FRIENDS OF
CORTE MADERA CREEK
WATERSHED

2020 Water Quality Report

Corte Madera Creek Watershed

Prepared by

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Thanks to the Marin County Fish & Wildlife Commission for funding the purchase of most of our loggers. Thanks also to Parker Pringle for installing the loggers and visiting them throughout the summer and Logan Smith for helping with installation.

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1. Background

The purpose of the monitoring is to determine temperature fluctuations and document dissolved oxygen (DO) at various locations in creeks in the Corte Madera Creek watershed. We have installed loggers in Ross Creek each year beginning in 2008. In 2009 we added loggers in Bill Williams Creek and Phoenix Creek, tributaries to Phoenix Lake. In 2012, we added loggers in Corte Madera Creek, San Anselmo Creek, Fairfax Creek, and Sleepy Hollow Creek. Typically, the loggers are installed in March or April and removed when the site dries or when winter rains start. Since 2016, we have not had loggers in Phoenix Lake or its tributaries. We removed the loggers near the mouth of Ross Creek because Corte Madera Creek at the mouth of Ross Creek is infested with New Zealand mud snails; they are easily carried on boots and equipment and we did not want to spread the infestation into the upstream reaches of Ross Creek.

2. Water Temperature and Dissolved Oxygen in Salmonid Habitat

Temperature is one of the most important environmental influences on salmonid biology. Water temperature determines the metabolism of salmon and steelhead trout. Temperature influences the availability of food, as well as growth and feeding rates; metabolism; development of embryos and alevins; and timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration. Elevated temperatures can cause stress and lethality. Temperatures at sub-lethal levels can effectively block migration, lead to reduced growth, stress fish, affect reproduction, inhibit smoltification, create disease problems, and alter competitive dominance. Additionally, the impact of elevated water temperature on salmonids is cumulative and positively correlated to duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival.

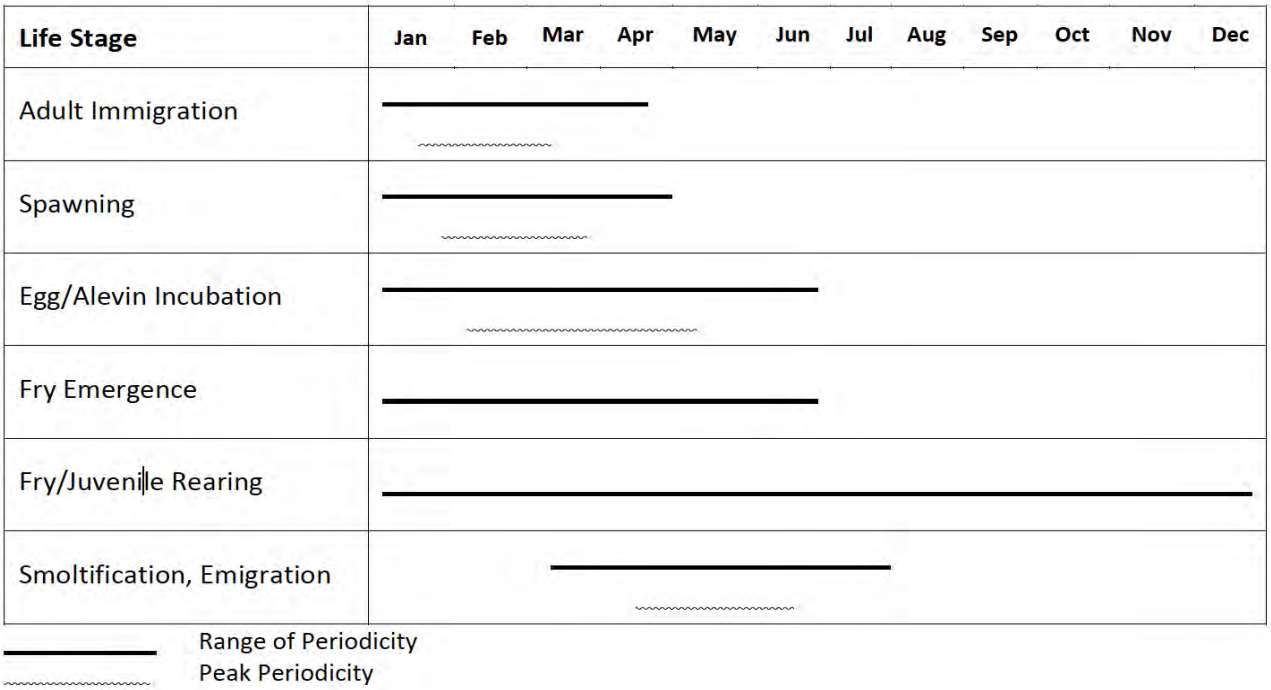
Table 1 and Table 2 provide the temperature requirements for different life stages of steelhead trout and when those life stages are likely to occur in the Corte Madera Creek watershed.

