



# Oregon

Kate Brown, Governor

**Department of Fish and  
Wildlife**  
Deschutes Watershed District  
61374 Parrell Road  
Bend, Oregon 97702  
(541) 388-6363



## **Memorandum on Crooked River Low Flows 2022**

Jerry George and Tim Porter

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### Background

The Crooked River below Bowman Dam is inhabited by a highly productive population of native Columbia basin Redband Trout (*Oncorhynchus mykiss*) and Mountain Whitefish (*Prosopium williamsoni*). This population supports a widely renowned trout fishery that contributes revenue to Prineville and Crook County. Bowman Dam, which creates Prineville Reservoir, is operated by the Bureau of Reclamation for the purpose of irrigation storage for patrons, namely the Ochoco Irrigation District. Under normal water storage and reservoir operations, cool water is drawn from deep in the hypolimnion of Prineville Reservoir providing important cold water refugia for salmonids, supporting a productive tailwater fishery for Redband Trout, and creating holding, spawning, and rearing habitat for Spring Chinook Salmon (*Oncorhynchus tshawytscha*) and summer steelhead (*O. mykiss*).

Since the fall of 2018, Central Oregon, and Crook County in particular, have experienced prolonged and extreme drought conditions leading to a scarcity in water available for agricultural uses and much below normal streamflow. The cumulative effect of consecutive years of below average precipitation are being expressed as reduced runoff, local declines in surface and groundwater, the lowest storage on record for Prineville and Ochoco reservoirs, a reduction and reallocation of water to contract holders that pay for storage to meet irrigation purposes, and the utilization of contracted water before the normal end of the irrigation season in mid-October. Following the end of the 2022 irrigation season on September 15th, the Bureau of Reclamation implemented a minimum release of 10 cfs from Bowman Dam through October when flows were increased to 50 cfs consistent with the Habitat Conservation Plan. Previous surveys found a strong negative relationship between low winter flows (35 cfs) and trout abundance the following spring/summer (Porter and Hodgson 2016); however, the impacts of low summer/fall discharge (10cfs) on native fish populations in the Crooked River have not been studied.

Going into the low flow period it was anticipated that water quantity and quality (warm, sediment laden, shallow reservoir water) could be reduced to levels that poses an acute threat to fish and aquatics species in both Prineville Reservoir and the Crooked River downstream. It is also anticipated that the historically low reservoir conditions will result in entrainment of many thousands of fish from the reservoir, including undesirable non-native fishes. Instream flow modeling of the Upper Crooked River Canyon Reach below Bowman Dam indicated that at flows of 10 cfs, adult Redband Trout habitat is reduced to less than three percent of maximum

available, adult Chinook Salmon spawning habitat is essentially eliminated ( $<0.1\%$  of maximum) and juvenile Redband, steelhead, and Chinook Salmon rearing is reduced to around 30 percent of maximum (Hardin 1993, 2001, 2011). The decrease in available and suitable habitat under low flow conditions could restrict diel or seasonal movement to important habitats, result in fish congregating in the remaining pool habitats, cause increased stress and disease transmission, and could lead to the immediate or delayed mortality of a large portion of the native fish population. Extremely low flows will also expose cobble and gravel bars reducing benthic macroinvertebrate production, an important forage base for Crooked River fishes. In anticipation of stressful conditions for fish at low flows, ODFW proactively closed the recreational fishery in the Crooked River from Bowman Dam to the Highway 97 Bridge near Terrebonne and Ochoco Creek from Ochoco Dam to its confluence with the Crooked River from September 15 through October 31, 2022.

## Methods

To document changes in the river under extreme low flows, we established reference photo points at key locations that included riffles and control points and installed continuous temperature loggers at Chimney Rock (RM 68.2) and Castle Rock (RM 63.7) campgrounds logging at 15-minute intervals. In addition, flow and temperature data are available from the gage PRVO (RM 71.1) located approximately  $\frac{1}{2}$  mile downstream of Bowman Dam (RM 71.6) and CAPO (RM 47.8) in Prineville. Following dissolved oxygen spot checks documenting supersaturated conditions and concerns about nutrient loading, plant and algae decay, and diel respiration we included one night of continuous dissolved oxygen monitoring at RM 70.7, October 13-14, 2022.

