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Evaluation of the Bonneville Dam Second Powerhouse Juvenile Bypass System, 2000

Annual Report for 2000.

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Executive Summary

In 1999, the U.S. Army Corp of Engineers completed the first phase of construction on a modified juvenile bypass system (JBS) at Bonneville Dam's Second Powerhouse (PH II). The system included a new conveyance pipe and outfall. Prior to modification, hydraulic conditions in the immediate tailrace created favorable feeding conditions for northern pikeminnow (*Ptychocheilus oregonesis*) and subjected outmigrating salmonids to high predation rates. The new bypass was designed to convey fish around the immediate tailrace area and liberate them 2.7 km downriver where high water velocity discourages predatory fish from maintaining feeding positions.

We evaluated the effects of travel through the modified bypass system in 2000. The main objectives of the study were to determine: 1) the physiological effects on smolts of traveling through the conveyance pipe, 2) the effects of passage through the conveyance pipe on tailrace egress behavior, and 3) the influence of tailrace water velocities on fish movements.

Physiological Effects of Bypass System

To evaluate the physiological effects of travel through the pipe, we compared blood plasma cortisol and lactate concentrations in juvenile salmonids, during their downstream migration, before entering and after passage through the conveyance pipe. From 17 April to 7 July 2000, we sampled 272 yearling chinook, 276 steelhead, and 266 subyearling chinook salmon.

The stress response from passage through the conveyance pipe was minimal and could not be separated from the normal stress response associated with the capture and holding procedure of the tests. Plasma cortisol did not increase immediately after passage through the conveyance pipe in five of six tests. When fish were held and sampled over time, cortisol levels increased 1-3 h after capture, then decreased within 24 h to levels similar to those observed at time of capture. Lactate concentrations increased in some fish sampled after passage when compared to fish collected before entrance, although in most cases the increase was minimal. Increased lactate levels indicated that fish may have physically exerted themselves as they traveled through the conveyance pipe, but the extent of exertion was uncertain. When fish were captured and held in tanks, lactate levels increased 1 h after capture, then decreased within 3 h to levels found in fish sampled at time of capture. It appeared that the capture and holding procedure caused an additive stress to fish and contributed to the elevated levels of cortisol and lactate. This also allowed us to determine that fish, which traveled through the conveyance pipe, were capable of exhibiting a stress response and recovering from the stress in a short period of time.

Tailrace Egress Behavior

To evaluate dam passage and tailrace egress behavior we monitored the movements of radio-tagged salmonids using shore-based antennas and boat tracking. Fish movements were monitored from the forebay through the bypass system to exit stations 8, 16, and 21 km downriver of the dam. From 8 May to 20 July 2000, we obtained travel time and movement data for 1,122 radio-tagged yearling chinook salmon and 645 steelhead released from upriver radio-telemetry studies. Additionally, we released approximately 50 radio-tagged yearling chinook salmon into the upstream end of the bypass, and compared their tailrace behavior to equivalent sized groups of stressed and unstressed yearling chinook that did not pass through the conveyance pipe. This was repeated using yearling steelhead and subyearling chinook. To determine if the behavior of actively migrating salmonids was discernable from the movements of dead fish being passively transported downriver, we released and tracked 27 dead radio-tagged yearling chinook and 29 dead steelhead. We also evaluated the influence of tailrace hydraulic conditions on fish movement by comparing the movements of radio-tagged fish to the movements of a passive drift buoy, or drogue, equipped with a global positioning system (GPS) that recorded its movement and chronological history.

Median travel time from the forebay to the outfall area through the JBS was longer than median travel time through non-JBS routes. Yearling chinook had a median travel time of 121 min and steelhead had a median travel time of 81 min from the forebay, through the JBS, to the outfall area. Delays by chinook may have been caused by fish holding in the collection channel upstream of the conveyance pipe. For steelhead, the majority of this time was spent in the conveyance pipe. Yearling chinook and steelhead that passed the dam through the spillway and

Powerhouse I had a median travel time of approximately 30 minutes between the forebay and the outfall. Overall, fish moved quickly through the conveyance pipe. We found no evidence of direct mortality caused by the pipe.