Table 1: Some habitat requirements for steelhead trout

Life Stage	Optimal Water Temperatures	Dissolved Oxygen (mg/l)
Immigration, Spawning, Incubation	7.8 – 11.2 °C	≥7 at ≤15°C ≥9 at >15°C
Fry Emergence	8.9 – 11.2 °C	
Rearing	12.8 – 15.6 °C	
Smoltification, Emigration	7.0 – 11.3 °C	

Source: A.A. Rich and Associates, 2000

Table 2: Steelhead trout life stage periodicities in the Corte Madera Creek Watershed



Source: A.A. Rich and Associates, 2000

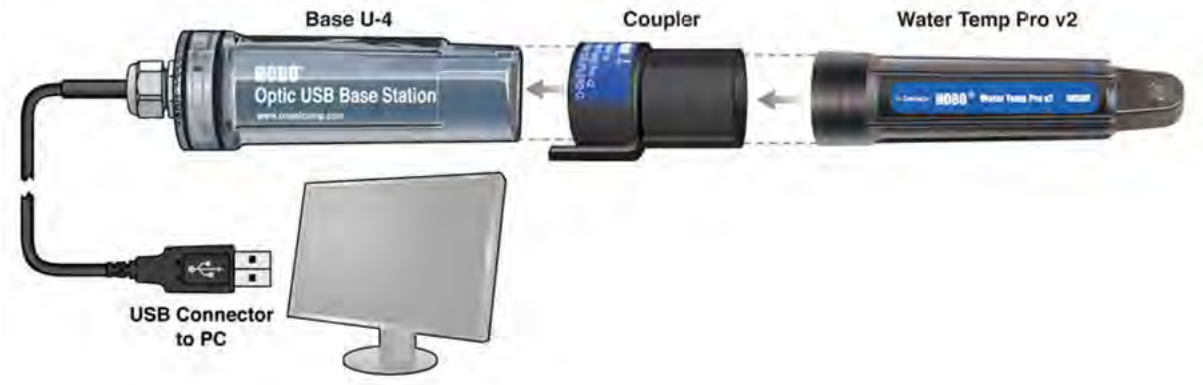
3. Equipment

YSI Pro20 Meter: During each visit when loggers are installed, downloaded, or removed, we measure temperature and DO using a YSI Pro20 Dissolved Oxygen Meter. This provides a check on the logger information. The YSI Pro20 is a handheld model that must be calibrated to "true" barometric pressure, i.e., not corrected to sea level, prior to sampling. It is an electrochemical sensor with an anode and a cathode confined in an electrolyte solution by an oxygen permeable membrane. Oxygen molecules that are dissolved in the sample diffuse through the membrane to

the sensor at a rate proportional to the pressure difference across it. The oxygen molecules are then reduced at the cathode producing an electrical signal that travels from the cathode to the anode and then to the instrument. Oxygen in the sample is rapidly depleted, leading to steadily dropping DO readings, unless there is a steady supply of water in the sample moving at least 6 feet per second past the membrane. Where the water is still, the sensor must be kept moving so that the oxygen immediately adjacent to the sensor is not depleted before the reading stabilizes. This works only moderately well later in the summer when water levels are low and some of the pools have stratified. Readings for both temperature and DO vary significantly within one pool when the water is stratified, even when it is mixed by the moving probe.

Temperature Loggers: Since the beginning of the project, we have used Onset Computer's HOBO Water Temp Pro v2 Loggers, which measure temperature only (Figure 1) They are downloaded in the field using a waterproof data shuttle (base station) to collect the data and launch the logger. In the office, the shuttle is connected to a computer to transfer the data.

Figure 1: Diagram of the HOBO temperature logger, shuttle, and computer to collect and transfer data



Source: Onset

The temperature loggers are designed for long-term deployment and are relatively robust. Each logger is attached to a stainless-steel cable with a shackle; the cable is fastened to a rock or tree root. We are careful to hide the cable and logger, but they are not completely invisible. These

loggers are vulnerable to damage from rocks in the water or curious passers-by. To provide some protection, we place the loggers in protective plastic covers (boots). Unfortunately, areas where people have easy access to the creek have proved problematical. Historically, three loggers have been stolen and some loggers have been removed from the water. Although it is easy to detect when a logger has been removed from the water, as it continues to record, and air temperatures are more extreme than water temperature, we now evaluate logger sites for their vulnerability to tampering.

