WATER QUALITY IN JOHN DAY DAM'S FISH LADDERS , 1997

by

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EXECUTIVE SUMMARY

Temperature, dissolved oxygen concentration, conductivity and pH were measured hourly in John Day Dam's north and south fish ladders from 11 April to 4 June and 11 September to 4 November , 1997. Objectives of the monitoring were: 1.) to determine if there are water quality differences within John Day Dam's fish ladders, 2.) determine if these differences changed with operation of the ladder's removable sills, 3.) determine whether water quality differences between the John Day and Columbia rivers could be seen in the fish ladders using multiparameter water quality probes, 4.) describe water quality trends in John Day Dam's fish ladders. Three multiparameter water quality probes were stationed in each ladder: one at each exit, upper diffuser pool and entrance. Temperatures ranged from 7.7 - 15.0° C in the spring and 20.6 - 13.1° C in the fall. Temperature differences as great as 1.6° C were present between locations within the ladders, but were most pronounced in the south ladder. Dissolved oxygen concentration ranged from 7.7 to 12.6 mg/l. Differences in oxygen concentration between locations were observed during the spring with the highest concentration found in the north ladder entrance. Specific conductance ranged from 100 to 190 microsiemens. pH ranged from 7.3 to 8.5 units. There were no consistent pH or conductivity differences between sites. Operation of the sills did not appear to influence water quality. On a monthly basis, a single probe was used to measure water quality in the John Day River, the Columbia River above its confluence with the John Day River and the north and south ladder exits at John Day Dam. These data were then compared to see if differences between the John Day and Columbia rivers were reflected in differences between the north and south ladder exits. Analysis of variance (ANOVA) revealed significant differences between the John Day and Columbia rivers but no statistically significant differences between the north and south ladder exits. The small samples size (n=7) may explain, in part, why differences between the north and south ladder exits were not statistically significant. Qualitative comparison of temperature, conductivity, and pH trends at the John Day River, Columbia River above the John Day's confluence and at the north and south ladder exits at John Day Dam suggest that John Day River water is present in the south ladder and influences water quality there. Additionally, temperature differences between the John Day and Columbia rivers correlated well with differences between the north and south ladders (r = 0.83).

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INTRODUCTION

Temperature, dissolved oxygen concentration, conductivity and pH were monitored in John Day Dam's north and south fish ladders from 11 April to 4 June and 11 September to 4 November , 1997. Monitoring in the spring was conducted to field test new sampling sites and collect baseline water quality data. The fall portion of monitoring was part of a fish jumping evaluation conducted by Portland District's Fish Field Unit (FFU). Two hypotheses for fish jumping behavior at John Day Dam were addressed by water quality monitoring. The hypotheses were: 1.) fish jumping and holding behavior is caused by dissolved oxygen concentration differences at the ladder's upper diffuser pools, and 2.) jumping and holding behavior is more prevalent in the south ladder because of the presence of John Day River water.

Dissolved oxygen differences were observed between the south ladder exit and diffuser pool in 1994 (Jonas 1995) and 1996 (Langeslay 1997). For both years, dissolved oxygen concentrations were lowest in the diffuser pool and dropped to as low as 5 mg/l. While we found no literature source that relates fish jumping with dissolved oxygen concentrations, there is ample support for salmonid avoidance reaction and reduced swimming ability due to low oxygen concentrations (Davis 1975; Jones 1971; Whitmore 1960).

The presence of John Day River water in the south ladder may be affecting fish behavior. Environmental odors from natal streams are thought to be the primary stimulus attracting homing salmon (Hasler 1951; Cooper et al. 1976). Salmonids have also shown strong electroencephalograph response to water taken from various locations along their freshwater migration route (Oshima 1969). Some have speculated that salmon retrace a trail of olfactory stimuli that is the reverse of what was imprinted during their seaward migration. We feel it is possible that at times John Day River water does not mix with Columbia River water until it passes through the dam. As such, it would enter the south ladder exit where it would be most concentrated in the flow control section above the upper diffuser. Water supplied to the upper diffuser is drawn from deeper in the reservoir (~20') and may be comprised of only Columbia River water or a mixture of John Day and Columbia rivers. A third source of water comes from the tailrace and enters the ladder at the lower diffusers. If the water in the flow control section was comprised mostly of John Day River water, while water in the lower ladder was more representative of the mainstem Columbia, the path of environmental odors which salmon are responding to would be drastically altered compared to what was imprinted on juveniles. This difference may bring about a behavioral response such as holding or jumping.

Objectives

1. Determine if there are water quality differences within John Day Dam's fish ladders.

2. Determine if these differences changed with operation of the ladder's removable sills

3. Determine whether water quality differences between the John Day and Columbia rivers could be seen in the fish ladders using multi parameter water quality probes.

4. Describe water quality trends in John Day Dam's fish ladders.

METHODS

From 11 April to 4 June and 11 September to 4 November, water quality parameters were measured hourly at three locations in each ladder: at the exits, upper diffuser pools and entrances. Water quality data were collected with multiparameter probes equipped with temperature, pH, conductivity, turbidity and oxygen sensors. At each location, probes were stationed in 4 inch PVC stillwells which terminated about 6 inches above the ladder's floor (except at the south ladder entrance which ends about 20 feet above the floor). Probes were programmed to log temperature, conductivity, pH and dissolved oxygen concentration hourly. Conductivity measurements were temperature compensated and dissolved oxygen measurements were salinity compensated. Oxygen sensors were fitted with low flow, semipermeable membranes. Oxygen and pH sensors were continuously powered by internal lithium polarizing batteries. A two minute sensor warm-up period occurred before data were logged.

Calibration and maintenance were conducted every 2 weeks. Maintenance was performed as per manufacturer's recommendation (see Hydrolab Datasonde 3 operating manual for details). Conductivity and pH sensors were calibrated by immersing the sensors in calibration standards and watching the readings until they stabilized. Once the readings stabilized, parameter values were set. Prior to immersion, sensors were rinsed in tap water, rinsed in deionized water, blotted dry with a paper towel, and rinsed twice with a small amount of calibration standard. Conductivity was calibrated to 100 microsiemens. During the spring period, the 100 microsiemens standard was made by diluting 50 ml of 1000 microsiemen prepared solution (KCl) in 450 ml deionized water. In the fall, a manufacturer prepared 100 microsiemen standard was used. pH sensors were calibrated with a pH 7 zero buffer and with a pH 10 slope buffer. The oxygen sensor was air calibrated by inverting the probe so the oxygen sensor's membrane extended just above the water's surface. Once the reading stabilized (20 minutes), it was corrected by inputting barometric pressure.

Each probe logged data hourly for 2 weeks then was replaced with a freshly maintained and calibrated probe. North versus south ladder probe replacement was conducted on alternating weeks.

Verification of field measurements was performed by deploying a freshly calibrated probe alongside or in the same stillwell as probes which were in the field for 2 weeks. Both freshly calibrated and deployed probes were then programmed to log readings every minute for 15 minutes following a 15 minute stabilization period. The 15 minute averages were then calculated and compared to see if probe precision fell within manufacturer specified accuracy ranges. Along with side-by-side verification, a calibration log was maintained which included stabilized pre-calibration readings, minutes to stabilization and post calibration readings.

In addition to hourly measurements in the ladders, data were collected monthly from the John Day River at Fox Canyon (rm 8), the Columbia River about 1.3 miles upstream of the mouth of the John Day River, and north and south ladder exits. Each location was sampled with the same probe for 15 minutes following a 15 minute stabilization period.

RESULTS AND DISCUSSION

Temperature

Ranges and daily standard deviation averages of hourly temperature measurements are presented in Table 1. Seasonal trends (Figures 1 and 2) were similar between the north and south ladders however hourly temperatures varied more widely in the south ladder than in the north, especially during the spring period. Spring-time daily temperature variation in the south ladder occurred most prominently in the upper diffuser pool and exit. Average daily standard deviation was 0.34, 0.28, and 0.20 for the south exit, upper diffuser pool and entrance respectively while at the north ladder, daily standard deviation averaged 0.12 for all three sites (Table 1). Temperature differences between adjacent sites (exit, upper diffuser, and entrance) were greatest in the south ladder. The largest differences occurred between the upper diffuser pool and the entrance (Figure 3). For a more detailed discussion of ladder temperatures, see Dalen et al. 1995 and 1996.

Table 1. Range and standard deviation of hourly temperature measurements taken at John Day Dam's fish ladders 11 April - 4 June (spring) and 11 September - 4 November (fall), 1997.