We conducted annual monitoring of trout and whitefish populations in late June at approximately 210 cfs. Annual fish monitoring took place in the 2.5-mile reach between just above Big Bend (71.2) to Cobble Rock Campground (RM 68.7) June 28-July 1, 2022 (Figure 1). Monitoring took place by boat electrofishing with the same reach repeated each day. Redband Trout and Mountain Whitefish ( $\geq 200\text{mm}$ ) were collected and marked with a caudal clip. Each day the number of previously marked and unmarked fish were documented to develop a population density (fish/mile) using mark-recapture methodology (Van Den Avyle and Hayward 1999). Weight was collected on a representative sub-sample of fish to evaluate body condition (relative weight). A two-sample t-test was used to test for differences in relative weight before (June) and after (October) low flow conditions.

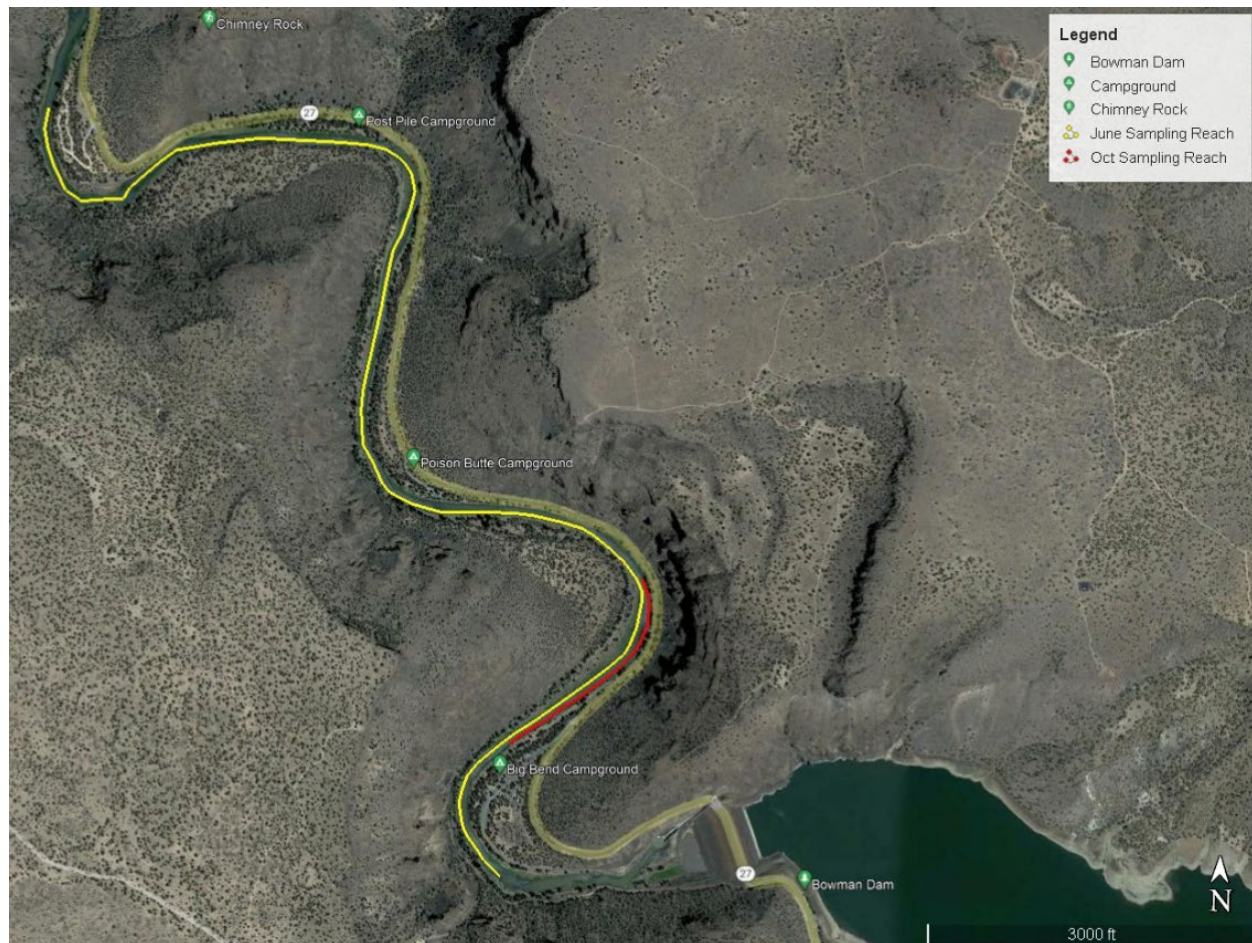


Figure 1. Boat electrofishing (June) and backpack electrofishing (October) reaches, 2022.

To evaluate fish response (survival and condition) to low stream flows, an index reach approximately 0.4 miles in length between RM 70.9-70.5 was sampled October 26-28 using the same methods as in June except fish were collected by two teams of backpack electrofishers working upstream in tandem instead of by boat (Figure 1). Fish were again marked with a caudal clip and a representative sample of weights was collected. Fish body condition was evaluated by calculating mean relative weight values for length-group and comparing the June and October values. Relative weight can serve as a surrogate for estimating fish body composition, as a measure of fish health, and to assess prey abundance, fish stockings, management actions, and in this case the impact of extreme low streamflow. To aid interpretation of relative weight, when values are well below 100 for an individual or a length-group, problems may exist with food availability or feeding conditions. When relative weight values are well above 100, fish may not be making the best use of a surplus of food (Neumann, Guy, and Willis 2012).

## Results

### Photo Points

Photos taken before and during the low streamflow period document the dramatic change to the river system between discharge levels of 175 and 10 cfs. The extreme low flows had a dramatic impact on wetted stream channel area and extent (Figure 2), potential for partial fish passage barriers at riffles, and control points such as former dam/diversion locations and aesthetic resources. Estimates