In 2020, we added three HOBO U26 Dissolved Oxygen Data Loggers (Figure 2). These optical loggers, used to monitor both temperature and DO, are calibrated before they are shipped. This logger uses optical communications for data offload in the field with the same waterproof shuttle as the temperature loggers and the data are analyzed using the Onset software.

Figure 2: Diagram of the HOBO U26 Dissolved Oxygen logger

Source: Onset

These loggers are fragile and relatively expensive, so we enclosed them in steel pipes to protect them from disturbance. Figure 3 shows Parker Pringle, a board member of Friends in 2020, and Logan Smith, an intern from Archie Williams (formerly Sir Francis Drake) High School's SEA DISC Academy preparing to install logger RC0.5.

Figure 3: Preparing to install a DO logger inside protective steel pipes

Photo by Sandra Guldman

4. Logger Installation

Table 3 lists locations of loggers and the dates they were deployed in 2020. Figure 4 shows their locations. No loggers were installed in Fairfax, San Anselmo, or Sleepy Hollow creeks due to very low water levels in 2020.

We attempt to locate sites with relatively deep, moving water. The deepest pools are not selected, because we want to measure the temperature of water moving in the creek, not standing in pools. Unfortunately, it is inevitable that as water levels drop, some loggers are in stratified pools with little or no current.

Table 3: Deployment of loggers in 2020

Location	Logger ID	Installed	Removed	Notes
Near Vault	2053958	3/7/2020, 11:40	11/10/2020, 15:50	
RC0.5	20799205	3/7/2020, 12:36	11/10/2020, 15:50	
RC1.5	2053959	3/7/2020, 12:17	11/10/2020, 14:50	
RC2	20799206	3/7/2020, 12:36	11/10/2020, 14:20	
RC3	2053960	3/7/2020, 13:20	6/8/2020 11:59	Creek Dry
RC4	20799207	3/7/2020, 13:45	7/16/2020, 13:14	Creek Dry

Figure 4: Location of Ross Creek loggers (RC1 was not deployed in 2020)

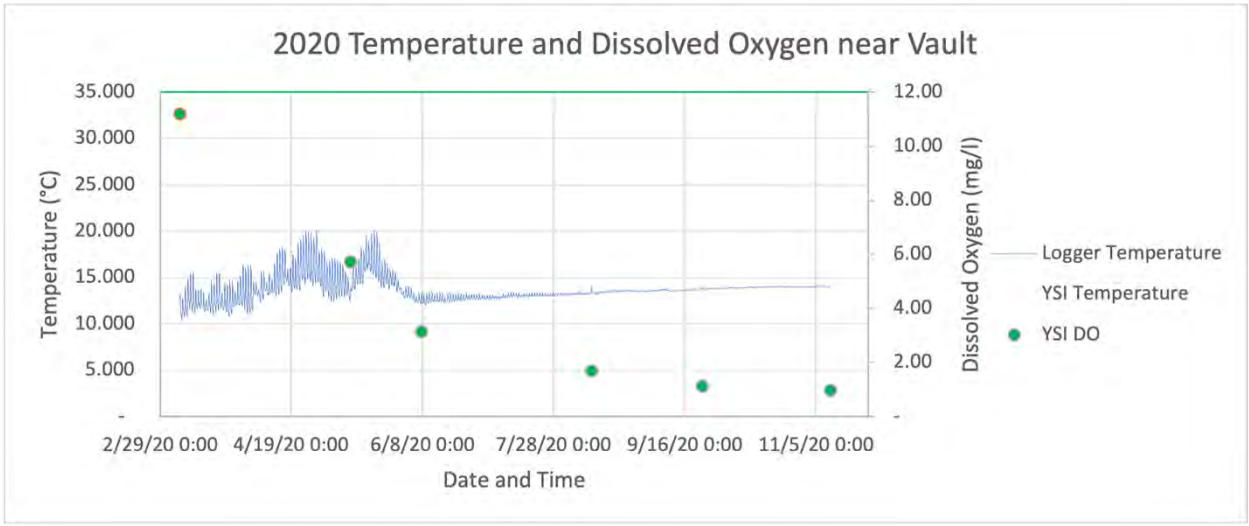
Loggers were set to record data points every 15 minutes. Temperature loggers were downloaded periodically. However, because of the difficulty of accessing the DO loggers in the protective pipes, we decided to download them once, at the end of the season. During a

download, each logger is connected to the data shuttle, which reads and then empties the logger memory.

