Effects of Canarygrass on Dissolved Oxygen and Fish in Chimacum Creek

March 15, 2024

Effects of Canarygrass on Dissolved Oxygen and Fish in Chimacum Creek

March 15, 2024

Prepared by

Glenn Gately

Jefferson County Conservation District

205 W. Patison St.

Port Hadlock, WA 98339

Purpose

The purpose of this report is to document severely low dissolved oxygen levels and related fish mortality observed in canarygrass reaches of Chimacum Creek.

Dissolved Oxygen Criteria

Dissolved oxygen is essential for fish and other aquatic organisms. Salmon and trout require more than most fish. The minimum dissolved oxygen level set by the Washington Department of Ecology for Chimacum Creek is 10 mg/L or 95% of saturation (whichever is lower; WAC 2023). The U.S. Environmental Protection Agency reported that at least 8 mg/L dissolved oxygen is required for maximum production of salmon and trout and that production is impaired when dissolved oxygen is below 8 mg/L (USEPA 1986). The lower the dissolved oxygen level, the greater the impairment. Furthermore, mortality can occur if dissolved oxygen is below 3 mg/L.

Overview of Impairment

Chimacum Creek, home to coho salmon, chum salmon, steelhead, and cutthroat trout, has been monitored for dissolved oxygen by Jefferson County Conservation District since 1995. Based on EPA's impairment levels, impairment has occurred in a substantial part of Chimacum Creek. Figure 1 shows the percentage of dissolved oxygen measurements that were below the 8 mg/L impairment level for the stations monitored from 1995 to 2023. Most of the impairment occurred between RM 2.0 and RM 7.0 (Figure 2). Dissolved oxygen levels were sometimes below the 3 mg/L acute mortality level within this reach.

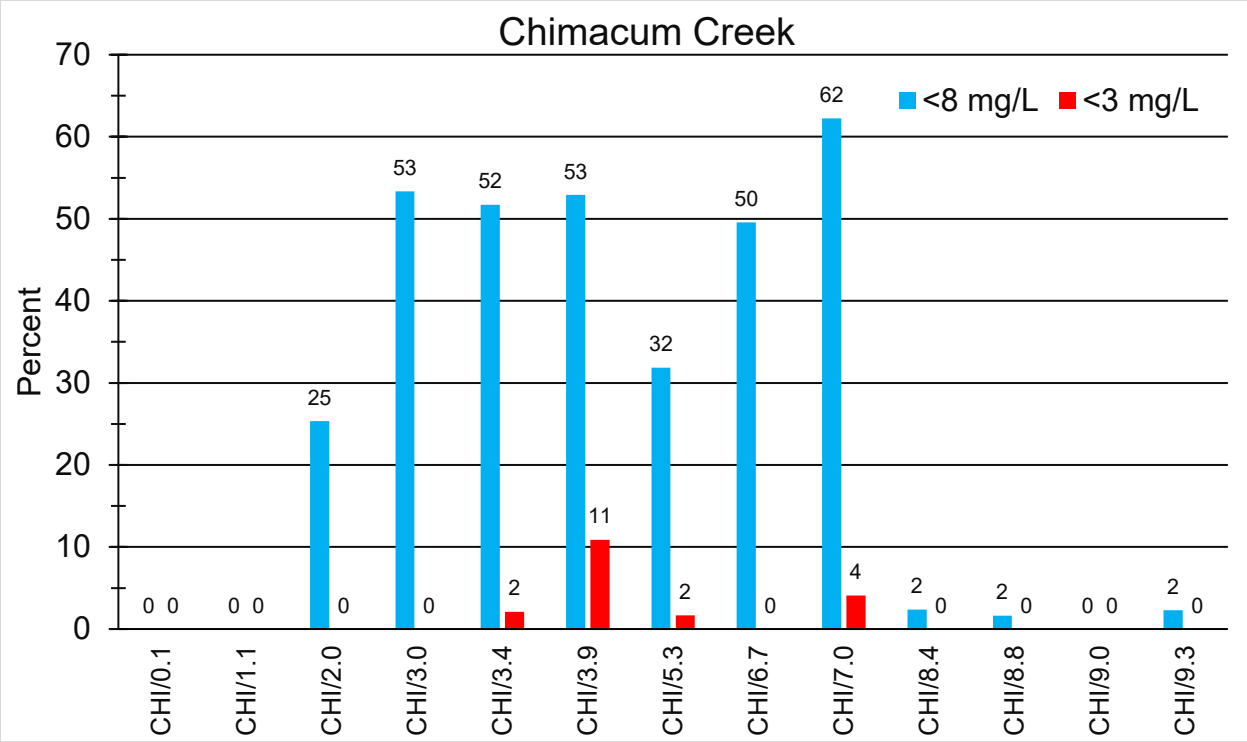
Dissolved oxygen measurements on East Chimacum Creek showed some impairment occurring over almost the entire creek, but mostly between RM 0.4 and RM 2.8 (Figures 1 and 2). Dissolved oxygen levels were sometimes below the 3 mg/L acute mortality level within this reach.

Trend analysis was conducted on dissolved oxygen levels at three stations (CHI/3.9, CHI/5.3, and ECH/1.0) within the low dissolved oxygen reaches. All exhibited downward trends (Figures 3, 4, and 5).

Causes of Low Dissolved Oxygen

Dissolved oxygen is temperature dependent. Cold water holds more oxygen than warm water. For example, 16 ^{o}C water holds 9.9 mg/L when it is 100% saturated, compared to 8.9 mg/L at 21 ^{o}C. Thus, anything causing stream temperature to increase lessens the water's ability to hold oxygen.

Lack of a riparian canopy (i.e., lack of shade) on much of Chimacum Creek and East Chimacum Creek is one cause of higher water temperature and associated low dissolved oxygen levels. Despite the thousands of trees that have been planted along both creeks over the past three decades, water temperature at most stations is increasing. Twelve of thirteen stations on Chimacum Creek and seven of nine stations