	Range (°C)		**Average daily standard deviation**	
Location	**Spring**	**Fall**	**Spring**	**Fall**
South Exit	7.8 - 15.0	20.6 - 13.1	0.34	0.13
South Diffuser	7.8 - 14.6	20.6 - 13.1	0.28	0.12
South Entrance	7.7 - 13.8	20.6 - 13.1	0.20	0.06
North Exit	7.7 - 14.0	20.6 - 13.2	0.12	0.09
North Diffuser	7.7 - 13.9	20.5 - 13.2	0.11	0.08
North Entrance	7.7 - 14.0	20.5 - 13.2	0.12	0.08

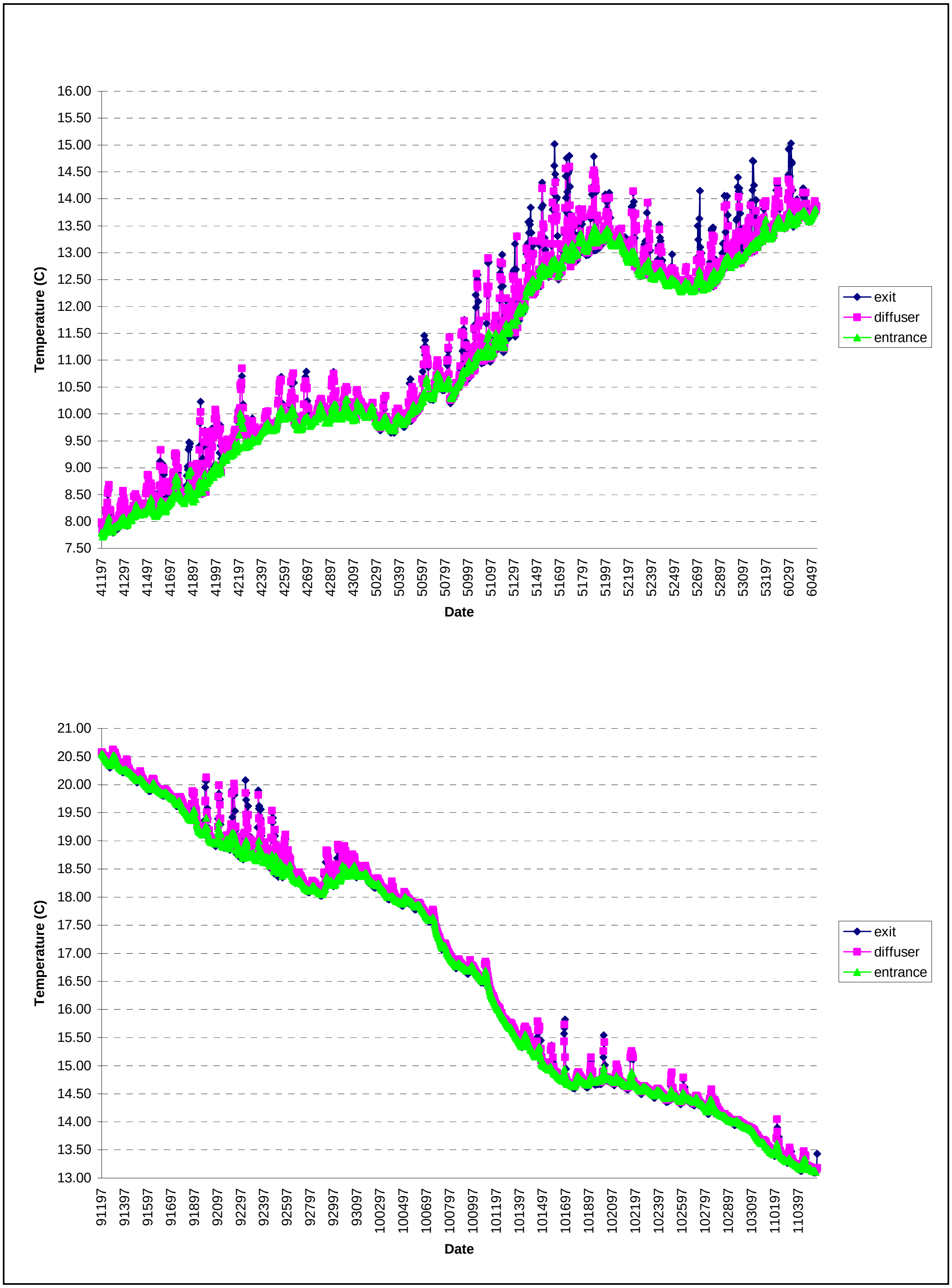


Figure 1. Temperatures from the exit, upper diffuser pool, and entrance sites at John Day Dam's south fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

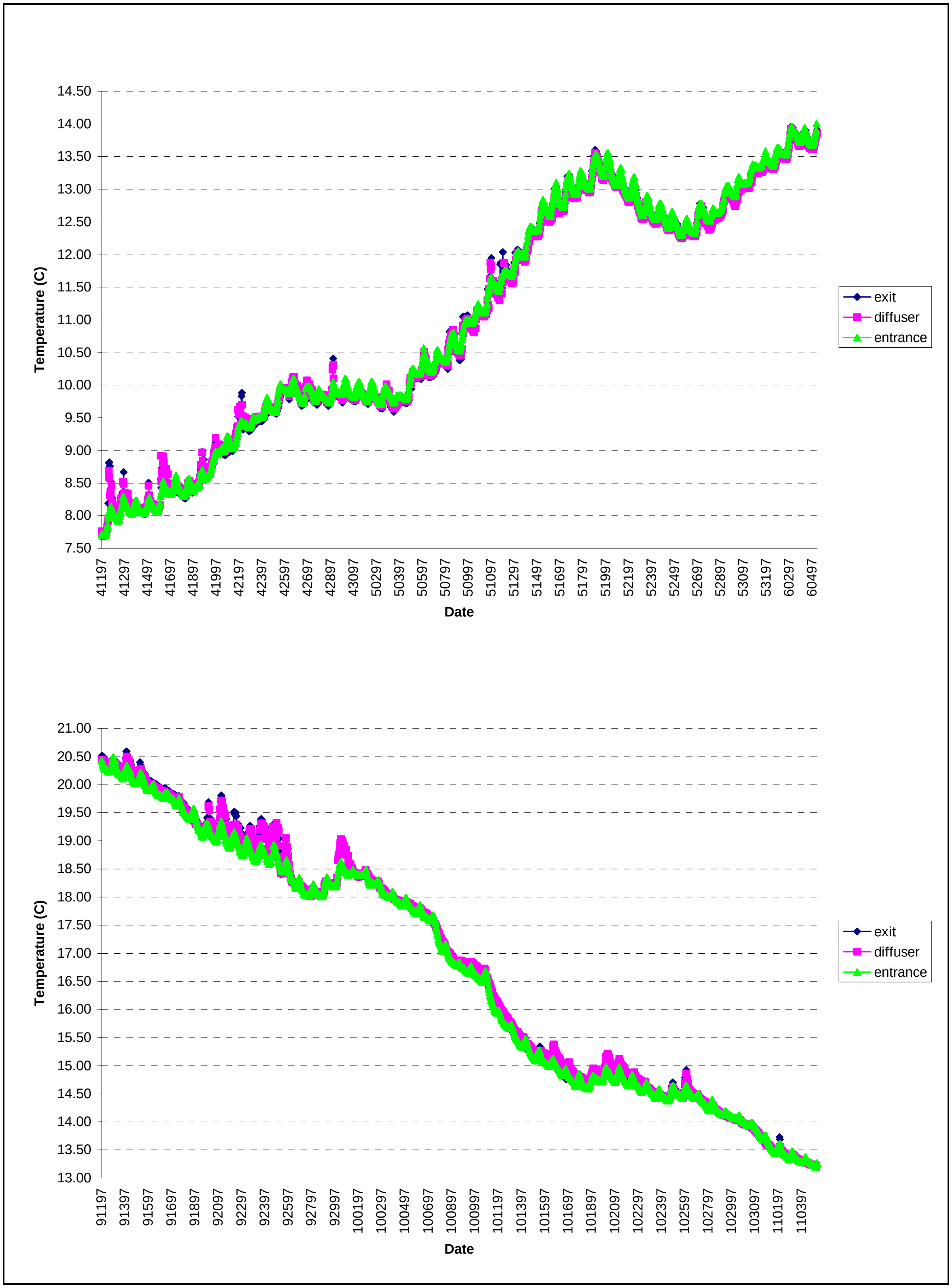
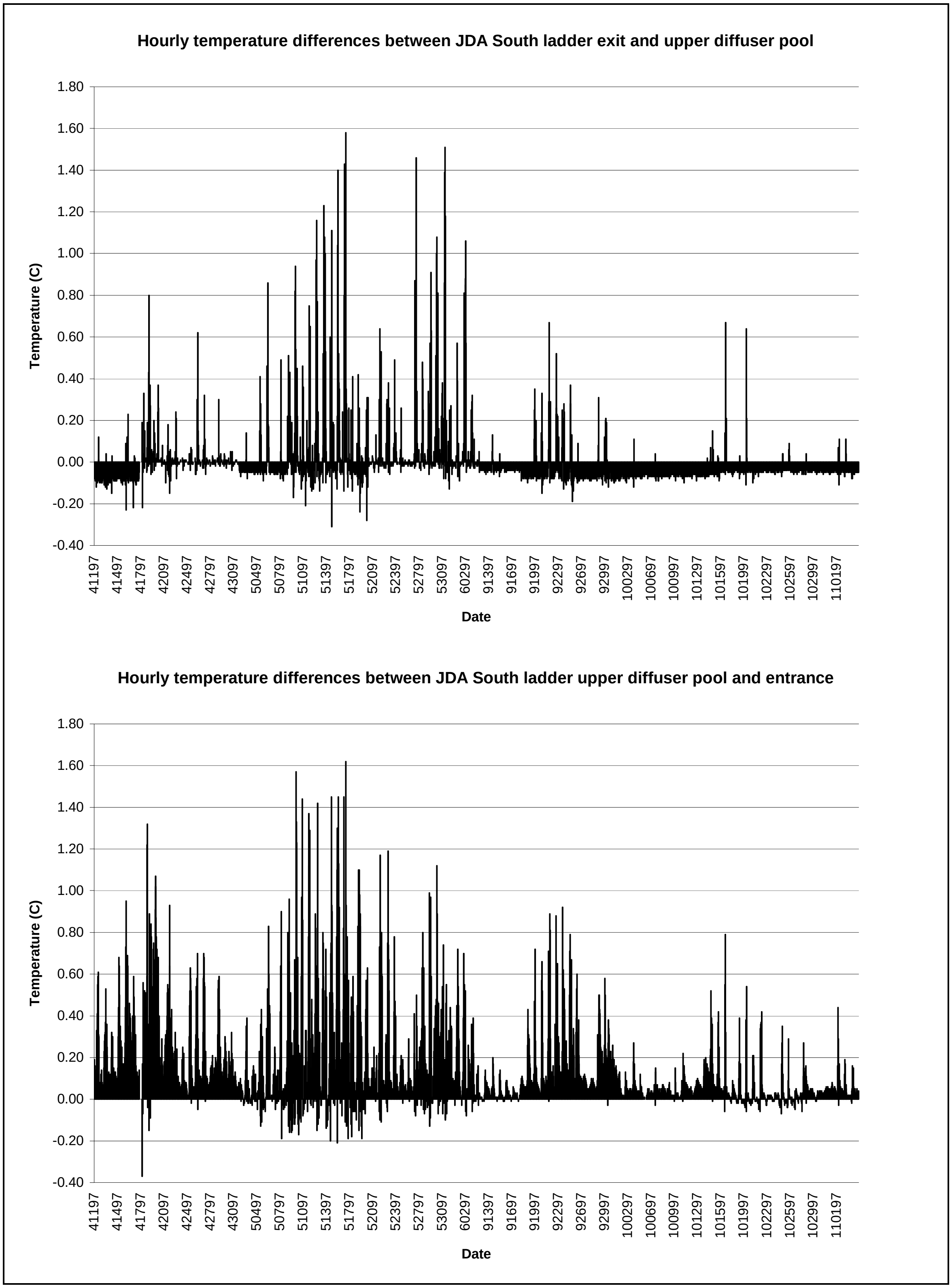