of wetted channel or wetted widths were not collected; however, in most photo point locations the wetted channel width was dramatically reduced (over 50% and in some locations 80-90 percent). The reduction in flow and wetted area resulted in the desiccation of gravel and cobble bars, large areas of macroinvertebrate mortality and drying and dead vegetation (example photo point Figure 2). At many photo points there was evidence of racoon and otter predation of crayfish and mollusks. While no mass fish mortality events were documented or reported by the public, small numbers of dead Mountain Whitefish and Redband Trout were observed (Figure 3), especially following the initial down-ramp in flows which caused fish stranding in some locations and isolation from main channel flows in others.





*Figure 2. Crooked River below Bowman Dam pictured at 175 cfs (August 16, 2022) and 10 cfs (September 22, 2022).*





*Figure 3. Exposed stream channel, dying aquatic vegetation and a Redband Trout mortality at 10 cfs on September 23, 2022, at Chimney Rock. The fish was estimated at 16-in in length.*

### Streamflow and Water Quality

During the 2022 water year, streamflow in the Crooked River downstream of Bowman Dam (PRVO) was below state recommended levels (Nov 1, 2021- April 10, 2022) and extremely degraded from September 15<sup>th</sup> to October 31, 2022 (Figure 4). Crooked River streamflow downstream of the COID and Peoples Diversions in Prineville (CAPO) were even further degraded with 152 days (42%) below 15 cfs and 95 days (26%) below 6 cfs (Figure 4).

Stream water temperatures (7DADM) immediately below Prineville Reservoir (PRVO) gradually increased throughout the water year and peaked at 70°F on September 29<sup>th</sup>, 2022 (Figure 4). Due a smaller volume of water in Prineville Reservoir and shallower depth to the outlet this is warmer than normal and exceeds the Oregon temperature standard of 64.4°F (18°C) for salmon and trout rearing and migration. Stream temperature monitoring at Chimney Rock and Castle Rock showed elevated 7DADM temperatures in the 68-70°F range for August and early September; however, temperatures at those sites declined when the streamflow was reduced to 10 cfs in late September and October and tracked near the PRVO gage upstream. The 7DADM stream temperature 24 miles downstream in Prineville (CAPO) exceeded 80°F for most of July and August and were in exceedance of the 64.4°F temperature standard from June 5 through October 12, 2022 (Figure 4).