Median travel time and behavior through the tailrace area below the outfall was similar for upriver fish that passed through JBS and non-JBS routes. We detected no significant difference in median travel times to the downriver exit stations for both yearling and subyearling chinook released into the JBS compared to stressed and unstressed fish released near the outfall. However, stressed steelhead took longer to reach the downriver exit stations compared to steelhead released into the JBS and unstressed steelhead released near the outfall. Less than 4% of the fish we released into the JBS and obtained travel times for took more than 90 min to travel between the outfall area and the first exit station 8 km downriver.

During mobile tracking we contacted 28 (18%) of the fish we released into the upstream end of the conveyance pipe. Of these, none were believed to be consumed by predators. One delayed before moving downriver, and none used the side channel behind Ives Island. We also contacted 86 fish that were released upriver. Of these, 2% were believed to be consumed by predators, 7% delayed before moving downriver, and 3% used the side channel behind Ives Island. Of the yearling chinook that were detected by fixed site antenna behind Ive's Island, 14% had passed through the JBS, and 15% of the steelhead detected there had passed through the JBS.

Drogues were released as radio-tagged fish entered the tailrace study area. We obtained GPS positions of the drogue and concurrent fish positions for 10 yearling chinook, 11steelhead, and 5 subyearling chinook released from upriver studies. In most cases, fish and drogue followed the thalweg on the south side of the main river channel indicating the fish moved passively between the outfall and the Beacon Rock area. Occasionally, fish moved in the mid to north channel while the drogue moved in the south side of the channel. The drogue did not pass behind the islands.

Introduction

Seaward migrating juvenile salmonids (*Onchorhynchus* spp.) are vulnerable to predation by northern pikeminnow (*Ptychocheilus oregonesis*) in the tailrace area of dams. At Bonneville Dam's Second Powerhouse (PH II) tailrace area, consumption of juvenile salmonids was found to be high compared to predation in reservoirs (Ward et al. 1995), and fish using the old PH II bypass showed reduced survival compared to that of fish passing through the turbines or over the spillway (Ledgerwood et al. 1990).

Dam passage through many routes, such as screens, gatewells, fish sorters, turbines, and spillways, can be stressful during the downstream migration of smolts (Mathews et al. 1986; Maule et al. 1988). Recent evidence indicates that physiological stress associated with passage (Mesa et al. 1994) and the location of bypass outfalls (Shively et al. 1996) may increase predation. Snelling and Matson (1997) found that when smolts were released in areas away from shore, where water velocities were relatively high, they tended to move downriver readily.

In 1999, the U.S. Army Corps of Engineers (COE) completed the first phase of work on a new juvenile bypass system (JBS) and outfall at PH II. The system was designed to convey fish around the immediate tailrace area and liberate them in high velocity water where predators were less likely to maintain position and prey upon passing fish. The new system became operational prior to evaluation, and concerns that fish were being subjected to stress by traveling through the JBS needed to be addressed.

In 1999 and 2000, the U.S. Geological Survey (USGS) evaluated the condition and behavior of yearling and subyearling chinook salmon (*O. tshawytscha*) and steelhead (*O. mykiss*) that passed through the new JBS conveyance pipe and outfall. The objectives of this research were to determine: 1) the physiological effects on smolts of traveling through the conveyance pipe, 2) the effects of passage through the conveyance pipe on tailrace egress behavior, and 3) the influence of tailrace water velocities on fish movements.