Figure 2. Temperatures from the exit, upper diffuser pool, and entrance sites at John Day Dam's north fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.



Hourly temperature differences between JDA South ladder exit and upper diffuser pool

Hourly temperature differences between JDA South ladder upper diffuser pool and entrance

Figure 3. Temperature differences between the south ladder exit and upper diffuser pool (exit - diffuser) and the upper diffuser pool and entrance (diffuser - entrance) at John Day Dam in 1997.

Dissolved Oxygen

Dissolved oxygen trends are displayed in Figures 4 and 5. Ranges and daily average standard deviations are summarized in Table 2. Some dissolved oxygen data were biased and were therefore excluded from the analysis. Dates of biased data, which were excluded from analysis, are identified and briefly explained in Table 3. For a more information regarding oxygen monitoring problems, refer to the Quality Control section of this report.

Oxygen concentrations remained higher than 7.6 mg/l in 1997, well above the 5 mg/l concentration observed in 1994 and 1996. We believe those earlier low concentrations reflect measurement error due to low flow in the sample areas (Langeslay 1997). Changes such as the low-flow membrane and raising the stillwell off the ladder's floor seem to have remedied this.

Table 2. Range and standard deviation of hourly dissolved oxygen measurements taken at John Day Dam's fish ladders 11 April - 4 June (Spring) and 11 September - 4 November (Fall), 1997.

	Range (mg/l)		**Average daily standard deviation**	
Location	**Spring**	**Fall**	**Spring**	**Fall**
South Exit	11.4 - 13.0	8.2 - 11.0	0.10	0.12
South Diffuser	11.1 - 12.8	7.8 - 10.3	0.11	0.11
South Entrance	11.7 - 13.7	7.7 - 11.0	0.09	0.10
North Exit	11.0 - 13.4	7.8 - 11.1	0.08	0.13
North Diffuser	11.7 - 13.8	8.7 - 11.3	0.06	0.08
North Entrance	12.6 - 15.1	8.7 - 10.8	0.16	0.10

Table 3. Biased dissolved oxygen data.

Location	**Dates**	**Cause**
South Diffuser	4/17; 5/19-6/4; 9/11-9/17	Sample interruption; bad sensor; bad lithium battery
South Entrance	5/27&5/19; 10/15-11/4	Sample interruption; bad sensor
North Exit	4/11-4/28; 9/17&10/22	Too short calibration wait (4 min); sample interruption
North Diffuser	4/11-4/28; 9/23-10/7	Bad lithium batteries; bad sensor
North Entrance	4/11-4/28	Bad lithium batteries; bad sensor

During removable sill testing, dissolved oxygen concentration differences within the ladders were less than 1.3 mg/l. Configured with low flow membranes, our probes should be accurate to within 0.5 mg/l. Comparing two probes gives an accuracy range of ± 1.0 mg/l. Considering the probes' wide accuracy allowance and the problematic oxygen sensor performance we experienced this season, we would conclude that we did not detect an oxygen concentration difference between the exit and upper diffuser, with sills open or closed. Furthermore, we detected no difference in any one location between the sills open and sills closed conditions.

Dissolved oxygen concentrations were highest in the north ladder during the spring, with the greatest concentrations occurring in the entrance (Figure 6). The north entrance dissolved oxygen concentrations were consistently higher than those of the exit and diffuser locations. At the south ladder, dissolved oxygen concentration were highest in the entrance pool until about mid May. Figure 6 plots entrance oxygen concentrations with tailrace and forebay total dissolved gas (TDG) levels reported by the Fish Passage Center. The north ladder entrance has a strong association with the tailrace TDG levels for the two deployments covering the period of 11 April to 7 May (r = 0.92 and 0.90 respectively). A deployment is defined as the period a particular probe samples. The south entrance appears more strongly correlated with the forebay TDG than with the tailrace TDG, however all south ladder entrance deployments had correlation coefficients (r) less than 0.70 except for the period of 18 to 30 April where r equaled 0.97. The north entrance stillwell terminates about 6" above a floor diffuser grating so that much of the water being measured there comes from the diffuser. It seems likely that the reason the north entrance area is more strongly correlated with tailrace TDG is because the add-in water supplied to north entrance diffusers is pumped from the tailrace below the spillway.