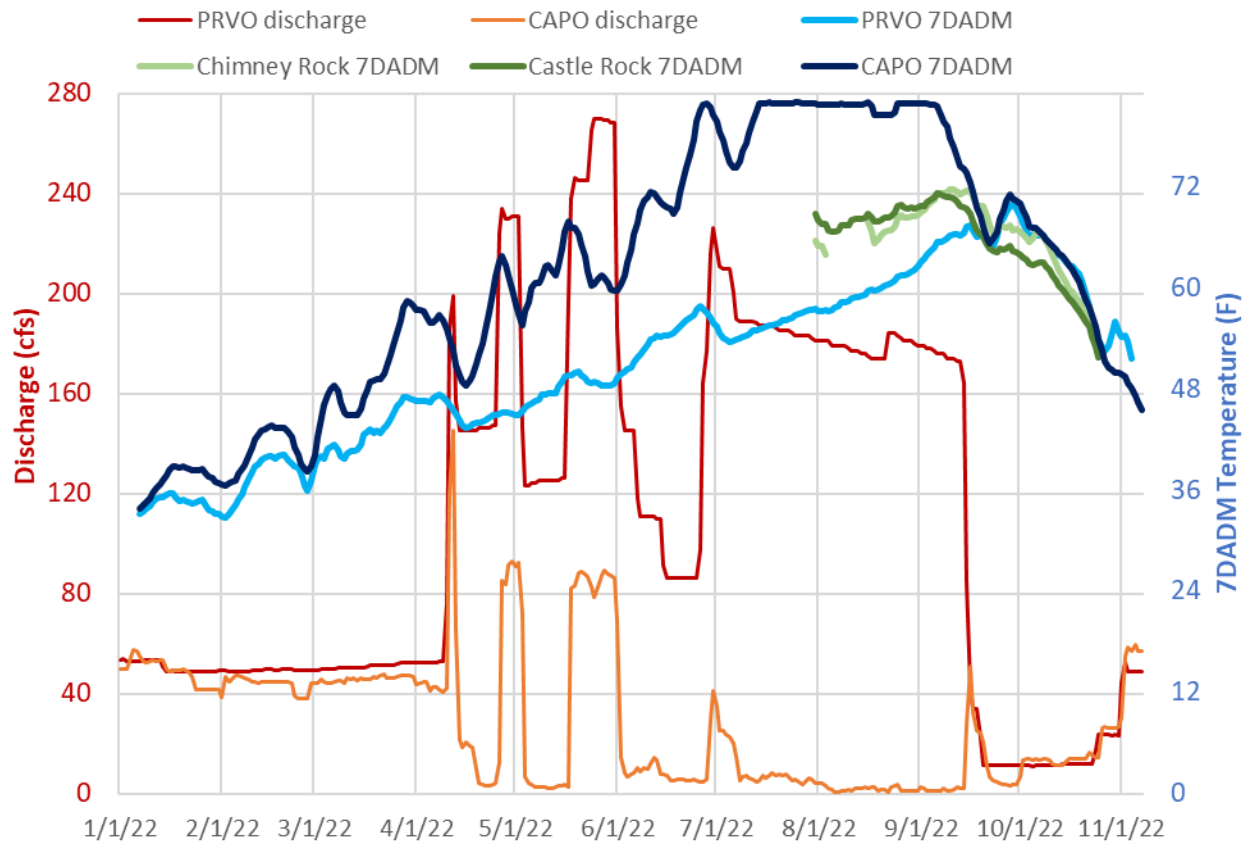


Figure 4. Discharge (shown in orange and red, left y-axis, cfs) and 7-day-average-daily maximum temperature (shown in blues and greens, right y-axis, Fahrenheit) just below Bowman Dam (PRVO), at Chimney Rock Campground, at Castle Rock Campground, and in Prineville (CAPO), 2022.