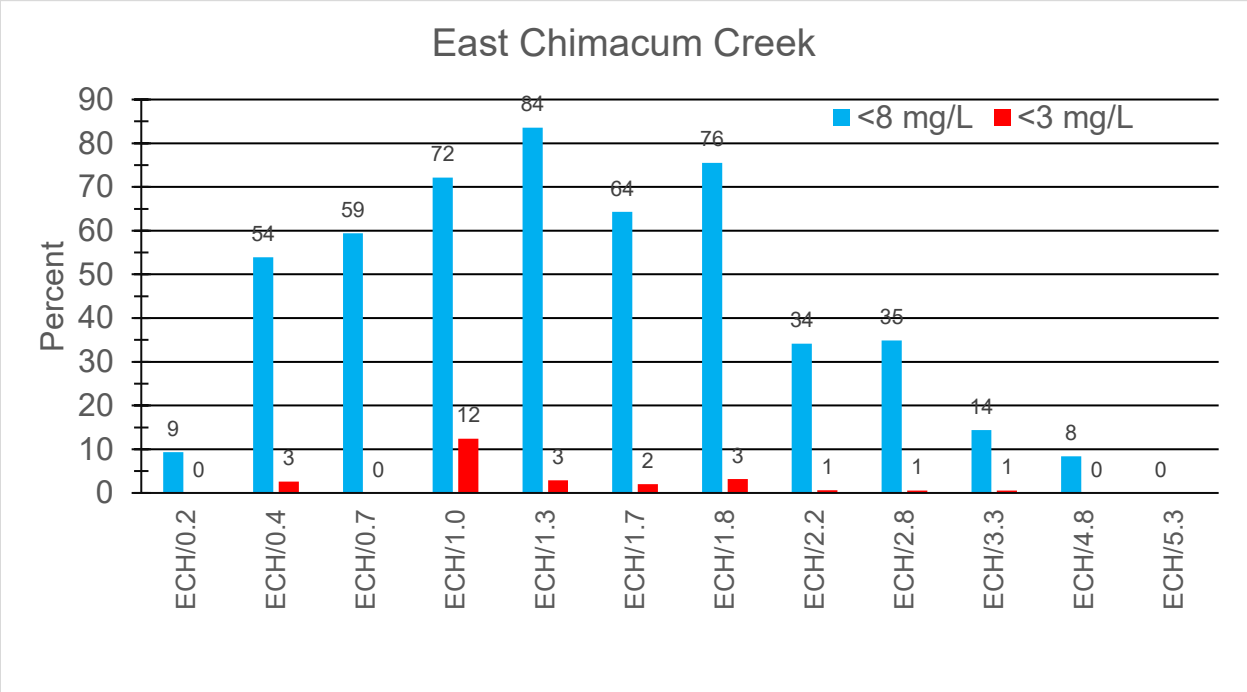


Figure 1. Percentage of dissolved oxygen measurements below 8 mg/L and 3 mg/L from 1995 to November 2023 in Chimacum Creek (top) and East Chimacum Creek (bottom). Salmonid production is impaired at dissolved oxygen levels below 8 mg/L and mortality can occur below 3 md/L.

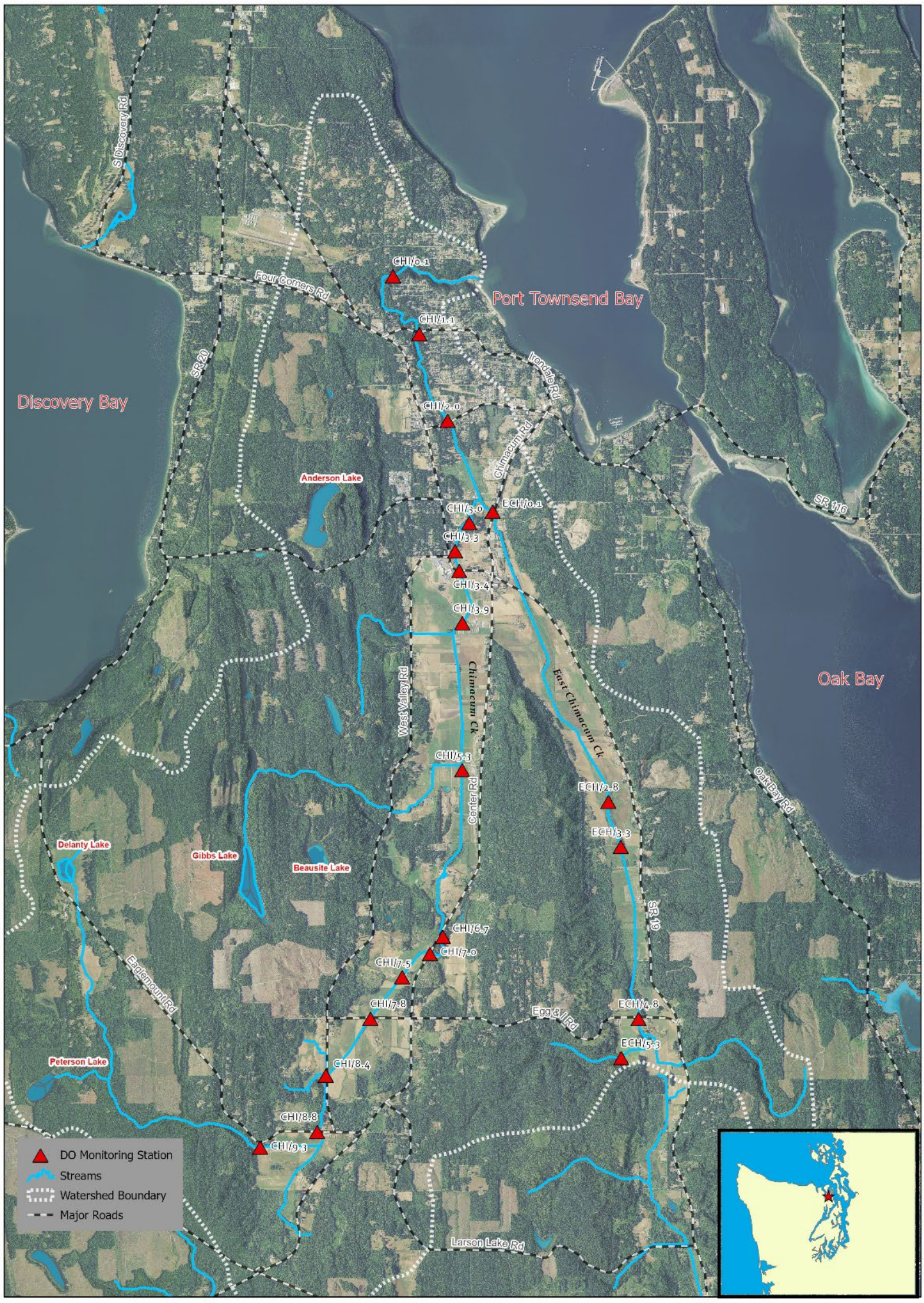


Figure 2. Map of Chimacum watershed showing monitoring stations.