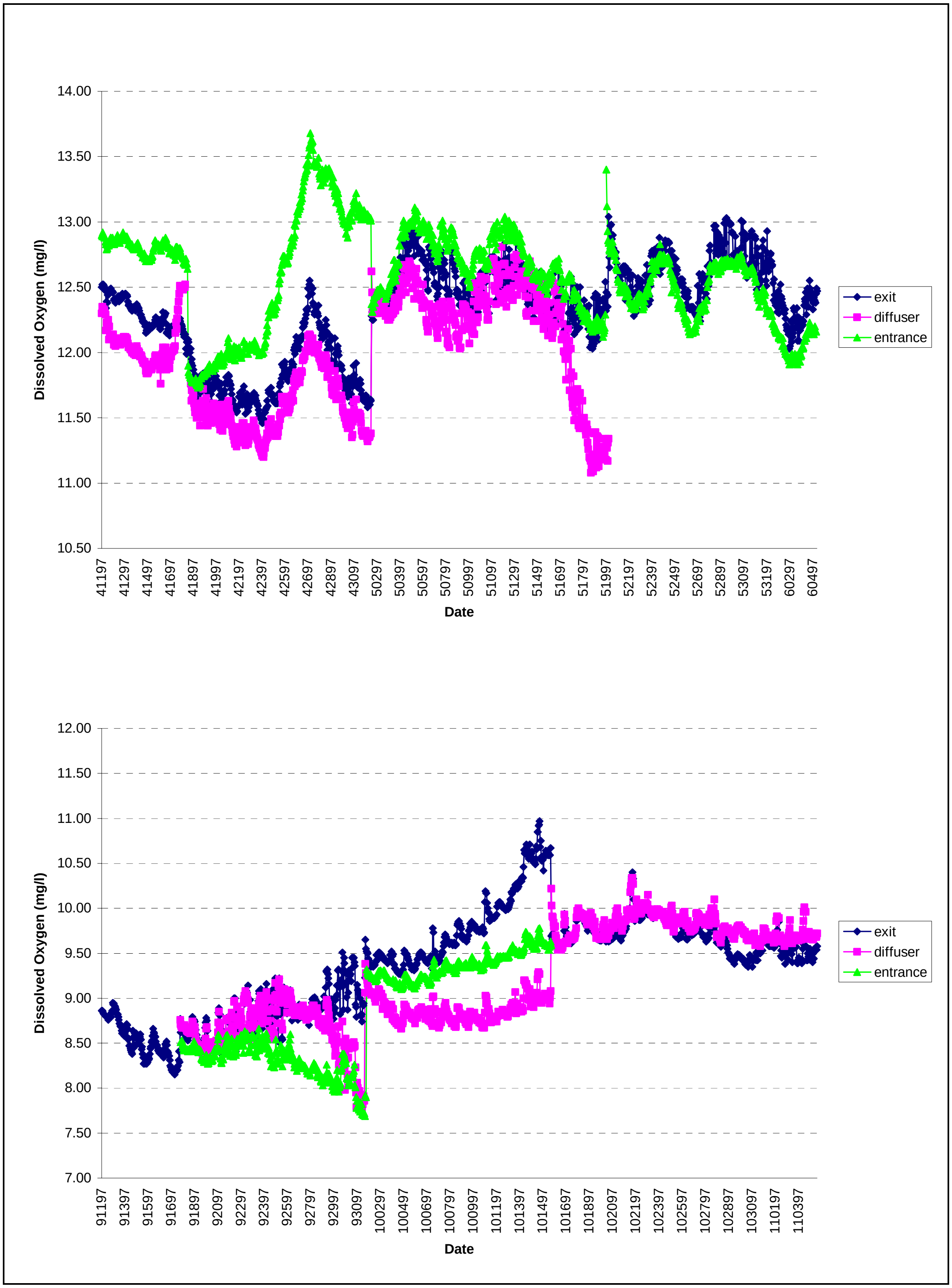


Figure 4. Dissolved oxygen concentration at the exit, upper diffuser pool, and entrance sites at John Day Dam's south fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

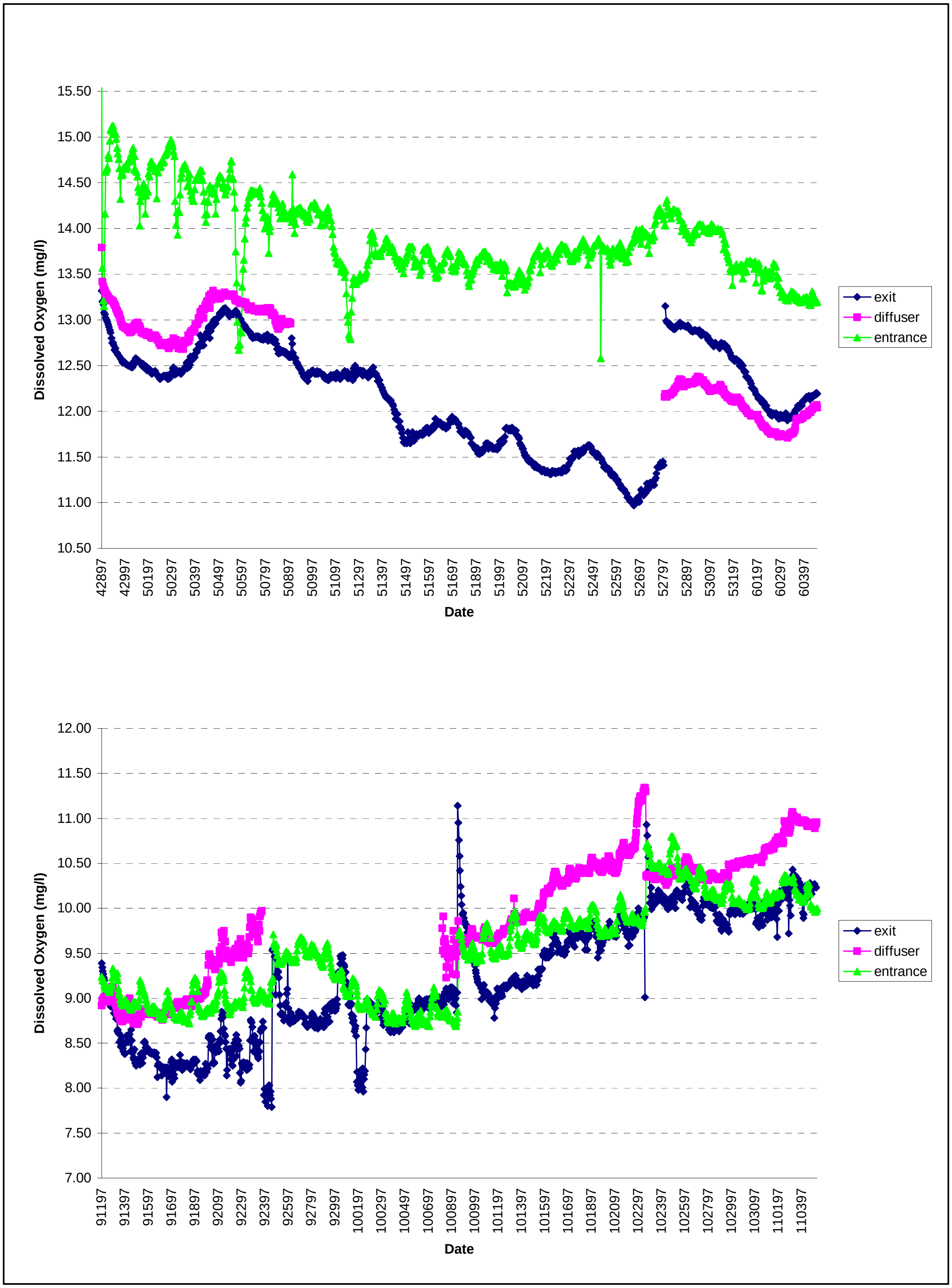


Figure 5. Dissolved oxygen concentration at the exit, upper diffuser pool, and entrance sites at John Day Dam’s south fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

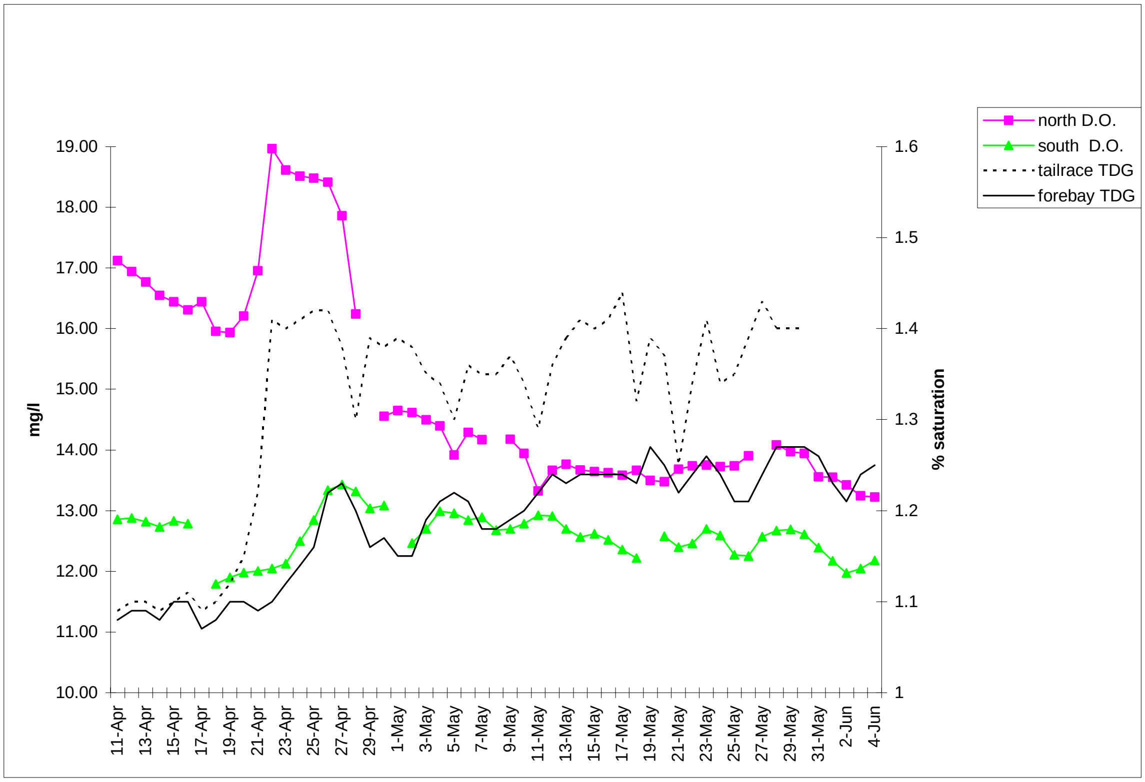


Figure 6. North and south entrance dissolved oxygen concentration and forebay and tailrace total dissolved gas (TDG) percent saturation at John Day Dam, 11 April - 4 June, 1997.