Spot-checks of dissolved oxygen on the afternoon of September 23, 2022, at six locations between Big Bend and Castle Rock revealed supersaturated conditions between 137-147% saturation. Similarly, spot measurements collected by the Crooked River Watershed Council and U.S. Fish and Wildlife Service on October 11<sup>th</sup> were supersaturated and ranged from 10.3 mg/L (120%) at Big Bend to 12.3 mg/L (134%) at Stearns Dam. Spot checks of dissolved oxygen on the afternoon of October 13, 2022, increased from 10.3 mg/L (104.9%) at the Bowman Dam stilling basin to 10.8 mg/L (112.1%) ½ mile downstream to 15.7 mg/L (166.8%) 1 ½ miles downstream of the dam. Dissolved oxygen flux approximately 1 ½ miles downstream of Bowman Dam (October 13-14<sup>th</sup>) ranged from 15.9 mg/L (170% saturation) in late afternoon to a low of 7.8 mg/L (73.5% saturation) just before dawn. The total diel flux observed was 8.1 mg/L indicating a bloom-bust cycle of primary production and respiration and the potential for nutrient impairment. The Oregon dissolved oxygen standard for cold-water aquatic life is an absolute minimum of 8.0 mg/L.

### Fish Sampling

Fish population monitoring conducted in June 2022 found fish populations to be healthy and estimated a Redband Trout population of 2,083 fish/mile and a Mountain Whitefish population of 6,950 fish/mile (Figure 5). Following low streamflows, sampling in October estimated a slight reduction in the Redband Trout population at 1,647 fish/mile and an estimated Mountain Whitefish decline of over 80% at 896 fish/mile (Figure 4). Additionally, sculpin (*Cottus* sp.),

Bridgelip Sucker (*Catostomus columbianus*), and Black Crappie (*Pomoxis nigromaculatus*) were collected in October but not in June, 2022. While not incorporated into the population estimate, much larger numbers of Redband Trout in the 80-100 mm (age-0) and 150-190 (age-1) range and Mountain Whitefish in the 140-170 mm range were collected in October vs June.