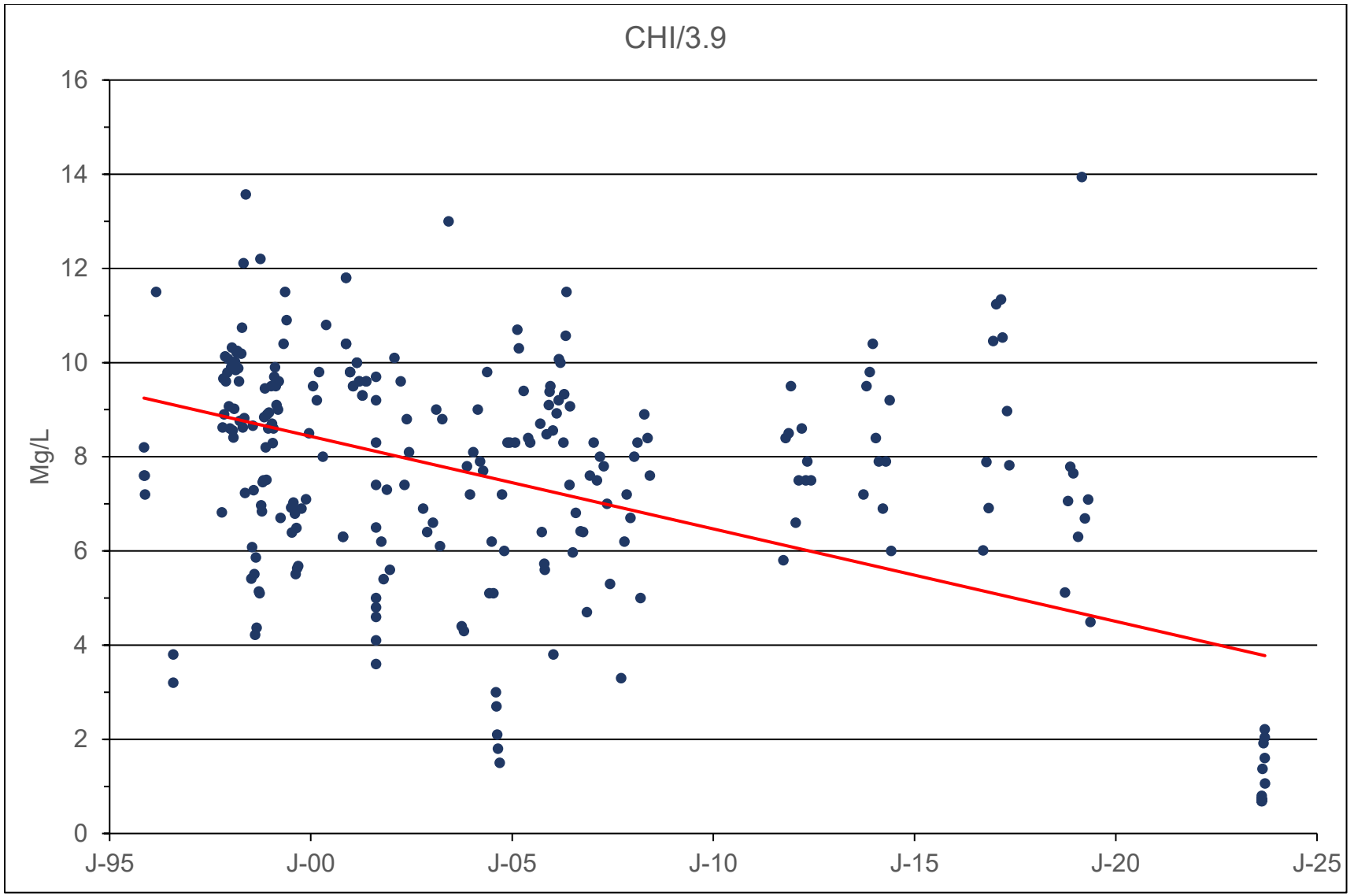


Figure 3. Dissolved oxygen concentrations with trend line at station CHI/3.9 on Chimacum Creek from 1995 to 2023.

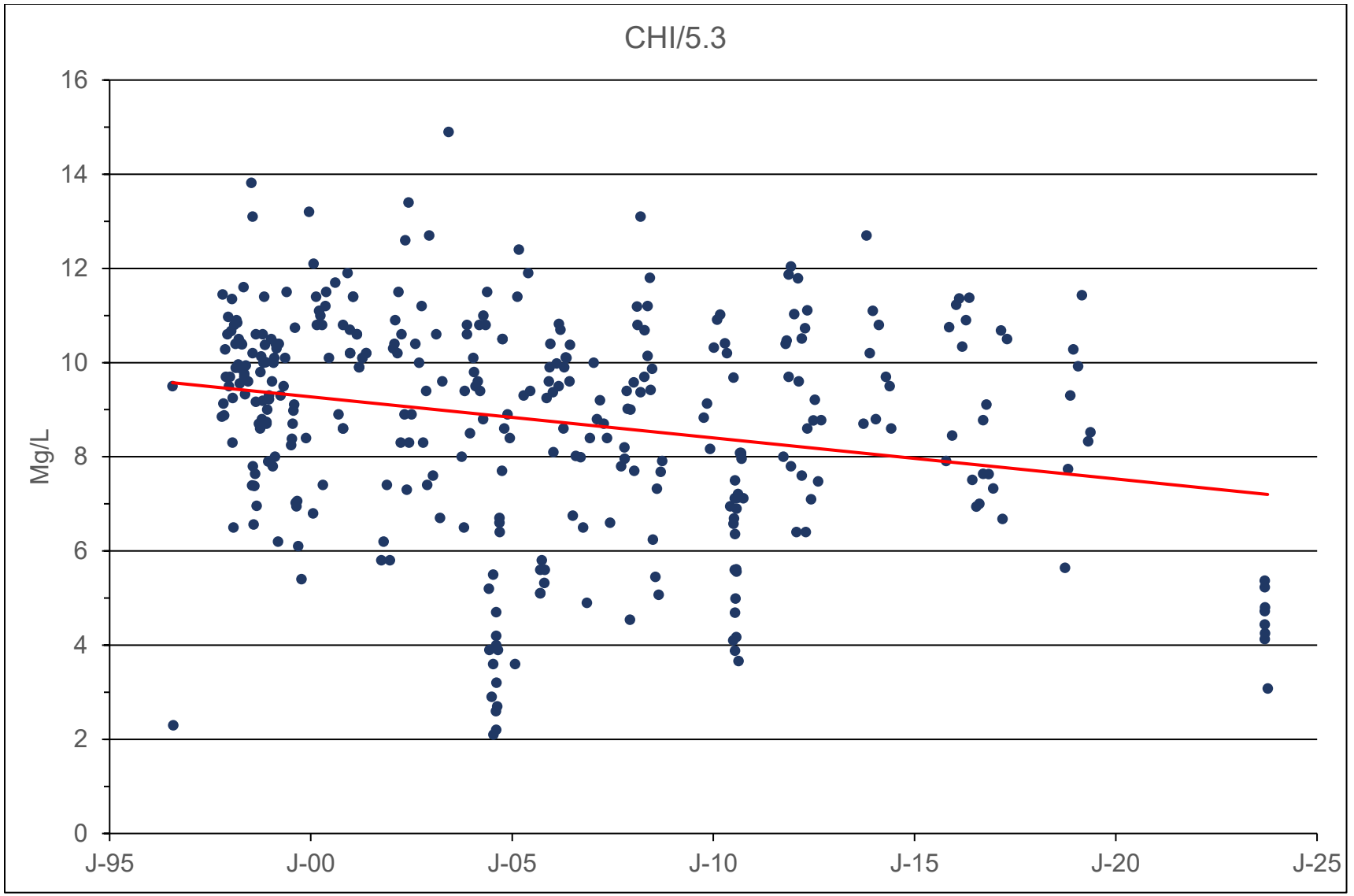


Figure 4. Dissolved oxygen concentrations with trend line at station CHI/5.3 on Chimacum Creek from 1996 to 2023.