Specific Conductance

All sites produced nearly identical specific conductance trends (Figures 7 and 8). During spring monitoring, specific conductance peaked at approximately 165 microsiemens in late April and declined to a low of around 100 microsiemens in May. In the fall, conductance climbed from 130 microsiemens in September to nearly 190 microsiemens in late October. There were no consistent conductivity differences between sites.

pH

For both the spring and fall periods, the trend in pH was relatively flat, ranging between 7.3 and 8.5 units (Figures 9 and 10). There were no consistent pH differences between sites.

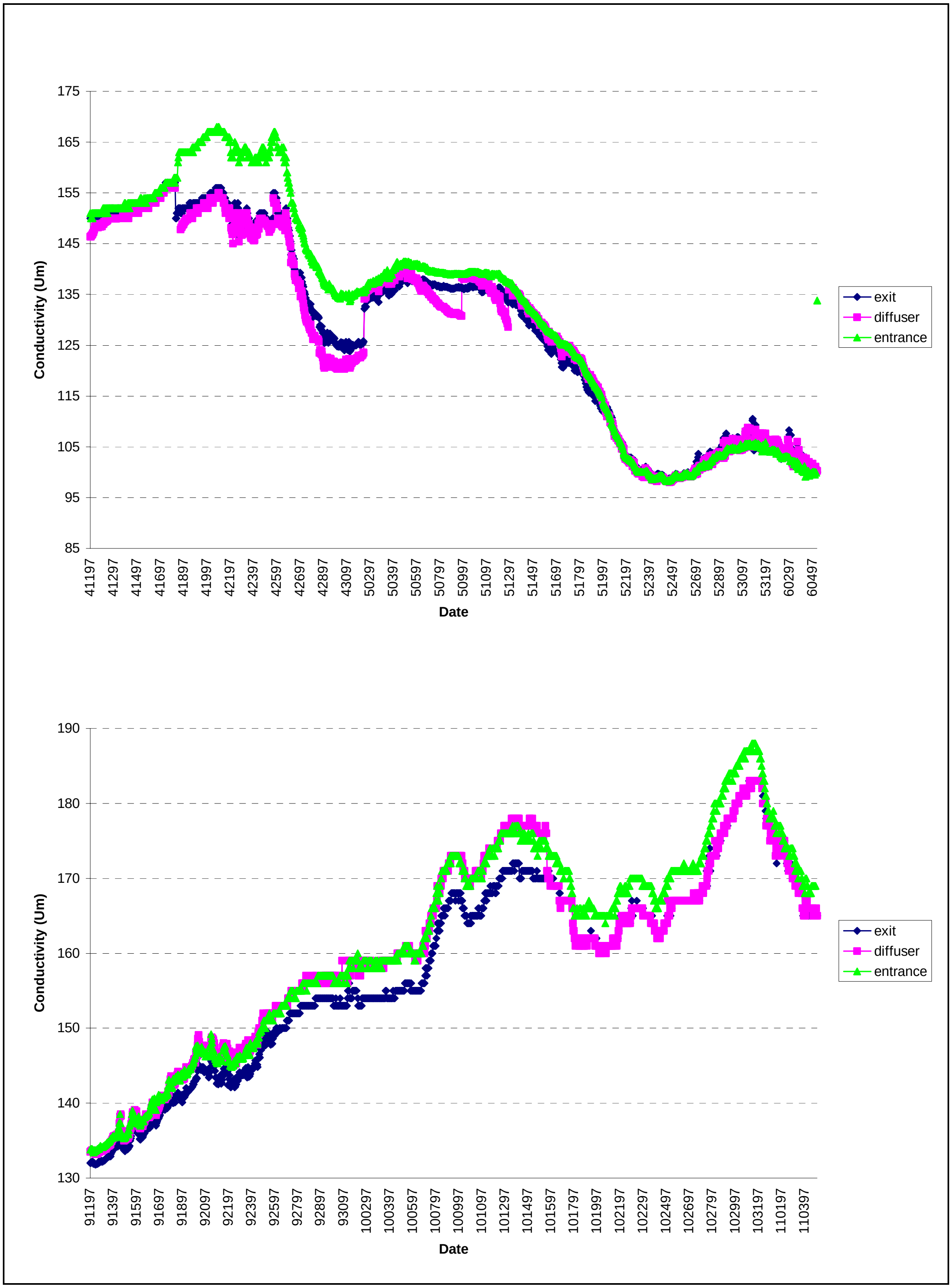


Figure 7. Specific conductance at the exit, upper diffuser pool, and entrance sites at John Day Dam's south fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

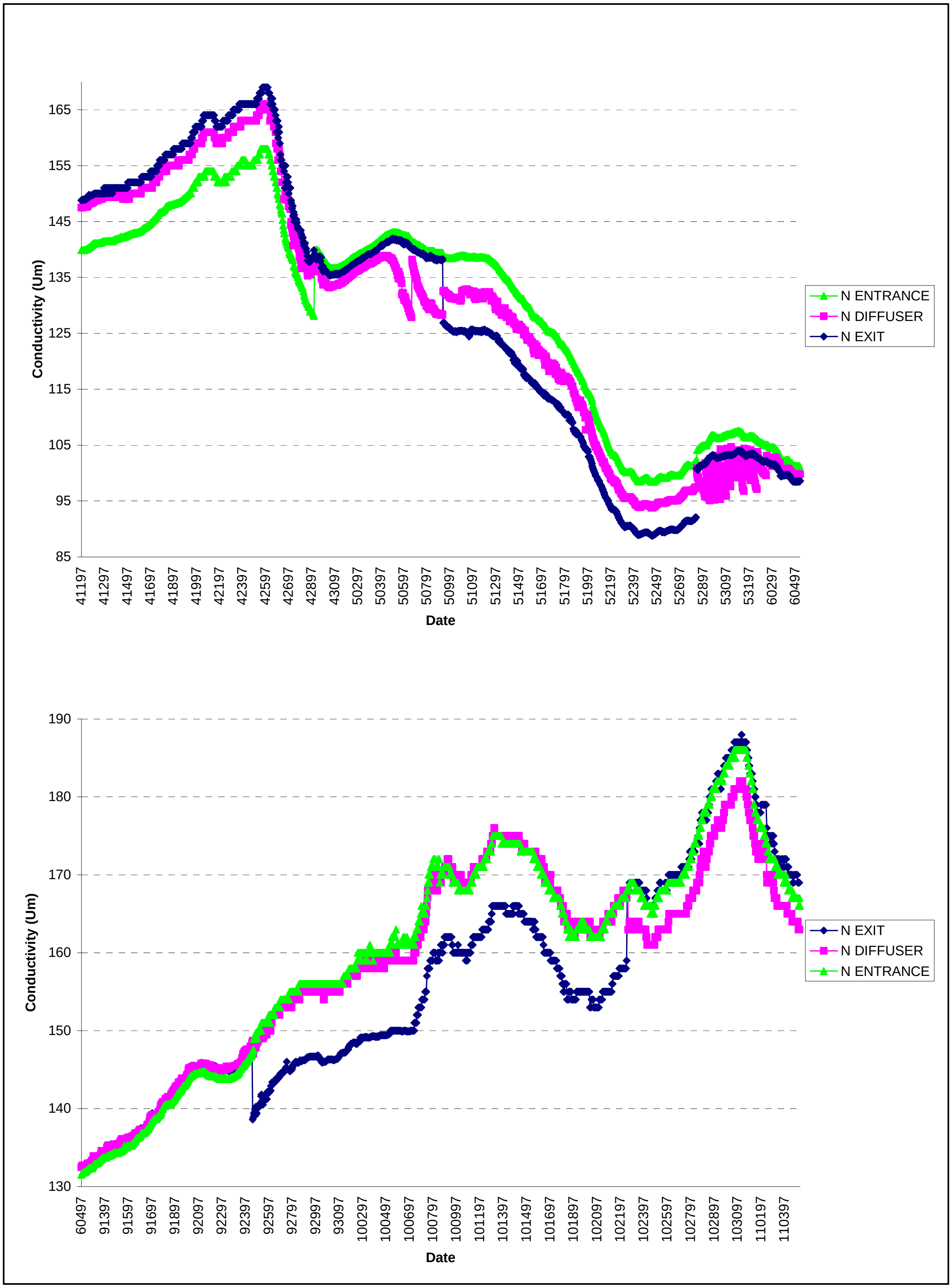


Figure 8. Specific conductance at the exit, upper diffuser pool, and entrance sites at John Day Dam’s north fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