Study Site

Bonneville Dam is located on the Columbia River at river km 235. The dam consists of two powerhouses and a single spillway, each separated by an island (Figure 1). Powerhouse I (PH I) spans from Bradford Island to the Oregon shore. Powerhouse II (PH II) consists of eight turbine units and is located on the north side of the river, spanning from Cascade Island to the Washington shore. At PH II, juvenile fish are guided away from turbines by submersible traveling screens into a fish collection channel. The channel is partially dewatered at the north end of the facility where fish enter a 1.22 m diameter high-density polyethylene plastic pipe. The pipe goes underground and runs west (downriver) for 3,530 m past a fish sampling facility at the downstream end to an outfall. Fish are conveyed through the pipe by flowing water to the outfall where fish and water plunge approximately 4 m into the main river channel. Water flows through the pipe at approximately 1.5 m/s. At the fish sampling facility, the pipe is partially dewatered by primary and secondary dewatering systems. Juvenile salmonids drop through separator bars and are channeled through a passive integrated transponder (PIT) tag scanner (Prentice et al. 1990). Fish with selected PIT codes are diverted to a holding tank where they can be crowded and anesthetized. Non-diverted fish re-enter the pipe 180 m from the outfall and are liberated into the main channel at the outfall.

From the outfall, the river flows west (Figure 2). Two kilometers downriver from the outfall the river splits into a main channel and a series of side channels that form a group of islands on the north side of the river known as the Ives Island Complex. The side channels were considered potential holding areas for juvenile salmonids. The side channels then rejoin the main river channel 6 km downriver from the outfall. The river continues west from there. Our study site reached from the Powerhouse II outfall to Cape Horn Rock at river km 211 (Fig 3).