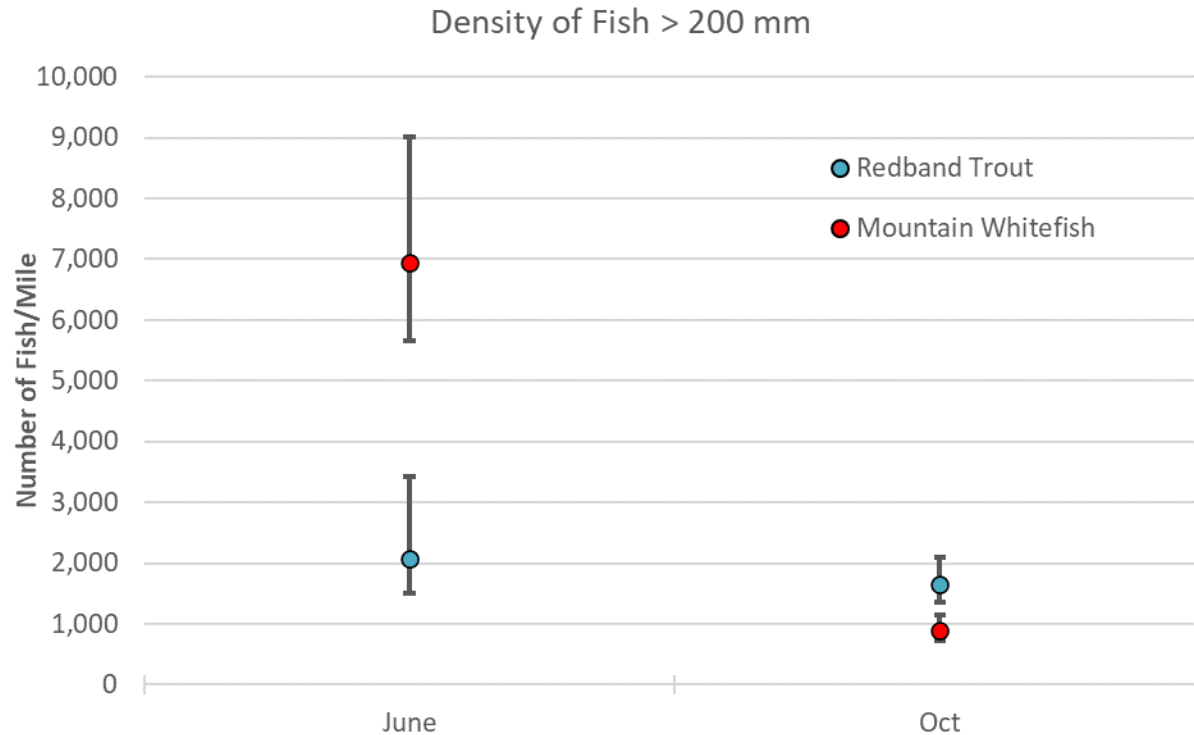


Figure 5. Redband Trout and Mountain Whitefish density estimates ( $\pm 95\%$  CI) June and October 2022.

The relative weight, a measure of condition, of Redband Trout was compared between June and October. Overall there was a decline in condition in October with most length groups in the 85-95 $W_r$  range (Figure 6). The mean relative weight of Redband Trout was found to have been significantly reduced from June (99) to October (90), ( $T=7.2$ ,  $p<0.001$ ). Rainbow Trout 100-250 mm (4-10 in) in length appeared to have the largest decline in relative weight. These fish would be mostly representative of age-1 fish with a few age-2 fish. Also notable was the absence of most of the large Redband Trout (380-550mm; 15-21 ½ in) observed in June in the October sample (Figure 6). Overall, the comparison of relative weight show that fish had a surplus of food in June and were in heavier body condition.