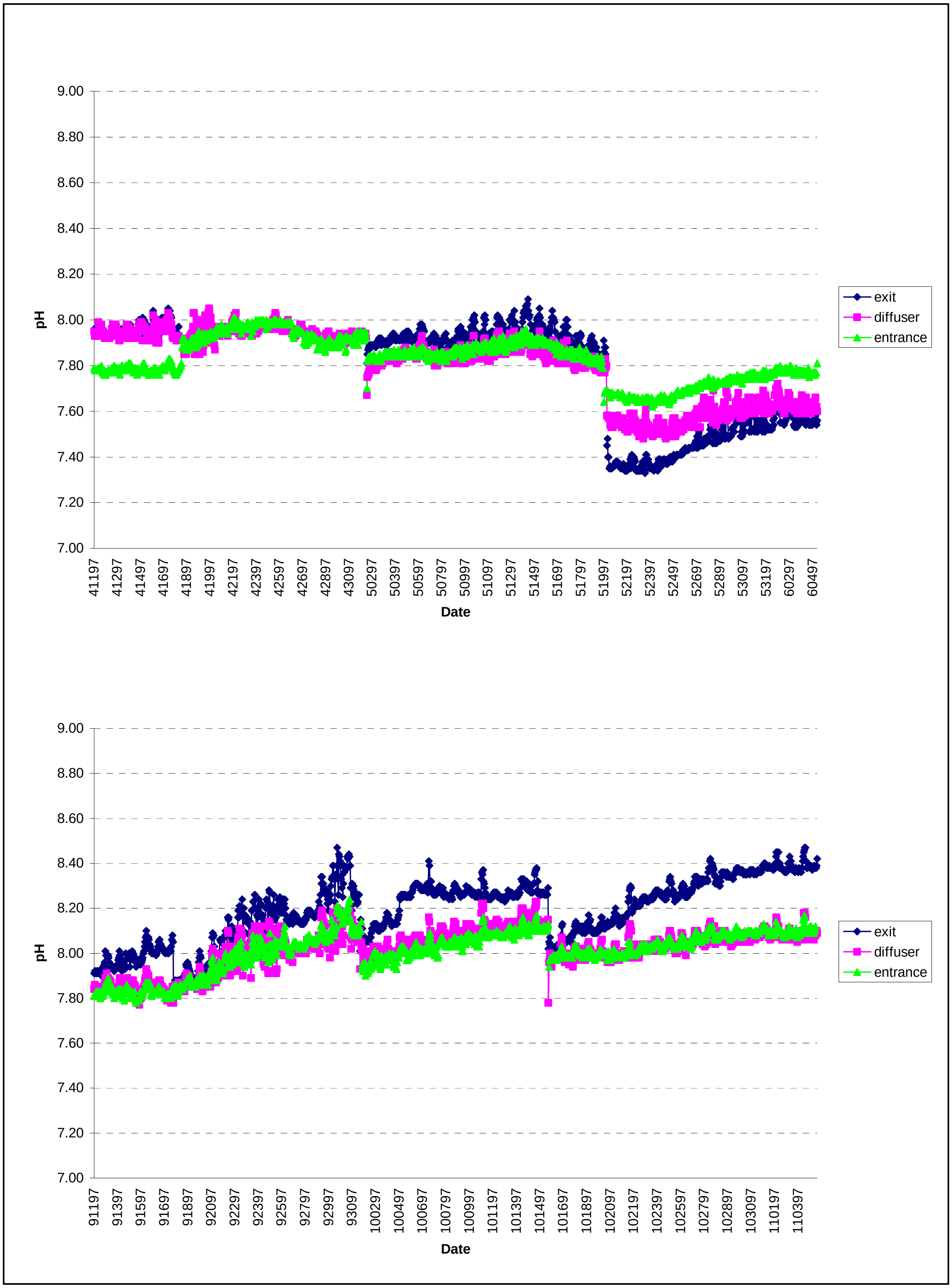


Figure 9. pH at the exit, upper diffuser pool, and entrance sites at John Day Dam's south fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

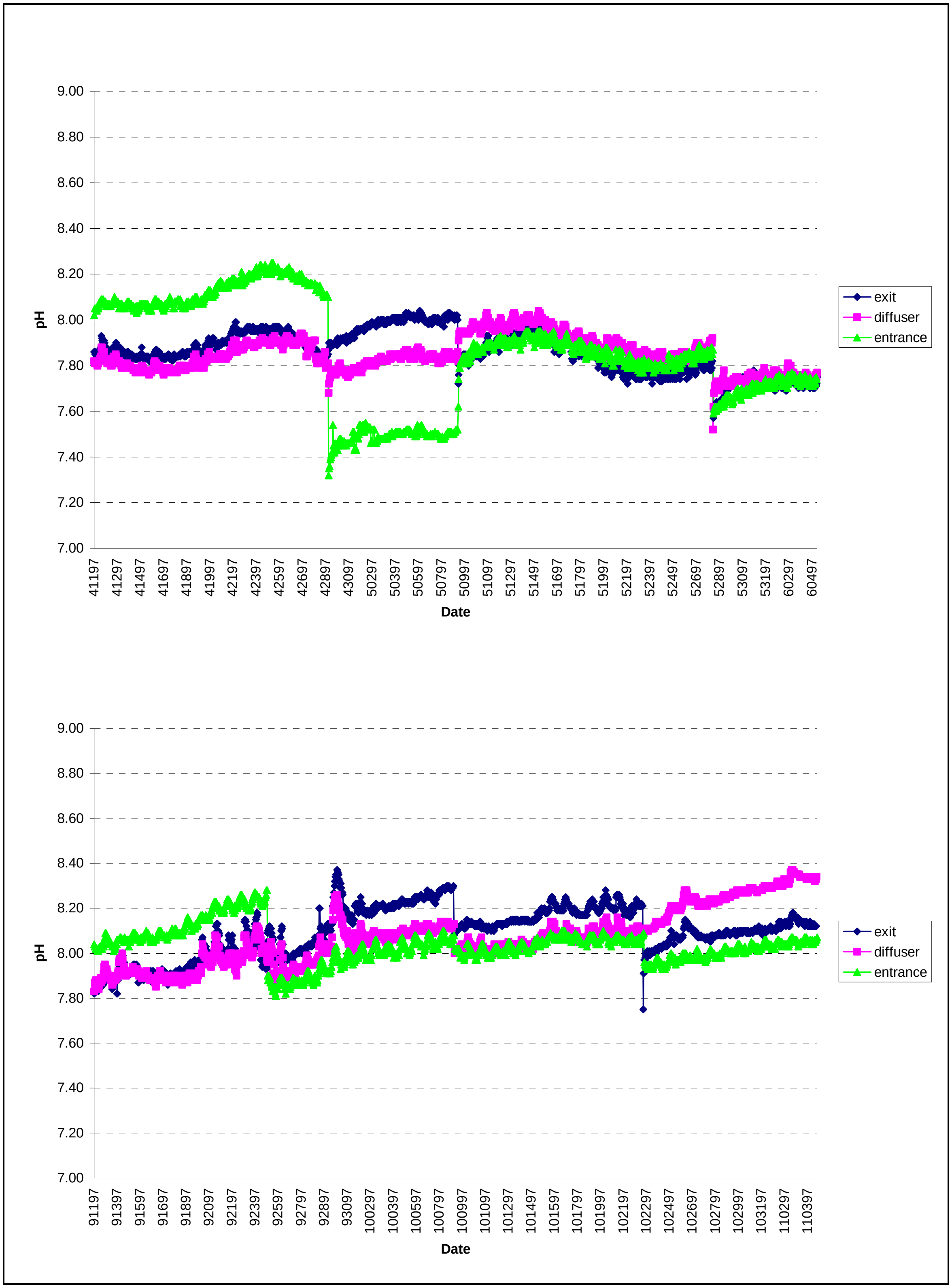


Figure 10. pH at the exit, upper diffuser pool, and entrance sites at John Day Dam's north fish ladder, 11 April - 4 June and 11 September - 4 November, 1997.

John Day River Influence

To determine John Day River's influence on water quality in the south ladder, we compared water quality differences between the John Day and Columbia rivers to those of the north and south ladder exits. Figures 11 - 14 present data collected at the John Day River (Fox Canyon, rm 8), the Columbia River 1.3 miles up (rm 220) from the John Day River mouth and the north and south ladder exits at John Day Dam. While data collected from 1 May through 1 October reveal differences between the John Day and Columbia rivers, these differences are not consistently seen in the north versus the south ladders. Based on temperature and conductivity trends (Figures 11 and 14), differences between the John Day and Columbia rivers are reflected at the north and south ladder exits from 1 May to 9 July. After that time, the relationship diminishes. This may be explained in part by John Day River discharge volume which, on average, peaks at 6,000 cfs in April and drops to below 200 cfs in July. The lower summer and fall discharge may reduce any influence John Day River has on the south ladder. Overall, temperature appears to be the strongest indicator of John Day River presence in the south ladder. Temperature differences between the John Day and Columbia rivers (John Day - Columbia) show a strong association (r = 0.83) with differences between the south and north ladders (south - north). It should be noted, however, that none of the apparent differences between the north and south ladders were statistically significant ($P<0.05$). This may be due to our small sample size (n=7).