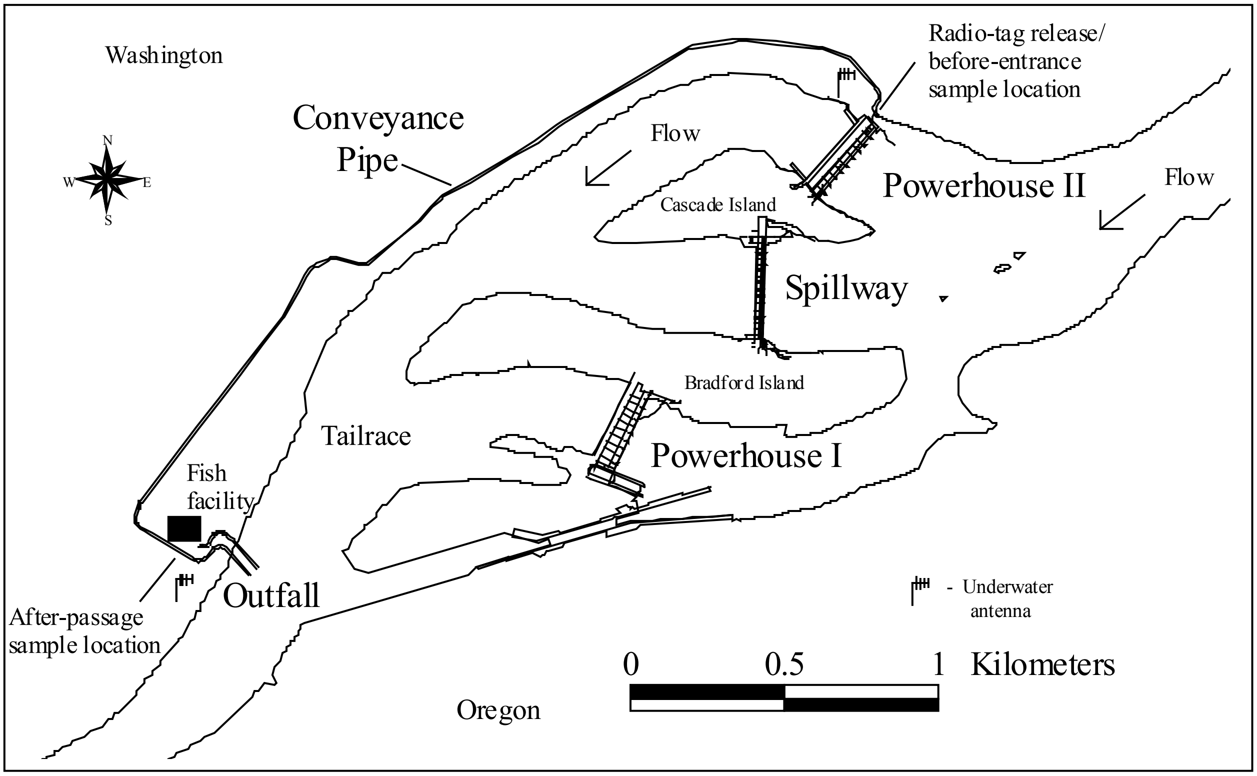

Figure 1. Bonneville Dam and Powerhouse II juvenile bypass system conveyance pipe, outfall, and sample locations, 2000. Does not include positions of forebay antennas

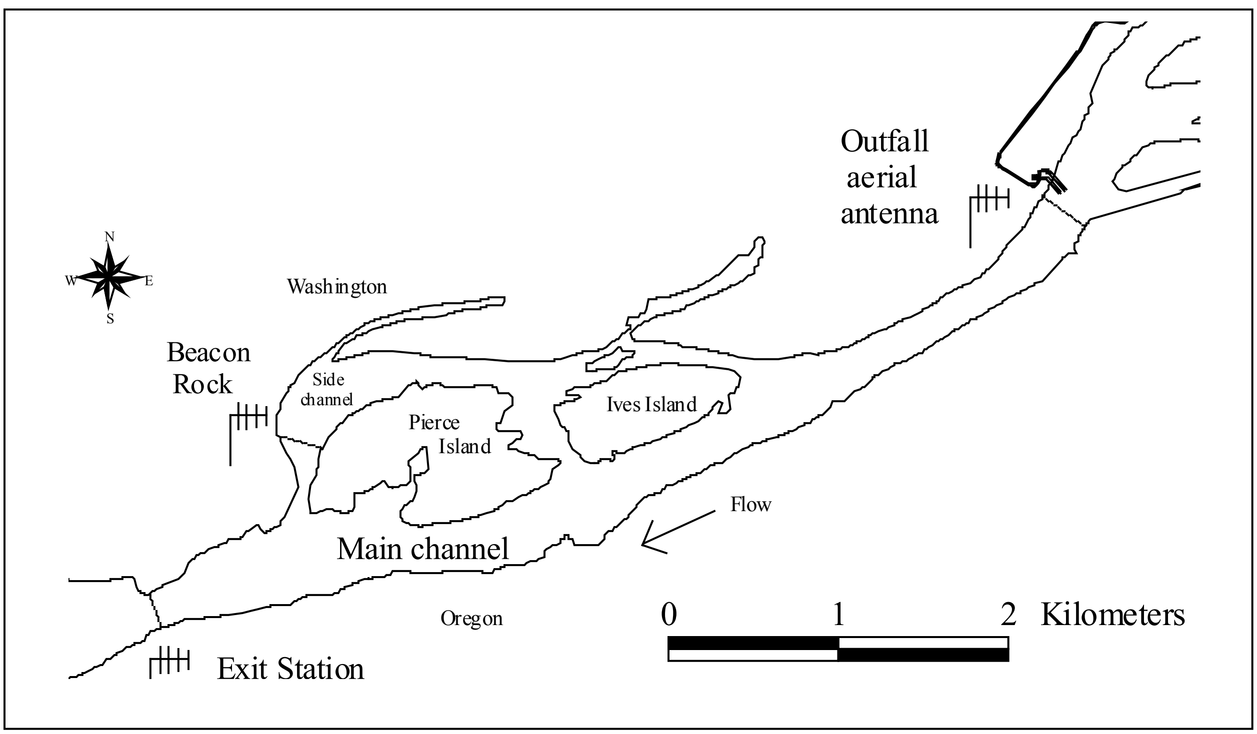

Figure 2. Bonneville Dam Powerhouse II juvenile bypass system evaluation area between outfall and first exit station 8 km downriver from dam, 2000.