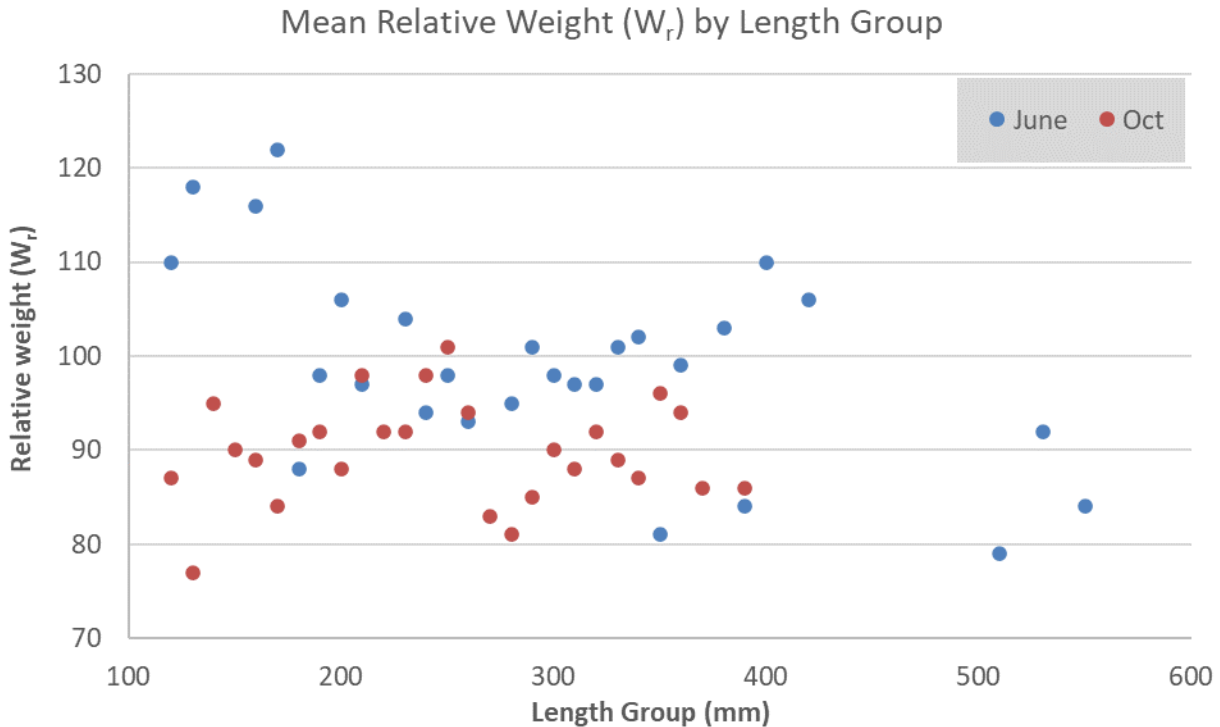


Figure 6. Mean relative weight for Redband Trout by length class, June and October 2022.  $W_r$  exceeding 100 is considered healthy while fish in the 90-90 range are considered slender and potentially prey-limited.

## Discussion

Following a water availability shortage and a curtailed irrigation season, the Crooked River downstream of Bowman Dam experienced six weeks of unprecedented low fall streamflows (10-cfs) in September-October 2022. Fish population monitoring near the end of the low-flow period documented overall survival of Redband Trout and Mountain Whitefish; however, density estimates (fish/mile) were reduced compared to before the drop in flows (June 2022). The density estimates presented were simple linear (fish/stream mile) estimates and did not account for changes in density with area (wetted width and depth) or suitable habitat available. Overall, Redband Trout has similar density (fish/mile) in October indicating many more fish were congregated into less wetted or suitable habitat available; whereas Mountain Whitefish densities appeared to have severely declined or fish had migrated from the study reach.

When compared to June, more age-0 and age-1 Redband Trout were found in the tailwater reach and few large trout (> 15-in) were present. We also observed a reduction in body condition/robustness of Redband Trout from June to October. While seasonal variation and life history influences can affect fish body condition, we would expect a higher weight-to-length ratio in October heading into winter compared to post-spawning fish condition in June. Given the impact of streambed desiccation and loss of invertebrate production at low flows, food availability may become severely limiting during the 2022-23 winter. Follow-up sampling in the spring of 2023 is needed to assess the impact of low flows on longer-term fish survival and condition.

Prineville Reservoir has an unscreened outlet located near the bottom of the reservoir and the potential for entrainment of large numbers of non-native warmwater fishes was a concern to ODFW as the reservoir was drawn down to historically low levels in 2022. Our sampling in June and October documented very small numbers of fish assumed to have originated from the reservoir in 2022 in the tailwater reach immediately downstream of Bowman Dam. Small numbers of juvenile Black Crappie were collected during sampling and a few bass (*Micropterus* sp.) were reported by anglers.

ODFW was also concerned that water quality could become severely degraded and unsuitable for salmonids during the low flow period. Initially the 2022 irrigation season was proposed to end in late July or early August and low flow conditions would have coincided with the warmest seasonal air and surface water temperatures of the year. The delay in the initiation of low flows until mid-September may have buffered the impact to surface water temperatures, at least in the few miles directly below Bowman Dam. At low flows we observed stream temperatures at Chimney Rock and Castle Rock tracking closely with the PRVO gage and some spatial variation in temperature in the Wild and Scenic segment suggesting that under extreme low flow conditions groundwater inputs or hyporheic flow may exert a greater influence on overall stream temperatures. Fish inhabiting the tailwater were exposed to significant periods of temperature exceedances; however, Redband Trout in particular, are known for their thermal tolerance having adapted to conditions in the high desert region. We also do not fully understand the groundwater-surface water interaction at extreme low flows, the presence of localized areas of thermal refugia, or the longer-term impacts (e.g., fitness, stress, disease) on Crooked River fishes.

Water quality monitoring also documented large daily fluctuation in dissolved oxygen at extreme flow flows. This was likely in response to nutrient loading and swings in primary production and respiration which were exacerbated under low flow conditions and a longer residence time. Dissolved oxygen levels did reach levels below criteria for salmonids during the night and large diel flux in DO can cause increased stress/and cause fish to migrate to areas with higher oxygen concentration (riffles) at night. Again, the long-term effects of cumulative water quality stressors and the anticipated loss of invertebrate production remain unknown.

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