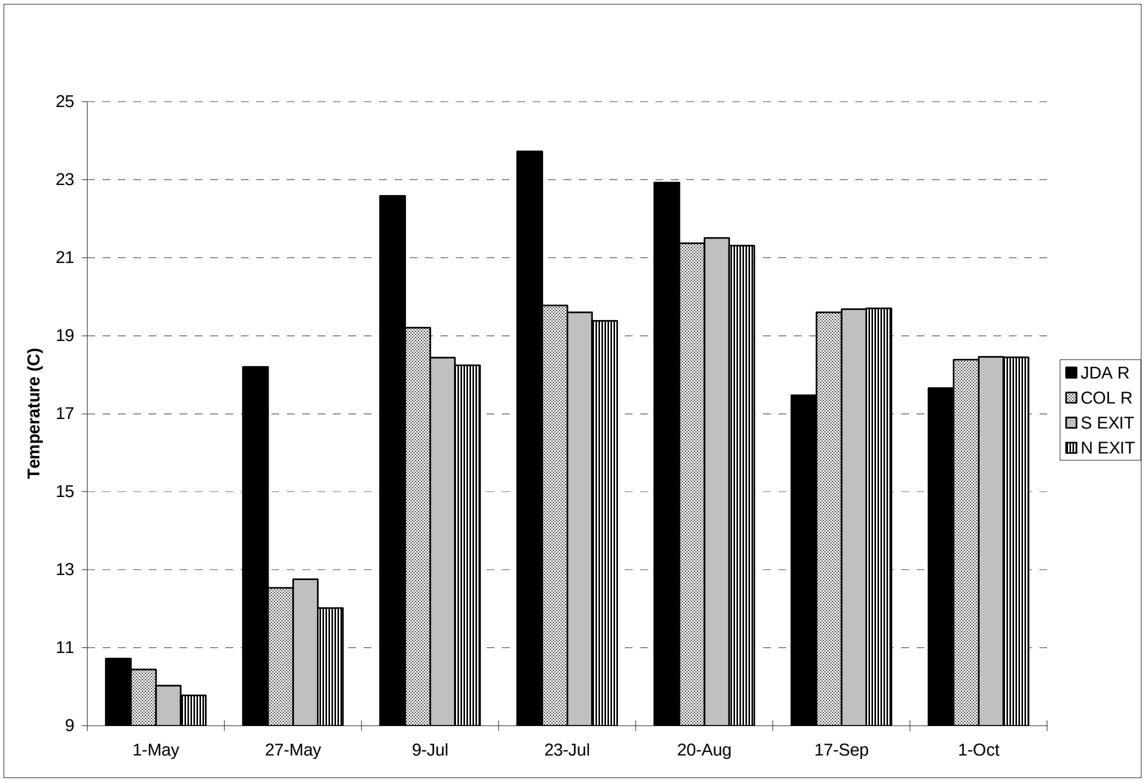


Figure 11. Water temperature at the John Day River (rm 8), Columbia River (rm 220), and north and south ladder exits at John Day Dam in 1997

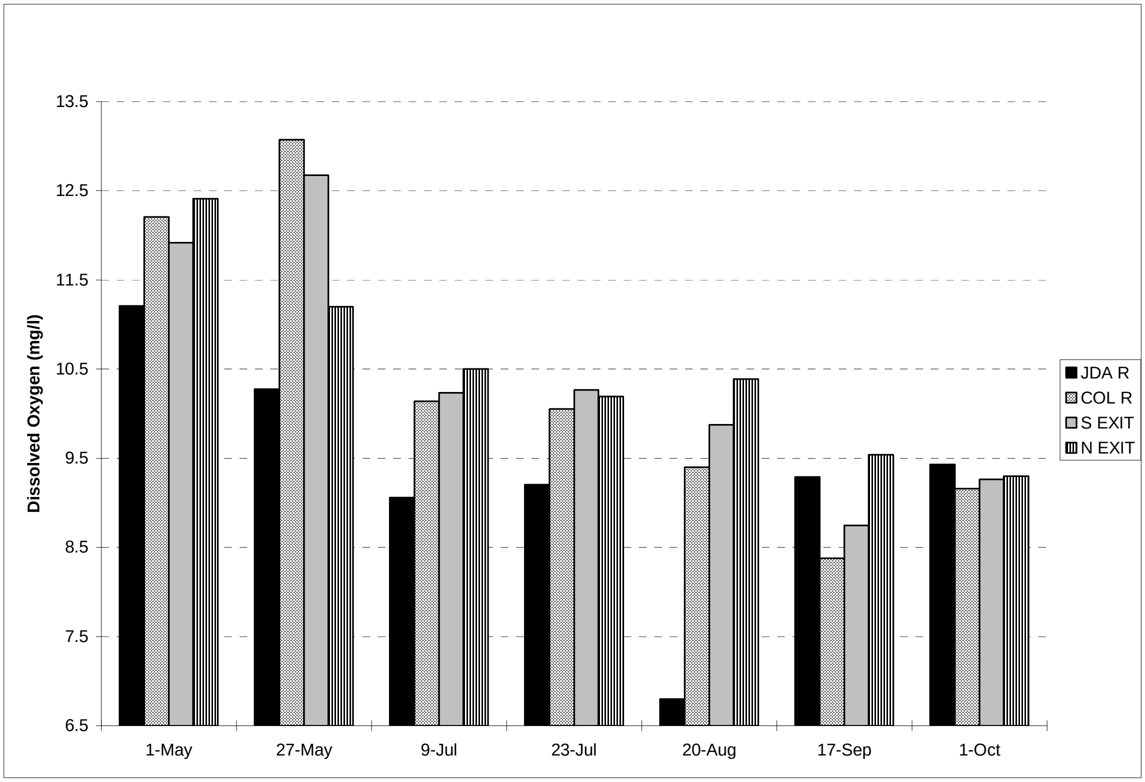


Figure 12. Dissolved oxygen concentration at the John Day River (rm 8), Columbia River (rm 220), and the north and south ladder exits at John Day Dam in 1997.

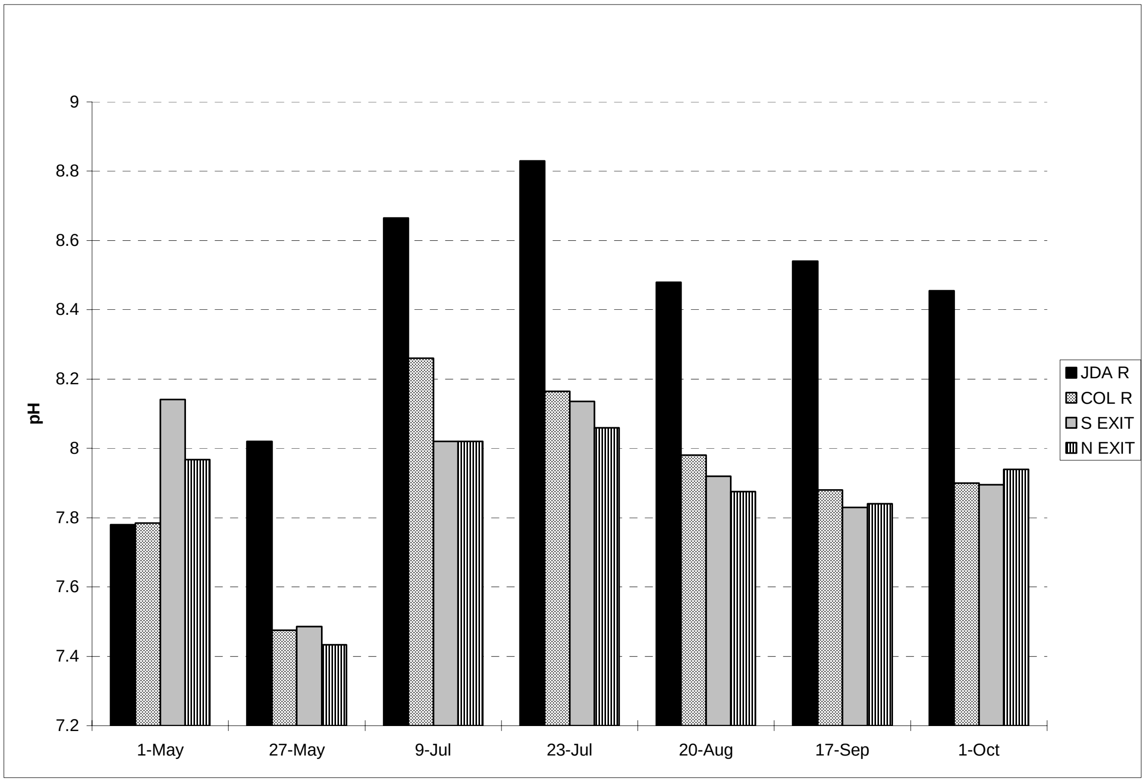


Figure 13. pH at the John Day River (rm 8), Columbia River (rm 220), and the north and south ladder exits at John Day Dam in 1997.