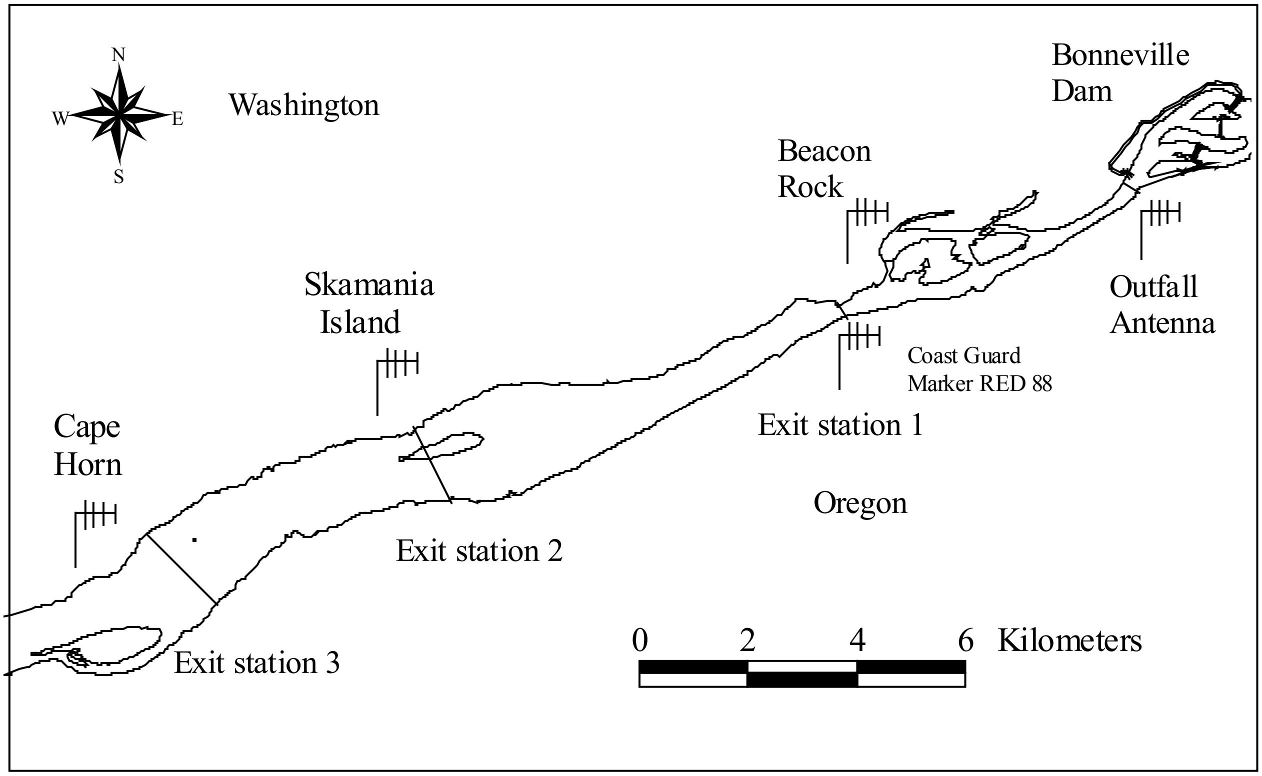

Figure 3. Downstream Exit stations for radio-tagged fish released into the Juvenile bypass system and from upriver telemetry studies 2000.

Physiological Effects of Bypass System

Methods

To assess physiological stress induced by passage through the conveyance pipe we measured two well-known stress indicators, blood plasma cortisol and lactate in steelhead, yearling chinook, and subyearling chinook. We sampled fish that were actively migrating down river and entered the bypass on their own volition. Levels of stress indicators were compared in fish captured before entering the conveyance pipe to levels in fish captured after passing through the pipe (Figure 1). To assess the delayed stress response indicated by plasma cortisol, we held some fish in tanks and sampled them at 0, 1, 3, 12, 24, 48, and 120 h after collection (Figure 4). These are referred to as “time series” experiments. During these experiments, some fish were sampled upon capture and referred to as the “time zero” groups. Each sample in the time series consisted of 10 fish. To document differences in stress responses during light and dark diel periods, fish were collected for two time series experiments starting at approximately 0930 hours for daytime (AM) and 2130 hours for nighttime (PM).