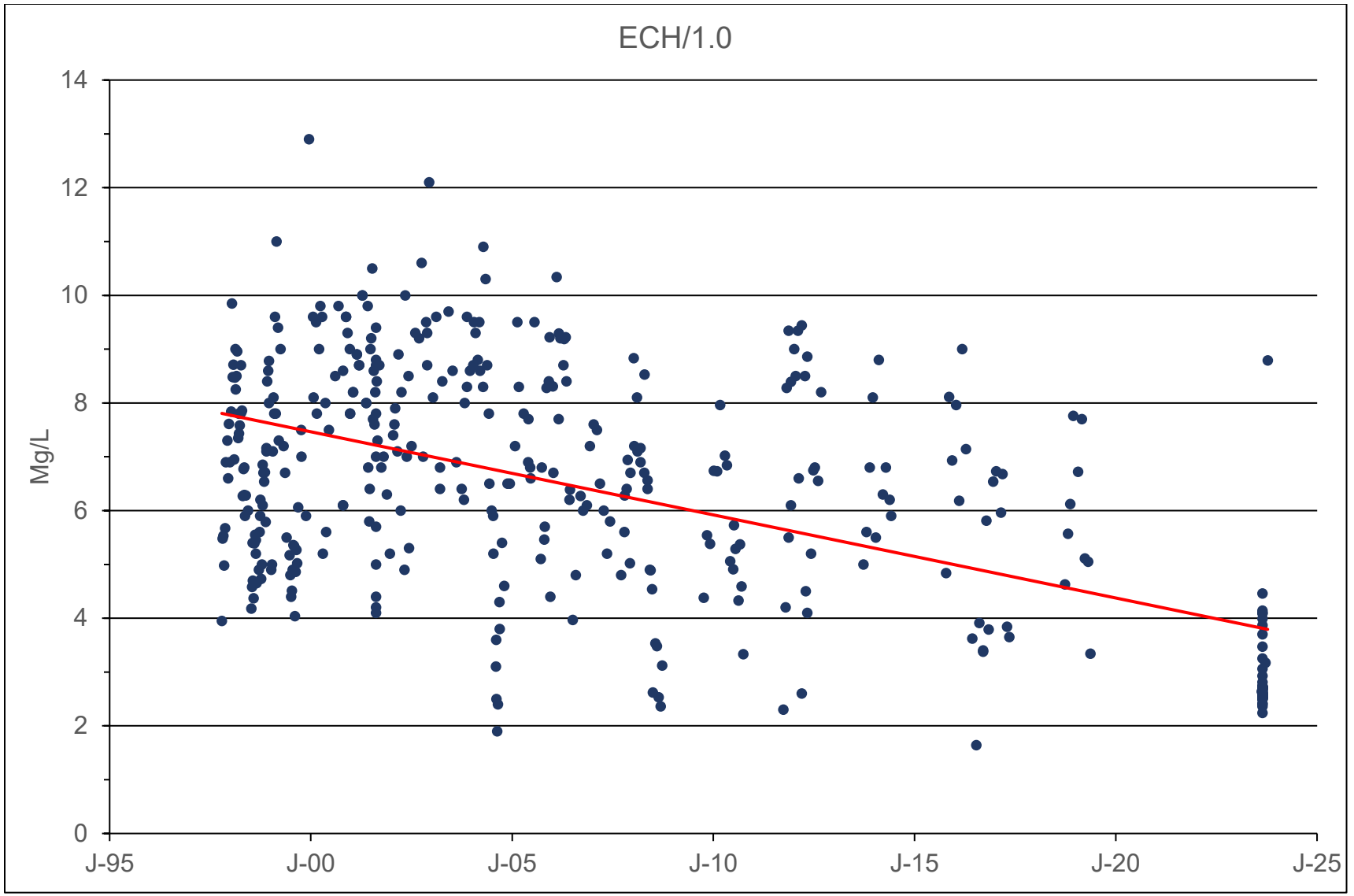


Figure 5. Dissolved oxygen concentrations with trend line at station ECH/1.0 on East Chimacum Creek from 1997 to 2023.

on East Chimacum Creek have upward trends. Increasing shade by the growing trees has not been able to counter the trend of increasing air temperature. Based on maximum daily high air temperatures for July and August at a Bremerton weather station, air temperature has been increasing at a rate of 0.7 ^{o}C per decade from 1991 to 2022. This is a seven-fold increase from the 0.1^{o}C per decade increase from 1952 to 1990.

Also related to solar heating is the creeks' north-south orientation. A north-south orientation allows more sunlight to reach the water surface than would occur for other orientations.

The extremely low stream gradient contributes to low dissolved oxygen. The gradient for Chimacum Creek from RM 3.9 to RM 6.0 is extremely low (0.05%). This amounts to a drop of only 2.6 feet per mile. In this low gradient, water travels slowly, allowing a long exposure to sunlight. Also related to the low gradient is the lack of riffles where aeration takes place. In this reach, aeration occurs only at the surface.

Ideal Plant Growing Conditions

Conditions for much of Chimacum Creek and East Chimacum Creek are ideal for aquatic plant growth. A nutrient-rich channel bottom, plentiful sunlight, and slow-moving water make for ideal growing conditions. Reed canarygrass grows on the banks of Chimacum and East Chimacum creeks. When left uncontrolled, it spreads across the stream from bank to bank. Because canarygrass is perennial and has robust rhizomes, it only takes 2-3 years for it to return after its removal. Figures 6 and 7 show canarygrass filling the channel in 2023 following removal in 2020. Figure 7 shows that it looked the same in 2014 at station CHI/3.9 as it did in 2023. This cycle of canarygrass removal and its subsequent return has been occurring in Chimacum Creek for decades.

Decomposition

When plants die, they are decomposed by bacteria, fungi, and macroinvertebrates (e.g. mayflies and caddisflies). In the decomposition process, oxygen is removed from the water. The greater the biomass of decomposition material, the greater is the amount of oxygen removed. Undoubtedly, canarygrass is at the top of the list in terms of plant biomass in Chimacum and East Chimacum creeks. Its bank-to-bank growth pattern, its abundant stems, leaves, and rhizomes make for a lot of biomass (see Figure 8). Rhizomes can be so dense that they will prevent a fish trap from reaching the bottom, and they can form a surface mat so thick that a person can walk on it.

Respiration and Photosynthesis

Live plants consume and produce oxygen. They consume oxygen 24 hours per day by respiration. They produce oxygen by photosynthesis during daylight hours only. In streams with submersed plants, dissolved oxygen increases throughout the day and decreases during the night. This is not the case in streams with certain emergent plants like reed canarygrass which dominate the stream channel.

Figure 6. Photo taken from station CHI/5.3 on November 14, 2023, looking downstream. Station CHI/3.9 is 1.4 miles downstream and much of the channel between the two stations is choked with canary grass.

Figure 7. Photos looking downstream from station CHI/3.9 on November 14, 2023 (top) and September 18, 2014 (bottom).

Figure 8. Photo of an excavator with a rake attachment removing canary grass from Chimacum Creek on August 14, 2020.

In August 2023, canarygrass was growing bank-to-bank in much of Chimacum Creek (Figures 6 and 7). Dissolved oxygen levels at station CHI/3.9 remained at a constant 0.7 mg/L from morning to mid-afternoon (Figure 9). At station ECH/1.0 on East Chimacum Creek, dissolved oxygen remained between 2.3 mg/L and 2.7 mg/L throughout the day. In contrast, in 2001, levels increased at both stations from about 4 mg/L to over 9 mg/L (Figure 9). Salmonids may survive low dissolved oxygen levels for brief periods but are not expected to survive at levels below 3 mg/L for extended periods.

Because the leaves of canarygrass are mostly above the water surface, most of the oxygen produced by photosynthesis is released to the atmosphere. This explains why dissolved oxygen levels did not increase during the day in 2023 when canarygrass was abundant (Figure 9).

Some emergent plants as well as floating plants have been associated with low dissolved oxygen levels. Not only do these plants contribute little or no oxygen to the water, but their shading effect minimizes or eliminates the growth of submersed plants which would release oxygen to the water. The degree of shading is associated with the density of the plant. This relationship was observed in a study on emergent plants in two Florida lakes (Bunch 2008; Bunch et al. 2014). Of the five emergent plants studied, smartweed and primrose exhibited low dissolved oxygen levels similar to canarygrass. Hourly measurements did not exceed 1 mg/L in 24 hours. Whereas, measurements in cattail, pickerelweed, and torpedograss increased from 0-4 mg/L in the morning to 8-10 mg/L in the late afternoon. Of the five species, smartweed and primrose had the densest growth pattern. In all cases, dissolved oxygen was lowest at the highest coverage (80-95%) and was highest at the lowest coverage (50-64%). Light availability to submersed plants was negatively correlated to plant coverage.

Floating plants also reduce light penetration and have a shading effect similar to that of emergent plants. In a study on the Hudson River, dissolved oxygen levels in water chestnut beds were compared to those in wild celery beds. Water chestnut is an invasive plant and has large floating leaves. Wild celery is a submersed plant with long ribbon-like leaves. Continuous dissolved oxygen measurements in the chestnut beds were below 2.5 mg/L 40% of the time. Whereas measurements in the wild celery beds never declined below 5 mg/L (Caraco and Cole 2002). Two floating plants, duck weed and pond weed, occur in Chimacum Creek. Duck weed occurs in small patches. Pond weed is not particularly dense and has leaves both below and on the surface. Neither of these plants appear to be a problem in Chimacum Creek.