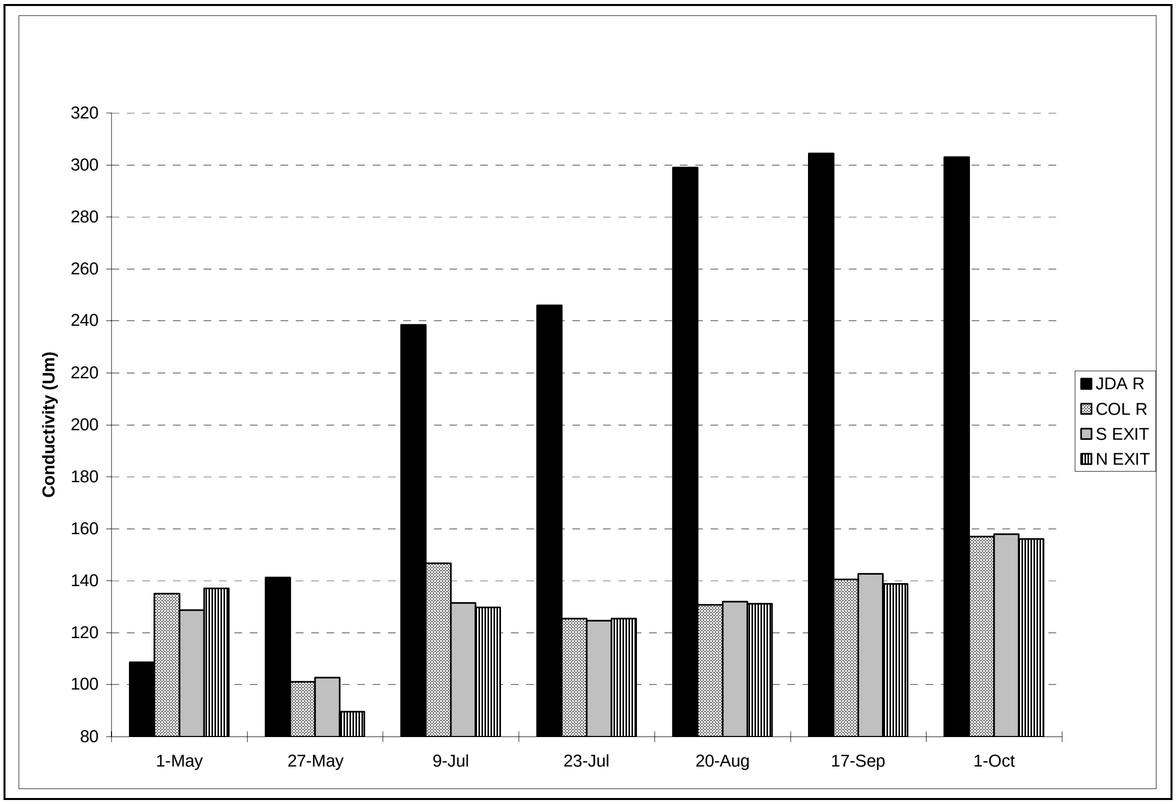


Figure 14. Specific conductance at the John Day River (rm 8), Columbia River (rm 220), and the north and south ladder exits at John Day Dam in 1997.

Quality Control

Comparisons between deployed probes and freshly calibrated probes were conducted approximately eight times at each site throughout the monitoring period. The results in Table 4 are derived by subtracting deployed probe measurements from calibrated probe measurements. Please note that manufacturer accuracy specifications are doubled to reflect the possible additive error of two probes. Average differences for temperature, pH and dissolved oxygen were within manufacturer allowed error values. During the spring, conductivity differences were outside the manufacturer specifications. Conductivity for that period averaged 125 μmhos which gives an expected maximum error of ± 2.5. Conductivity measurement precision improved during the fall because we improved our calibration procedure by switching to a manufacturer prepared 100 microsiemen standard rather than diluting a 1000 microsiemen prepared solution to 100 microsiemens. Calibration for pH was improved as well in the fall and an increase in precision was noted. Before calibrating, pH sensors were rinsed once in tap water and twice with calibrating standard rather than once with tap water, once with deionized water and once with standard. Dissolved oxygen differences ranged outside manufacturer specifications for both spring and fall periods. Oxygen sensors posed several problems this season: internal polarizing batteries went dead, sensors did not stabilize before calibration, and one sensor wore out. Because multiprobes monitored remotely for 2 week periods, dissolved oxygen sensors were fitted with low flow membranes. This alleviated some of the membrane fouling problems that occur due to algae, bacteria and sediment buildup. While low flow membranes were our best option for stationary, long-term monitoring, they had some disadvantages. This included additional battery requirements, longer stabilization times, reduced accuracy (0.5 mg/l vs. 0.2 mg/l), and increased sensor wear.

Table 4. Average difference and range of differences between probes that had been deployed 2 weeks and freshly calibrated probes. For comparrison, manufacturer specifications are also included.

		Spring		**Fall**	
Variable	**Specs.**	**Avg.**	**Range**	**Avg.**	**Range**
Temperature (°C)	± 0.4	-0.01	-0.12 - 0.05	-0.03	-0.12- 0.03
pH (units)	± 0.4	0.33	-0.05 - 0.97	0.22	0.18 - 0.43
Conductivity (μmho)	± 2%	-3.30	-13.54 - 3.11	-0.57	-2.11 - 0.99
Dissolved Oxygen (mg/l)	± 1.0	-0.44	-1.85 - 2.10	-0.64	-2.78 - 0.42

New sites for this season included the south fishway entrance, the exit, upper diffuser pool, and entrance in the north fishway, the Columbia River 1 mile up from the John Day River mouth, and the John Day River at approximately river mile 8. New fishway sampling sites posed some problems for simultaneous side-by-side calibration checks: flows were too high to station freshly calibrated probes outside of the stillwells where deployed probes were located. Instead, we logged data on deployed probes for 15 minutes, then replaced them with freshly calibrated probes and logged data for the subsequent 15 minutes. We feel this is still an adequate check of precision, but takes twice as long as side-by-side checks in locations where both probes can log data in the same location at the same time. The sites in the John Day and Columbia rivers were both near shore and, later in the season, had less flow going by them than earlier. The shallow (~1 m), near-shore water may have made these sites more susceptible to short term, local weather changes.

CONCLUSIONS AND RECOMMENDATIONS

In terms of our objectives, we determined the following at John Day Dam in 1997:

Objective 1. Determine if there are water quality differences within John Day Dam's fish ladders. There were temperature differences between adjacent sites in the south ladder, the largest occurring between the upper diffuser pool and entrance (>1.6 ° C). These temperature differences have been observed and are discussed in more detail by Dalen et al. (1996 and 1997). Site to site dissolved oxygen concentration differences were also observed. Dissolved oxygen concentration was consistently higher in the north ladder entrances for the entire spring monitoring period. Higher dissolved oxygen concentrations occurred in the south ladder as well but lasted only until early may when differences disappeared. We attribute the higher dissolved oxygen concentrations at the north ladder entrance to supersaturated add-in water drawn from below the spillway.

Objective 2. Determine if water quality differences changed with operation of the ladder's removable sills. The operation of the removable sills did not appear to affect water quality.

Objective 3. Determine whether water quality differences between the John Day and Columbia rivers could be seen in the fish ladders using our multi parameter water quality probes. Qualitative comparison of temperature and pH trends at the John Day River, Columbia River above the John Day's confluence and at the north and south ladder exits at John Day Dam suggest that John Day River water is present in the south ladder and influences water quality there. Additionally, temperature differences between the John Day and Columbia Rivers correlated well with differences between the north and south ladders ($r = 0.83$). It should be noted, however, that none of the water quality parameter differences between the north and south ladders were statistically significant ($P<0.05$). This may be due to our small sample size ($n=7$).

Recent water quality investigations at John Day Dam should lead us to more closely scrutinize auxiliary water (AWS) sources. Not only should we consider juvenile fish entrainment when designing and locating add-in water intakes, but we should also investigate the water quality of any proposed AWS source. In particular, temperature at AWS intakes should be uniform with respect to temperatures in the ladders. AWS designers should also consider total dissolved gasses when selecting water sources. Research by Gray (1977) indicates that adult chinook salmon may avoid gas supersaturated water. Excessive gas supersaturation may be reduced by locating intakes in forebays, in deeper water, away from stilling basins or by using aerated sources such as juvenile bypass system excess water.

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