Fish were netted directly from the conveyance pipe using a modified fyke net equipped with a live box or hand-held dip nets. After being placed in an aquarium to identify species and fin clips, fish were sampled at the time of capture or placed in holding tanks to be sampled sequentially over time (time series) after capture. Fish were sequestered in 20 gallon holding tanks and provided with a steady flow of river water.

Blood plasma samples were collected by rapidly netting and placing fish in a lethal dose of tricain methanesulfonate (200 mg/L). Fish were then removed from the anesthetic, measured and weighed, and the blood was collected in an ammonium-heparinized capillary tube after severance of the caudal peduncle. Plasma was obtained by centrifugation. Plasma was placed in liquid nitrogen for transportation, then stored at –70ºC for future analysis in the laboratory.

Plasma cortisol was determined by an enzyme linked immunosorbent assay (ELISA) modified from procedures described by Munro (1985). Plasma lactate was measured using a commercial kit assay (Sigma Diagnostics, St. Louis, Missouri) that we modified for use with

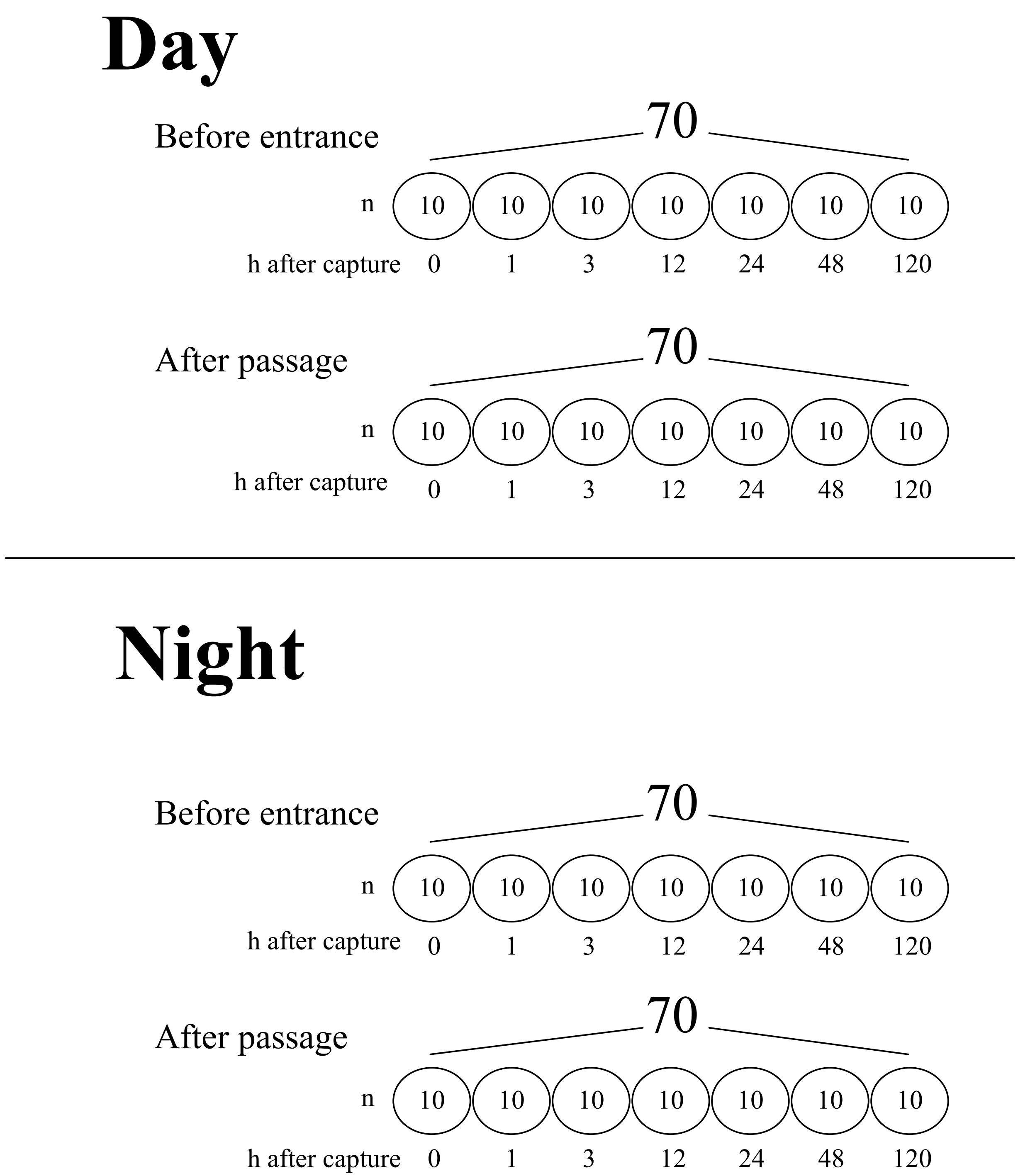

Figure 4. Physiology sampling of yearling chinook salmon, steelhead, and subyearling chinook salmon at Bonneville Dam's PHII juvenile bypass system, 2000.

micro plates. To measure stress experienced by passage through the conveyance pipe, we calculated the mean concentration in each time series group and compared fish before entering and after passage through the pipe within series groups. For each species sampled immediately, we conducted a two-way analysis of variance (ANOVA) to test for pipe effects and diel effects. To test differences between means, we used a t-test that assumed unequal variances. All statistical tests were conducted at the 5% probability level and analyses were conducted using SAS statistical software (SAS Institute, Inc. 1990).

Results

Stress Indicators at Capture