5. Results

Logger near Vault: Although much less obvious in 2020 than in previous years (see Section 6), the upstream logger data (Figure 5) show the effect on Ross Creek of water flowing over the spillway at Phoenix Lake. Warm water from the top layer of Phoenix Lake, which stratifies early in the summer, flows over the spillway, and is further warmed by the sun shining on the spillway. This water, with high temperature and high DO, dominates flow in the upstream portion of Ross Creek. In mid-May 2020, after the lake level dropped and water stopped flowing over the spillway, the water temperature and DO dropped; at that point, Ross Creek flow was dominated by leakage from the low-level release valve and groundwater.

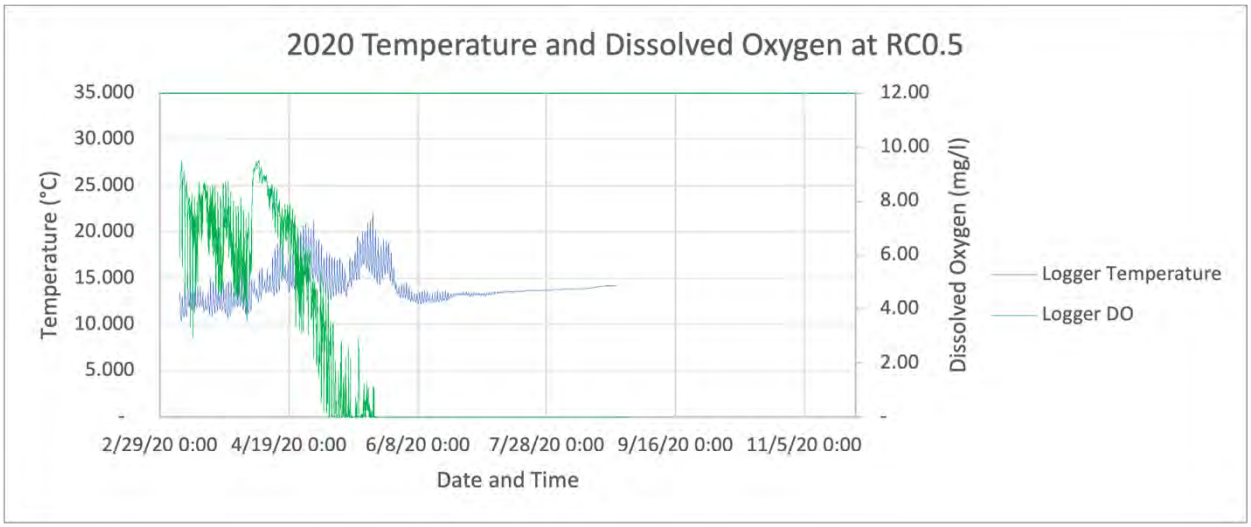
Figure 5: Temperature and DO in Ross Creek near Vault



Logger at RC0.5: The logger at RC0.5 recorded both temperature and DO (Figure 6). The data show a similar temperature profile to the logger near the Vault. However, in May it began to produce erroneous DO readings. When we removed the logger, the lens of the logger was covered with iron oxide precipitates making it impossible for the optical sensor to function. The water in upper Ross Creek is mostly fed by leakage from the low-level release valve in the dam

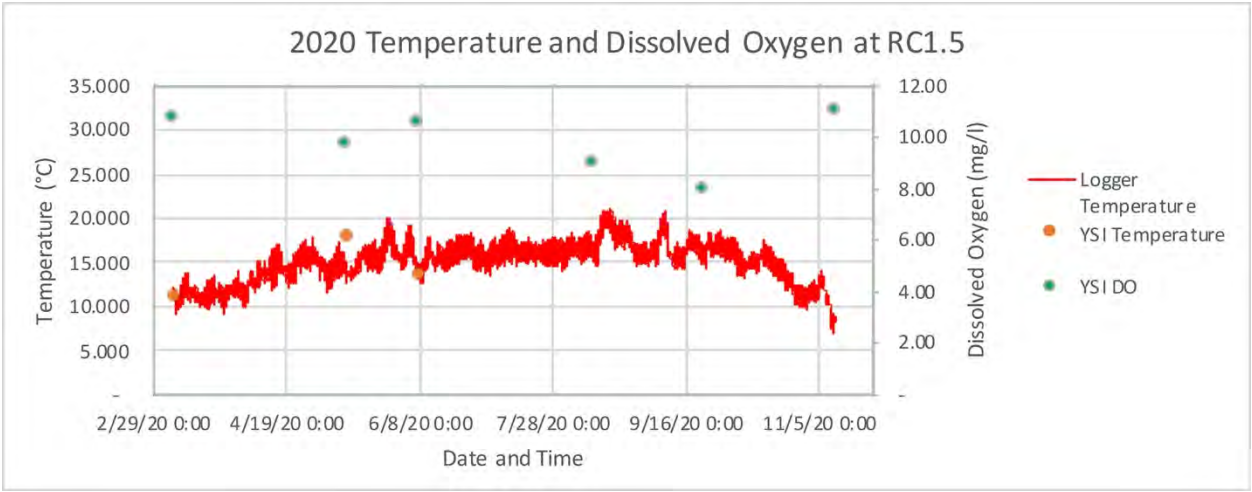
that is very high in iron and manganese; these oxidize quickly when the water is aerated and coat underwater surfaces.

