creek constitutes such as refugia (NMFS 2014). ERRP found that coho salmon juveniles not just survived in the upper South Fork Eel River and some key tributaries (Figure 60) through the summer of 2021, but that they thrived despite the record drought (https://vimeo.com/620959373). Tenmile Creek has more low gradient reaches that are optimal and suitable gravel for coho spawning than the upper South Fork (Williams et al 2006). Therefore, if flows and habitat were improved, coho salmon could recolonize. In the short term, any measures taken to reduce sediment, increase flows and to cool water temperatures will also benefit Chinook salmon, steelhead and native trout.

Figure 60. Coho salmon juveniles with high fitness in main South Fork Eel River upstream of Mud Creek. 9/24/21.

Water conservation elements within our SCC Prop 1 Phase II grant are helping plan and permit water storage for the organic farm at Black Oak Ranch and for Camp Winnarainbow that is also located there so both enterprises can ultimately forbear from surface water withdrawals from nearby Streeter Creek, which is a steelhead refugia.

As noted above, our more ambitious water conservation effort is on the west side of the Tenmile Creek watershed in what is recognized as the Tenmile Creek Priority Water Conservation Area. Our outreach worker is scoping people in this area to determine their interest in acquiring grant-subsidized water storage in exchange for consideration of forbearance from withdrawal of surface water and connected groundwater during periods of low flow (April 15 to November 15).

We expect to find so much interest that it may strain available grant funding resources, and there may need to be some level of community organizing to get more support from agencies. The best solution to water supply in the western Tenmile Creek basin is from disbursed storage where rainfall catchment is emphasized as a major source of stored water. This will not affect runoff or infiltration because the area from which water is caught (i.e. a rooftop) is insignificant when looking at the basin as a whole. Although the cost for meeting this need would be in the tens of millions cumulatively, plumbing people on the west side with Laytonville County Water District water would be many times the expense, take a lot of electricity to run, and maybe over-obligate their groundwater supply. The community also needs to work with Mendocino County on getting taxes on new water storage infrastructure waived or reduced so that tax increases associated with water conservation implementation do not create undue burdens on landowners of lesser means. ERRP will be working with the community on this new vision for meeting water needs and restoring Tenmile Creek.

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