Canarygrass Removal

The removal of canarygrass can cause an immediate increase in dissolved oxygen. This was demonstrated in August 2006 when a one-half mile reach of Chimacum Creek (RM 7.5 – RM 8.0) was cleared of canarygrass and European bittersweet (Figure 10). European bittersweet is a vine that grows along the stream bank and extends over the stream when it has something to cling to. Like canarygrass, it decomposes in the

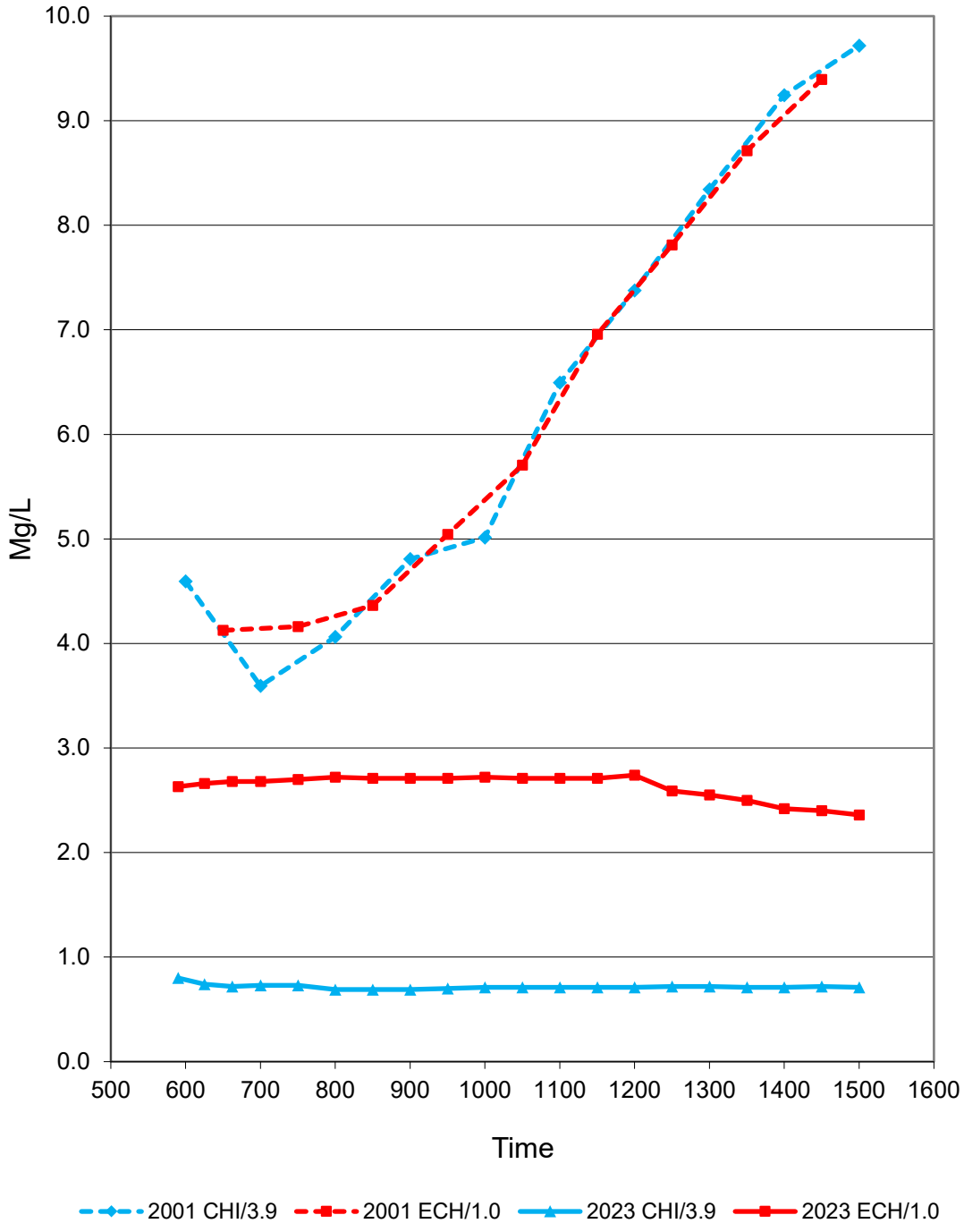


Figure 9. Dissolved oxygen levels at stations CHI/3.9 and ECH/1.0 measured every hour on August 13, 2001, and every 30 minutes at CHI/3.9 on August 18, 2023, and at ECH/1.0 on August 24, 2023.

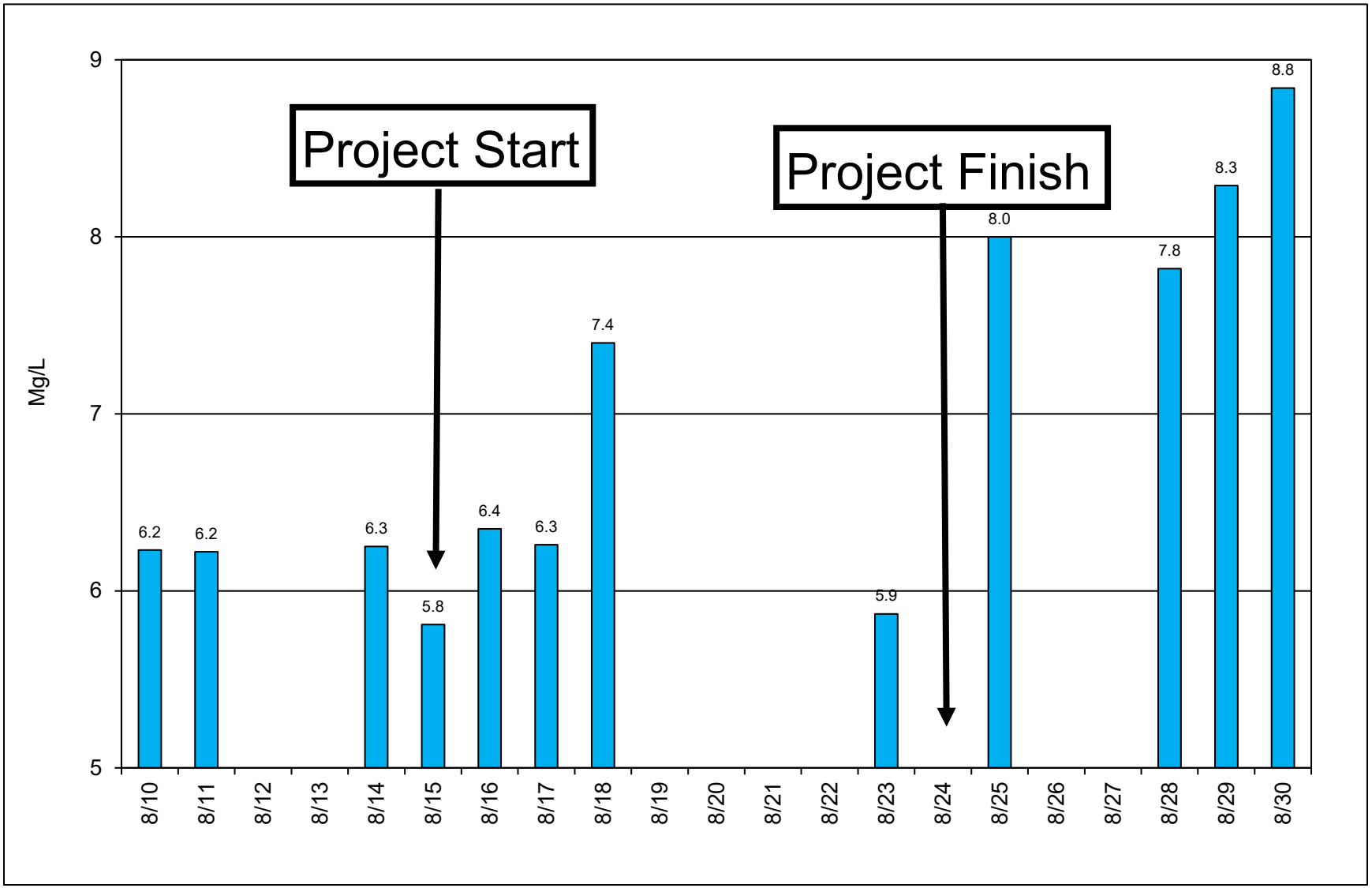


Figure 10. Dissolved oxygen levels monitored from August 10 to August 30, 2006 between 10:40 AM and 11:48 AM at station CHI/7.5 on Chimacum Creek. Canary grass and European bittersweet were removed from a half-mile section of channel (RM 7.5 – RM 8.0) from August 15 to August 24.

stream. Dissolved oxygen was measured at station CHI/7.5 at the downstream end of the reach on a regular basis at about 11:00 AM from August 10 to August 30. Canarygrass and European bittersweet were removed by an excavator fitted with a rake attachment from August 15 to August 24. Prior to the start of the project, dissolved oxygen ranged from 6.2 mg/L to 6.3 mg/L. After the plants were removed, dissolved oxygen increased to a range of 7.8 mg/L to 8.8 mg/L.