Figure 6: Temperature and DO in Ross Creek at Logger RC0.5



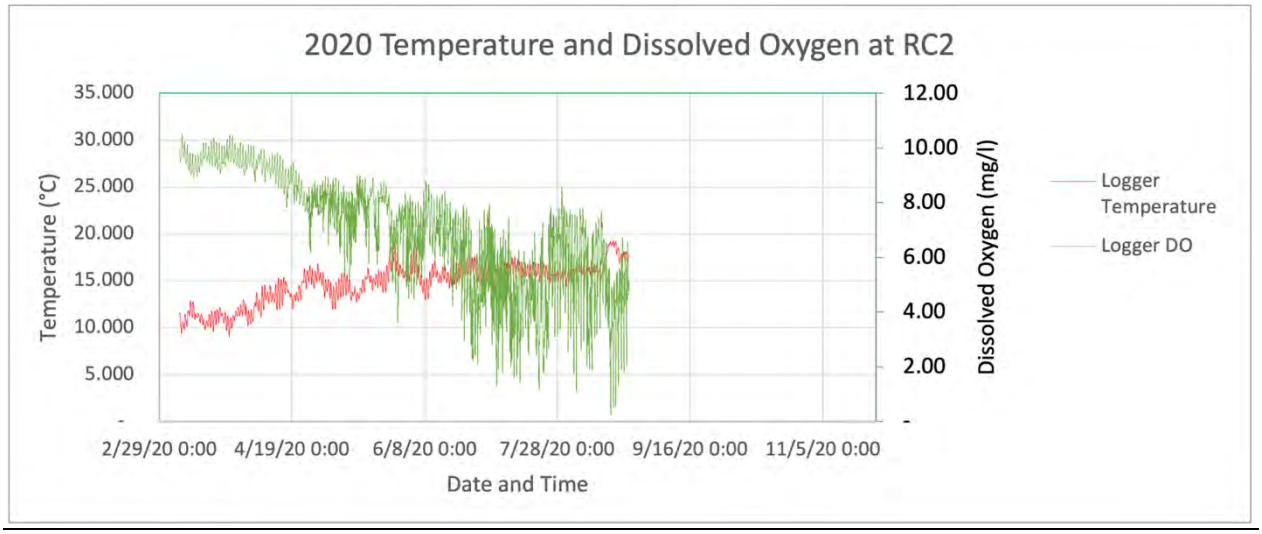
Logger RC1.5: The data recorded by the logger at RC1.5 (Figure 7) show strong diurnal variations in temperature, with typically high daytime and lower nighttime temperatures. This reach of the creek has some deep pools and structures that provide summer rearing habitat for salmonids. DO began to drop through the summer, but it remained high enough for salmonids throughout.

Figure 7: Temperature and DO in Ross Creek at Logger RC1.5



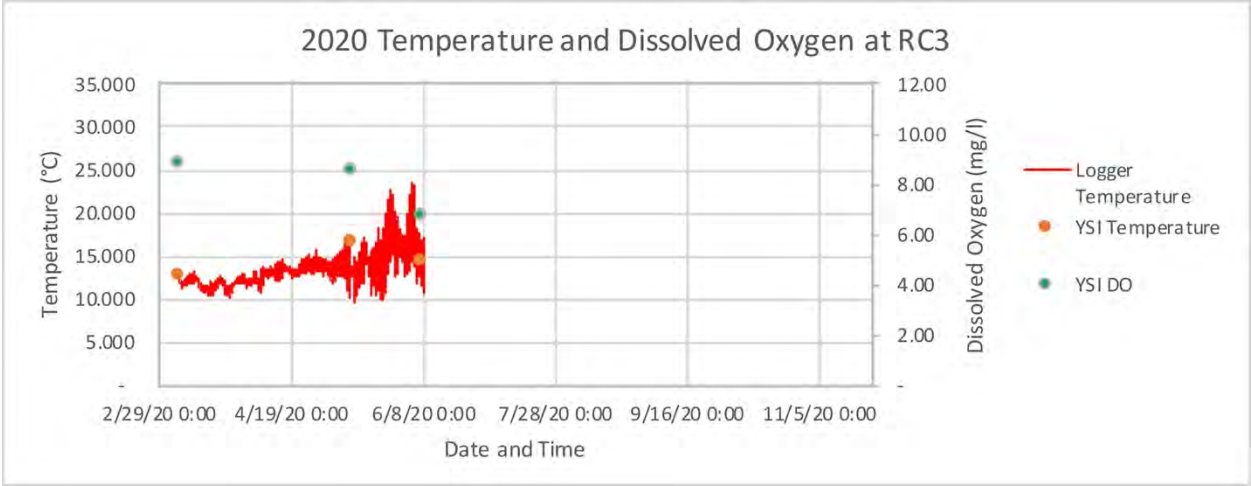
Logger RC2: The data recorded by the logger at RC2 (Figure 8) show slowly rising temperature and dropping DO levels. The strong diurnal variation in DO suggests that the creek was substantially dry by early May. When the site was visited on 6/8/20, the creek was dry.

Figure 8: Temperature and DO in Ross Creek at Logger RC2



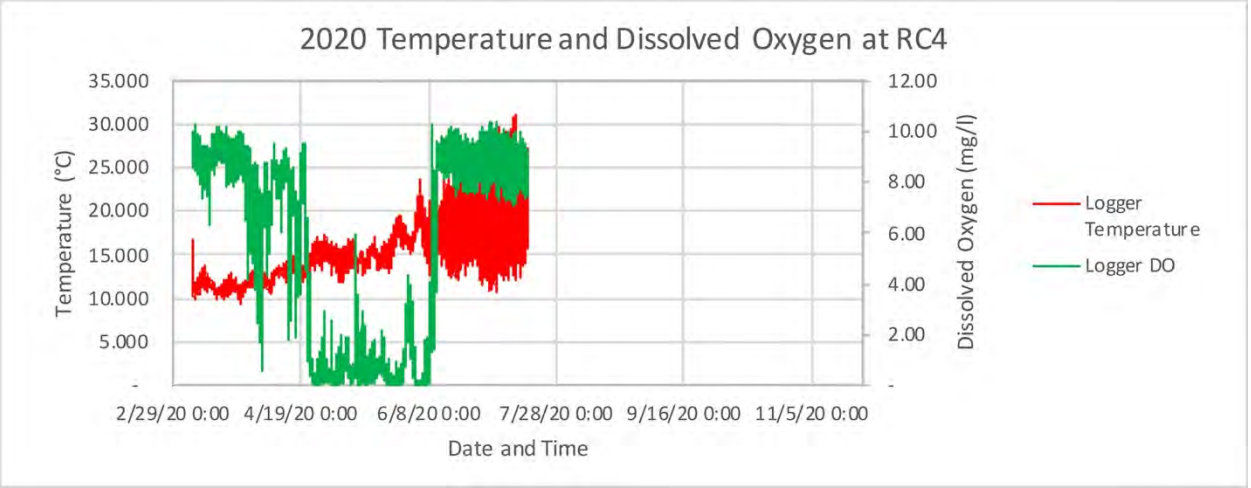
Logger RC3: This logger was in the residential section of Ross Creek, with abundant riparian vegetation and temperatures suitable for steelhead. However, Figure 9 shows that this reach was dry by the end of April.

Figure 9: Temperature and DO in Ross Creek at Logger RC3



Logger RC4: The data recorded by this logger, near the downstream end of Ross Creek (Figure 10) documents adequate conditions for salmonids until an abrupt drop in DO in late April, which suggests that the creek stopped flowing and oxygen became depleted. Another abrupt change in DO occurred in early June when the diurnal variation of air temperature and the rapid increase in DO confirmed that the stream was dry. The logger was removed on June 18, 2020.