The act of removing canarygrass from waterways can have a short-term negative effect as evidenced during the summer of 2010 when canarygrass was removed from Chimacum Creek from RM 3.4 to RM 6.2 (Figure 11). On July 14, the day before work began on the reach RM 3.9 to RM 4.2, dissolved oxygen at station CHI/3.4 measured 3.5 mg/L. On July 15 at 4:53 PM, dissolved oxygen there was 0.8 mg/L. The water appeared black, and some salmonids were in distress. At 6:02 PM, dissolved oxygen had decreased to 0.25 mg/L, the water was black, four salmonids were dead, and about twenty were in distress. The black color of the water was probably due to peat particles being suspended from the stream bottom and/or banks when the canarygrass was removed. The biological oxygen demand of the suspended organic matter undoubtedly caused the low dissolved oxygen level on July 15.

About half a mile downstream at station CHI/3.0, dissolved oxygen was 5.6 mg/L, the water was clear, and no distressed fish were visible at 5:11 PM. However, at 6:24 PM, the water there was black and dissolved oxygen had decreased to 4.2 mg/L. No distressed fish were observed. Observations farther downstream at stations CHI/3.3 and CHI/2.0 between 5:25 PM and 6:34 PM revealed no black water or distressed fish, but the black water may not have reached there yet.

After the extremely low measurement of 0.25 mg/L at station CHI/3.4 on July 15, oxygen levels progressively increased as the canarygrass removal continued to September 2 (Figure 11). On July 16, dissolved oxygen at station CHI/3.4 was 2.8 mg/L. On July 19 it was 4.0 mg/L, 6.7 mg/L on July 26, and 7.6 mg/L on July 29. No black water, dead or distressed fish were observed after July 15.

Effect of Low Dissolved Oxygen on Fish

August and September probably have the lowest dissolved oxygen levels. In August and September 2023, dissolved oxygen levels were measured on six days at station CHI/3.9 and on nine days at station CHI/3.4. Levels ranged from 0.7 mg/L to 2.2 mg/L at station CHI/3.9 and from 2.4 mg/L to 2.6 mg/L at station CHI/3.4. All of these measurements were below the 3 mg/L acute mortality level.

To ascertain the seriousness of these low levels, an in-stream bioassay was conducted. On September 12, 2023, two minnow traps were set on bottom at station CHI/5.3, one on the upstream side of the bridge and one on the downstream side. Both traps were pulled on September 13 at 2:30 PM. The upstream trap contained 30 stickleback, 1 pumpkinseed, 1 sculpin, and 1 cutthroat trout. Dissolved oxygen near the stream bottom at this trap’s location was 5.4 mg/L. The downstream trap contained 4 pumpkinseed and

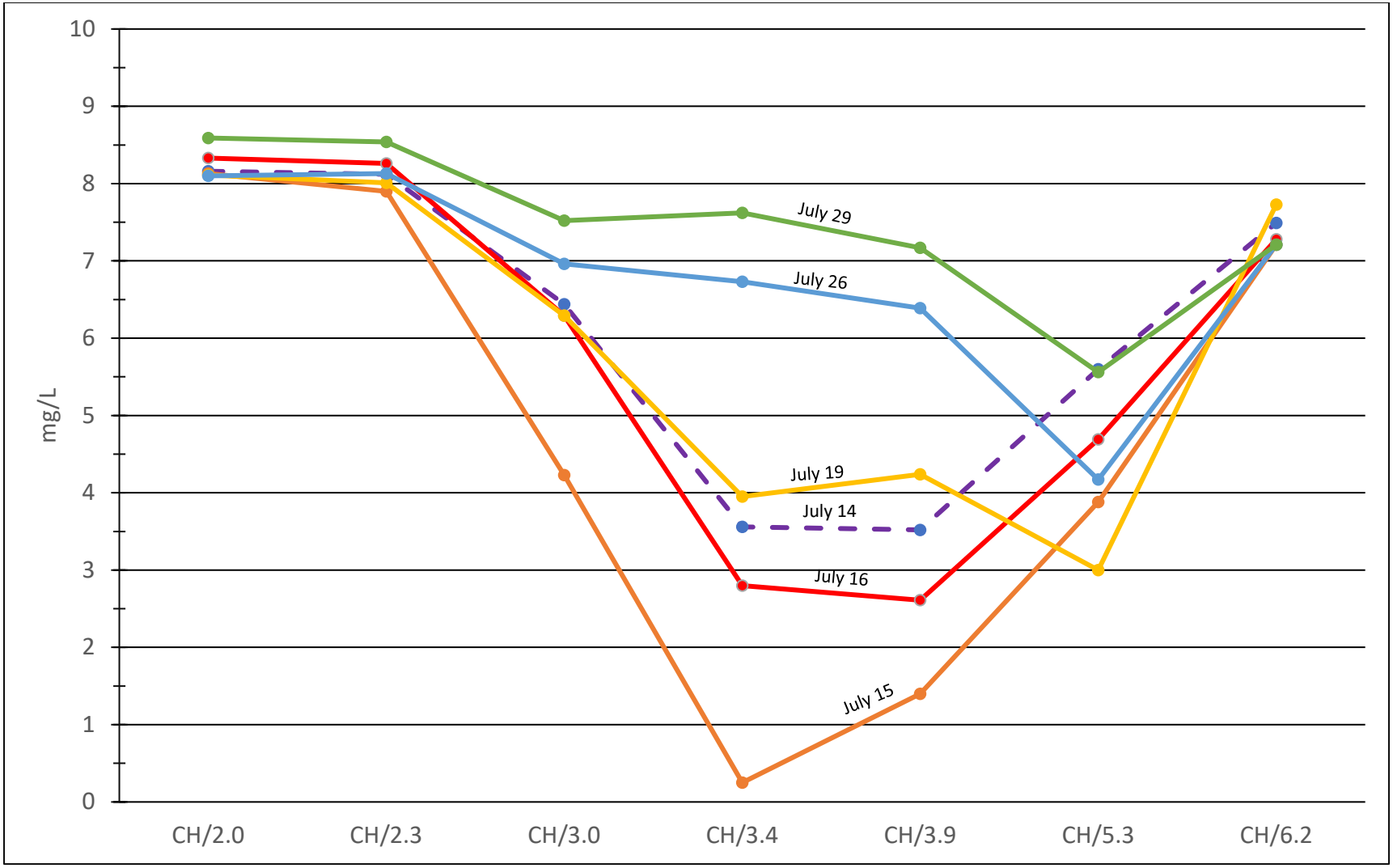


Figure 11. Dissolved oxygen levels at Chimacum Creek stations beginning on July 14, 2010 (dashed line), the day before canarygrass removal began, to July 29, four days before removal ended. Removal took place between RM 3.4 and RM 6.2.

8 stickleback. Dissolved oxygen at this trap's location was 4.1 mg/L. All fish in both traps were alive.