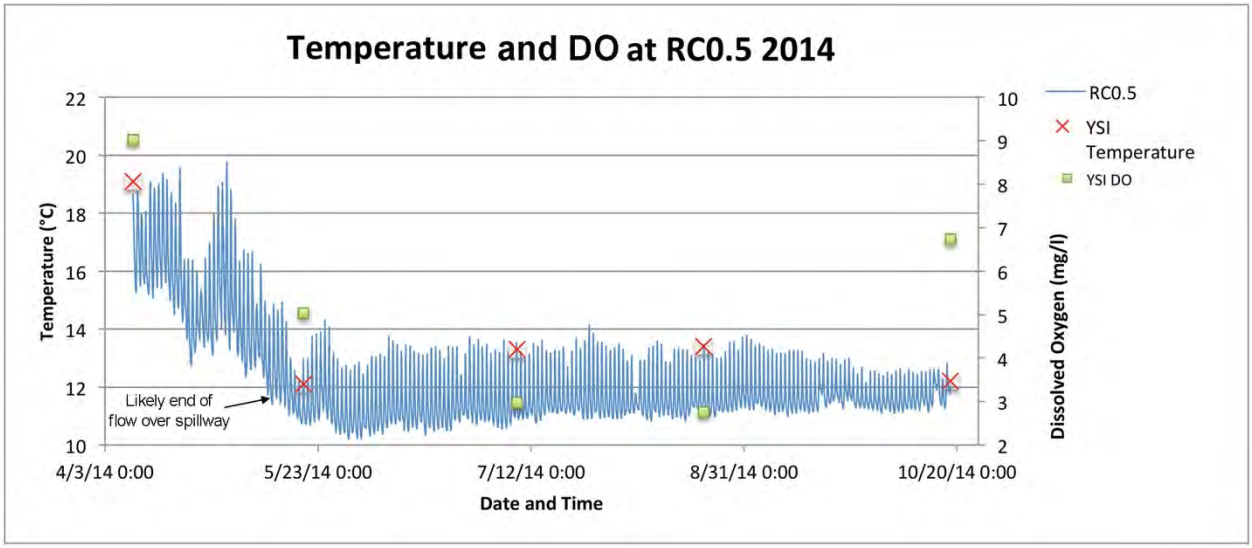
Figure 10: Temperature and DO in Ross Creek at Logger RC4

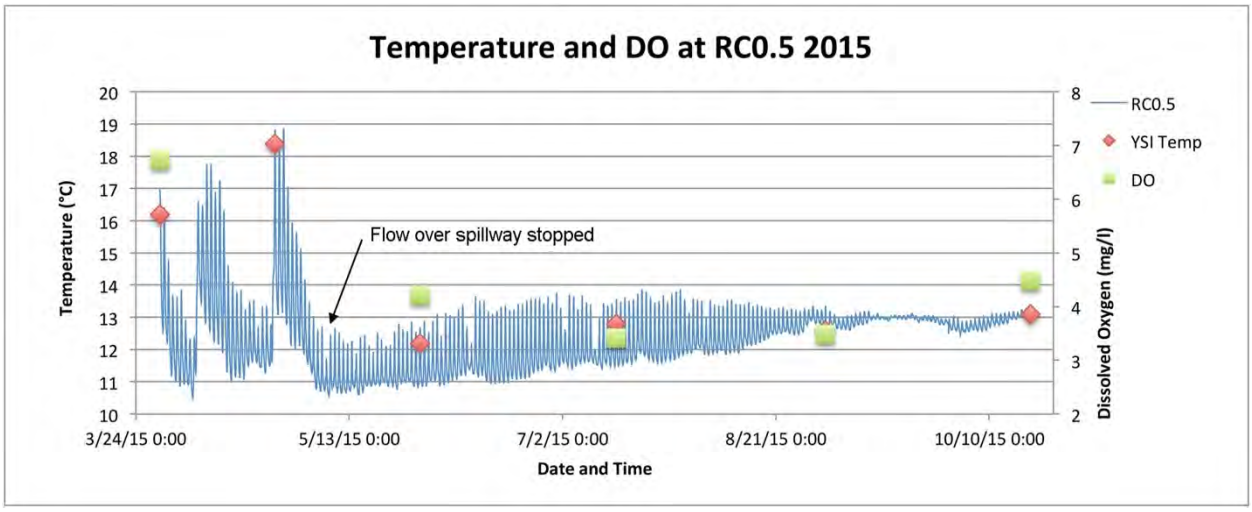


6. Discussion

Phoenix Lake and Conditions in Ross Creek. After Phoenix Lake has stratified in the spring and the warm water is further heated as it flows over the spillway, water in the upper section of Ross Creek is too warm for salmonids (see Figure 11) for data from 2014 and 2015, which show this problem more clearly. The temperature immediately drops when flow over the spillway stops and the stream is dominated by leakage from the low-level release valve and groundwater inputs. This suggests that if water in upper Ross Creek becomes too warm for salmonids, releasing water from the low-level release valve until flow over the spillway ceases has the potential to benefit salmonids in Ross Creek, particularly if the water can be aerated near the low-level release valve. The added flow might also encourage smolts to move downstream before lower Ross Creek dries.

Figure 11: Plots of data at RC05 In 2014 and 2015





Drying of Ross Creek in Residential Areas and Groundwater Depletion: Ross Creek is perennial within Natalie Coffin Greene Park, where no water is diverted from the creek. In residential areas downstream of the park, below RC2, the creek typically dries early in the summer. Although we have no proof that groundwater pumping is the cause of this early drying, most parcels downstream of the park have wells and we suspect that pumping for irrigation of large gardens is lowering the groundwater and causing the creek to dry very early in the summer. Unless smolts move into the mainstem before lower Ross Creek is dry, they are not able to leave the creek.

Early in the 20th century, the courts identified two broad categories of groundwater: 1) sub-surface streams flowing in known and definite channels; and 2) percolating groundwater. Underflow, an outdated term that is still in the California code, is water moving through the sands and gravel under or next to a stream channel and is considered part of the stream (Water Education Foundation, 2021). For a century, California did not regulate groundwater. Finally, in 2014 the California legislature enacted and Governor Brown signed the Sustainable Groundwater Management Act (SGMA) to halt overdraft and balance pumping and recharge in groundwater basins. SGMA requires local agencies adopt sustainability plans for high- and medium-priority groundwater basins. Under SGMA, basins must reach sustainability within 20 years of implementing their plans (California Water Boards, 2021). This is a big step forward, but it has limited value for the Corte Madera Creek watershed, which contains no high- or medium-priority basins.

Any regulatory control on groundwater use requires documenting that the pumping is unreasonable and damages the aquatic resources. This is usually done by documenting a direct link between pumping and streamflow, a challenging task that involves conducting pump tests and streamflow measurements. Without the participation of the well operator in this process, it is virtually impossible to prove the connection. For a high- or medium-priority groundwater basin, SGMA gives the local agency managing the basin the authority to conduct tests. There is no mechanism to require such tests in the Corte Madera Creek watershed.

Barriers to Passage in Ross Creek: Ross Taylor & Associates conducted an assessment of barriers to salmonid passage in the watershed (RTA, 2006). Four barriers were identified in Ross Creek, including two on publicly-owned property in Natalie Coffin Greene Park. Removing these two barriers would improve habitat within the park, allowing fish to move freely in the perennial section of the creek.

The pipeline shown in Figure 12 is owned by Marin Water and its removal should be coordinated with it. The much more serious barrier, shown in Figure 13, is a weir under a pedestrian bridge with an extensive upstream apron and rock walls that form a wading pool. This area is heavily

used by children in the summer and treating this barrier would require close coordination with the Town of Ross.

Figure 12: Water pipeline crossing Ross Creek

Source: RTA 2006

Figure 13: Pedestrian bridge with weir

Overall Deterioration of Conditions: The observations for the last few years suggest that conditions have deteriorated in this watershed since 1999. In 2020, temperatures were higher than those observed in 2013 – 2019. In previous years, temperature remained above 15°C beginning in July, whereas temperatures hit averages of 15°C or higher beginning in late May.

The cause of this degradation may have several causes. The impact of pumping groundwater for irrigation from numerous wells along Ross Creek is likely to contribute. Furthermore, climate change is known to affect water resources. Increases in air temperature cause water temperatures to rise, and DO levels tend to decrease due to the inverse relationship between DO and temperature. Higher air temperatures also increase rates of evapotranspiration from waterbodies, causing them to shrink (U.S. Environmental Protection Agency ,2021). Drought conditions in Marin ranged from Moderate to Severe during the data collection period. Historic drought conditions contribute to dry creek beds and deteriorating wildlife habitat (National Oceanic and Atmospheric Administration, 2021).

7. Recommendations

General recommendations that would improve conditions in the entire watershed include the removal of barriers, enhancement of riparian vegetation, and addition of structure.

Recommended actions to deal with specific conditions we have observed include:

- Implementing monthly cleaning of the lens on each optical DO logger;
- Working with Marin County, and State agencies as appropriate, to implement groundwater monitoring; and
- Seek funding to treat barriers, particularly those in Natalie Coffin Greene Park.

8. References Cited

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