Ten of the fish were placed in a clear-sided plastic container with stream water and immediately transported to station CHI/3.9, only a few minutes away. All fish appeared healthy when removed from the container. The fish were put in two traps and placed in the stream at the downstream side of the bridge where there was a visible current. Dissolved oxygen at the traps' location measured 1.6 mg/L at 3:22 PM.

The traps were checked on September 14 at 11:15 AM. One trap contained 1 live pumpkinseed, 1 live sculpin, and 3 dead stickleback. The second trap contained 2 live stickleback, 2 dead stickleback, and 1 dead cutthroat trout. Dissolved oxygen at 11:50 AM was 2.2 mg/L.

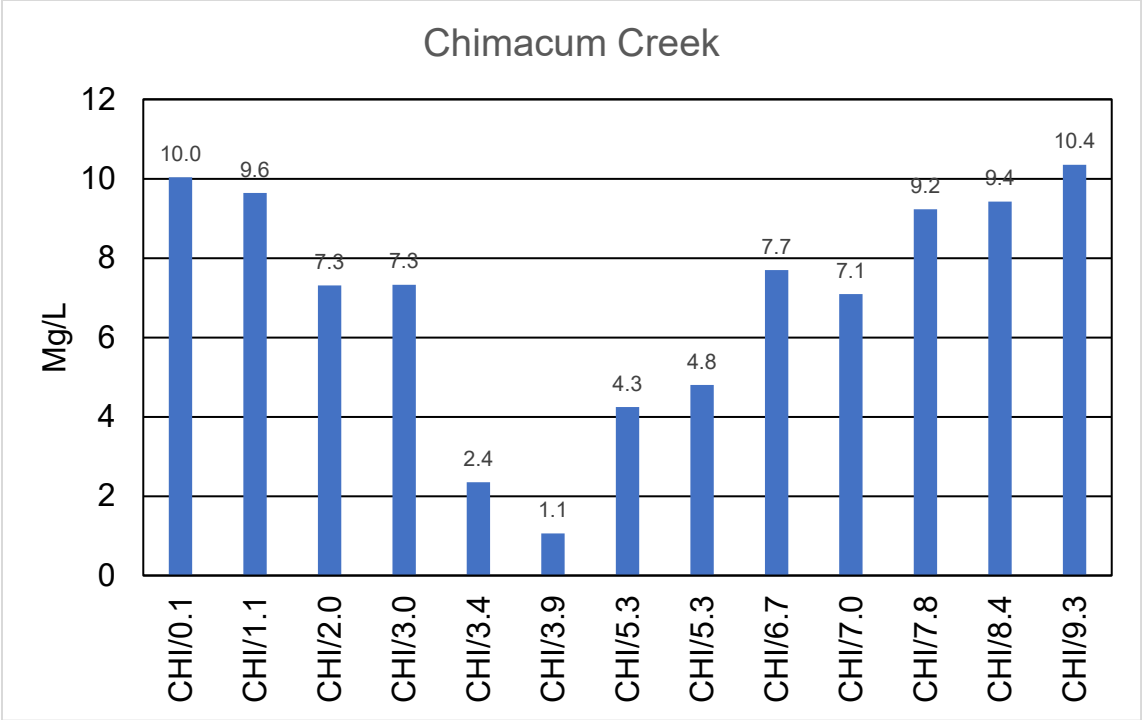
It is likely that if the traps remained in place longer than that more fish would have died. It is also likely that if the fish were not confined in traps that none of the fish would have died. The bioassay confirmed that the low dissolved oxygen level at the traps' locations on bottom was lethal. However, had the fish not been confined in the traps, they could have moved to a more oxygenated location, such as near the surface. Fish in lakes having hypoxic conditions near bottom are known to forage on bottom for short periods.

As mentioned, August and September are the months with the lowest oxygen levels. To determine the extent of the low oxygen levels, Chimacum Creek and East Chimacum Creek were monitored from upstream to downstream in September (Figure 12). On September 15, Chimacum Creek dissolved oxygen levels progressively decreased from a high of 10.4 mg/L at upstream station CHI/9.3 to a low of 1.1 mg/L at station CHI/3.9 and then progressively increased to 10.0 mg/L at downstream station CHI/0.1.

On September 20, East Chimacum Creek dissolved oxygen levels progressively decreased from a high of 10.4 mg/L at upstream station ECH/5.3 to a low of 0.5 mg/L at station ECH/2.8 and then progressively increased to a high of 8.4 mg/L at downstream station ECH/0.1. Thus, the lowest levels occurred near the middle of both creeks where the gradient is low and the canarygrass is abundant. The upper and lower reaches have steeper gradients with little or no canarygrass.

Fish mortality, predominantly stickleback, occurred in fish traps in other years. Chimacum Creek reach CHI/5.0-5.3, in which canary grass grows profusely, was trapped in all seasons from 2015 to 2023. From 2 to 119 stickleback died in traps in 2019, 2020, and 2023. Two cutthroat were found dead in separate traps on September 5, 2023 (Table 1).

It is noteworthy that Chimacum Creek's chum salmon spawn in the lower reach of Chimacum Creek, primarily downstream from RM 2.0. Coho salmon spawn upstream and downstream from the middle canarygrass reach. They pass through the canarygrass reach in November when monthly rainfall averages 3.9 inches, compared to 0.9-1.2 inches from July to September. Dissolved oxygen in November at station



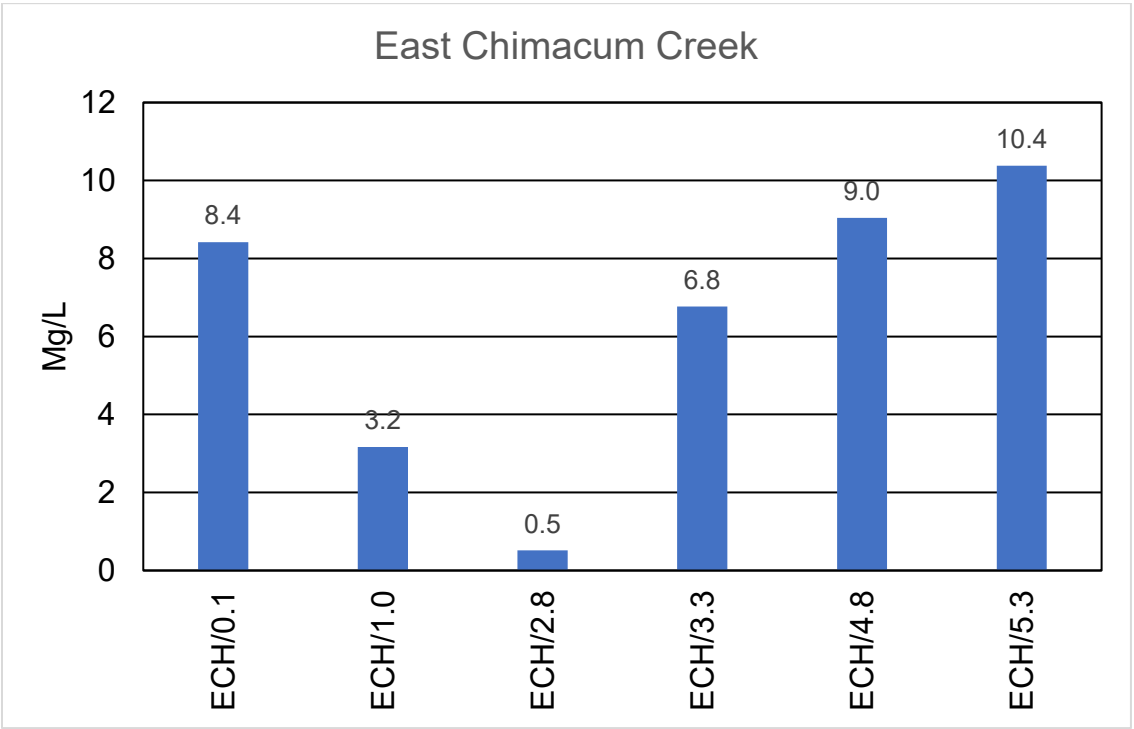


Figure 12. Dissolved oxygen concentrations monitored at Chimacum Creek on September 15, 2023 (top) and East Chimacum Creek on September 20, 2023 (bottom).

Table 1. Fish trapping results for Chimacum Creek reach CHI/5.0-5.3 from 2015 to 2023. Only dates with one or more dead fish are shown. Dead fish are shown in red.

Station	Trap No.	Date set	Date Checked	Coho		Crayfish		Cutthroat		Sculpin		Stickleback	
				Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
CHI/5.0-5.3	1	9/2/2019	9/3/2019	0	0	1	0	0	0	0	0	58	15
CHI/5.0-5.3	2	9/2/2019	9/3/2019	0	0	0	0	0	0	0	0	12	6
CHI/5.0-5.3	3	9/2/2019	9/3/2019	0	0	8	0	0	0	0	0	60	17
CHI/5.0-5.3	2	6/8/2020	6/9/2020	0	0	0	0	0	0	0	0	4	2
CHI/5.0-5.3	2	6/29/2020	6/30/2020	0	0	0	0	0	0	0	0	17	14
CHI/5.0-5.3	3	6/29/2020	6/30/2020	0	0	0	0	0	0	0	0	122	8
CHI/5.0-5.3	1	8/3/2020	8/4/2020	0	0	5	0	0	0	0	0	103	24
CHI/5.0-5.3	2	8/3/2020	8/4/2020	0	0	1	0	1	0	0	0	87	17
CHI/5.0-5.3	3	8/3/2020	8/4/2020	0	0	11	0	0	0	0	0	54	119
CHI/5.0-5.3	3	8/17/2020	8/18/2020	0	0	3	0	0	0	0	0	90	115
CHI/5.0-5.3	1	9/4/2023	9/5/2023	0	0	0	0	1	1	0	0	75	0
CHI/5.0-5.3	2	9/4/2023	9/5/2023	0	0	0	0	0	1	0	0	24	0

CHI/3.4 averaged 8.4 mg/L from 1993 to 2018. Fish trapping results show that some coho salmon and cutthroat trout rear in the canarygrass reach. Stickleback are abundant and some sculpin reside there, too.

Summary

Dissolved oxygen is essential for fish and other aquatic organisms. Salmon and trout require more than most fish. The minimum dissolved oxygen level set by the Washington Department of Ecology for Chimacum Creek is 10 mg/L or 95% of saturation (whichever is lower). The U.S. Environmental Protection Agency recommends at least 8 mg/L for maximum production of salmon and trout because production is impaired with anything less. The lower the dissolved oxygen, the greater is the impairment. Furthermore, mortality can occur if dissolved oxygen drops below 3 mg/L.

Since 1995, hundreds of dissolved oxygen measurements have indicated that salmonid production was being impaired in canarygrass reaches. Most of the impairment on Chimacum Creek occurred between RM 2.0 and RM 7.0. and between RM 0.4 and RM 2.8 on East Chimacum Creek. Trend analyses conducted at three stations within these reaches show downward trends for dissolved oxygen. Concurrent upward trends for water temperature suggest that increasing temperature is at least partly responsible.

Dissolved oxygen is temperature dependent. Anything that raises temperature lowers dissolved oxygen. Factors raising water temperature are increasing air temperature, solar exposure (e.g., incomplete riparian canopy and a north-south orientation), and slow-moving water . All these factors apply to Chimacum and East Chimacum creeks and contribute to low dissolved oxygen levels.

The extremely low gradient from RM 3.9 to RM 6.0 on Chimacum Creek eliminates riffles and negates their aerating effect.

Canarygrass has ideal growing conditions in the middle reaches of Chimacum and East Chimacum creeks: a nutrient-rich bottom, plentiful sunlight, and slow-moving water. These ideal growing conditions produce a large biomass of canarygrass. Its decomposition removes a large quantity of oxygen from the water.

Canarygrass removed in 2020 was back in 2023 and looking the same as it did in 2014. This cycle of removal and return has been reoccurring for decades.

Submersed plants release oxygen to the water through photosynthesis. The emergent canarygrass releases oxygen to the atmosphere because its leaves are above the water. Dense canarygrass eliminates oxygen-producing submersed plants by shading them out.

Canarygrass removal had short term negative effects and fairly fast positive effects. In 2006 and 2010, dissolved oxygen increased dramatically a few days after its removal. However, on the day of its removal in 2010, suspended peat particles caused dissolved

oxygen to plummet to near zero, resulting in dead and distressed salmonids. Dissolved oxygen recovered by the next day and continued rising to higher levels than before the canarygrass removal.

In September 2023, an instream bioassay was conducted near the lower end of a long canarygrass reach where dissolved oxygen was consistently below the 3 mg/L acute mortality level. Seven stickleback, 1 pumpkinseed, 1 sculpin, and 1 cutthroat trout were held in minnow traps overnight. The following day, 5 of the 7 stickleback and the 1 cutthroat trout were dead. Had the fish not been confined near bottom, they may have survived by moving to an area with more dissolved oxygen, such as near the surface.

Substantial stickleback mortality along with two cutthroat trout occurred in traps set in a dense canarygrass reach in 2019, 2020, and 2023.

Conclusions

Canarygrass is causing extremely low dissolved oxygen levels in the middle reaches of Chimacum Creek. The low dissolved oxygen levels are potentially lethal to juvenile coho salmon and rainbow and cutthroat trout during summer. The canarygrass reaches are probably not a problem to adult salmon and trout because they migrate through the canarygrass to upstream spawning grounds in fall (coho) and winter/spring (trout) when the water is cooler, flows are higher, and dissolved oxygen is higher. Chum salmon spawn in lower Chimacum Creek.

Three years after its removal, canarygrass is back and causing dissolved oxygen to be very low. Thus, it needs to be removed every year or every other year.

Care should be taken in removing canarygrass with an excavator. The excavator should be fitted with a rake and operated without contacting the bottom because suspending the bottom sediment lowers the dissolved oxygen.

Canarygrass could be eliminated or reduced by creating a riparian canopy. Even a reduction in density would allow some submersed plants to grow and release oxygen. Sooner or later, beaver dams would likely appear and require their removal along with the beaver.

Whatever the removal method, canarygrass control and beaver control will need to be ongoing.

Literature Cited

Caraco, N. J. and J. J. Cole. 2002. Contrasting Impacts of a native and alien macrophyte on dissolved oxygen in a large river. Ecological Applications 12(5):1496-1509.

Bunch, A. J. 2008. Dissolved oxygen dynamics and fish community composition in dense emergent plants at lakes Istokpoga and Kissimmee, Florida. Master of Science Thesis, University of Florida. Gainesville, Florida.

Bunch, A. J., M. S. Allen, and D. C. Gwinn. 2014. Influence of macrophyte-induced hypoxia on fish communities in lakes with altered hydrology. Lake and Reservoir Management 31 (1):1-19.

U. S. Environmental Protection Agency (USEPA). 1986. Ambient water quality criteria for dissolved oxygen. U. S. Environmental Protection Agency, Off. Water regulations and Standards. Washington, D.C. 46 pp.

WAC 2023. Water quality standards for surface waters of the state of Washington. Washington Department of Ecology, Chapter 173-201A, Updated 10/28/23.

Acknowledgements

I thank Joe Holtrop, Sierra Young, George Sibley, and Al Latham for reviewing this report. Thanks to Sierra for making the monitoring station map. And thanks to Howard Teas for consistently collecting fish trapping data since 2015.