We collected cortisol and lactate samples between 17 April and 25 April, 2000 from yearling chinook, 1 May and 16 May from steelhead, and 27 June and 12 July from subyearling chinook. Yearling chinook and steelhead were each collected during a single day. Subyearling chinook were collected on multiple days due to a change in dam operating conditions, which directed most of the flow, and therefore fish, toward Powerhouse I instead of Powerhouse II. Fork length ranged between 118 and 235 mm for yearling chinook, 127 and 290 mm for steelhead, and 77 and 130 mm for subyearling chinook salmon (Table 1).

We used measurements of plasma cortisol and lactate as an index of the relative stressfulness of passage through the conveyance pipe. The two-way ANOVA for cortisol of steelhead showed no pipe or diel effects, while there was a diel effect in yearling ($P=0.0019$) and subyearling chinook ($P=0.017$) (Appendix 2). We compared mean plasma cortisol concentrations in fish entering the pipe to concentrations in fish after passage through the pipe and found concentrations were not significantly different at the time of capture in four of six sampling comparisons (Figure 5). Cortisol concentrations in steelhead during the daytime remained similar (138 and 136 $ng{\cdot}mL^{-1}$) between entering the pipe and after passing through the pipe (Figure 5A). However, there was a significant decrease ($P = 0.0125$) in cortisol concentrations in steelhead after passage through the conveyance pipe during the nighttime experiment, concentrations decreased from 163 to 96 $ng{\cdot}mL^{-1}$. Mean cortisol concentrations in yearling chinook increased significantly ($P = 0.0204$) after passage through the conveyance pipe

Table 1. Mean fork length and weight, including standard deviation and range, of yearling chinook, steelhead, and subyearling chinook collected for physiology sampling at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Included are species, collection date, diel period, sample location (BE=Before Entrance, AP=After Passage), and sample size.

Species/ Collect date	Diel period	Sample location	N	Fork length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
Yearling chinook									
4/17/00	Day	BE	70	165.4	27.1	118-225	50.8	25.5	18.5-112.8
		AP	62	170.2	27.4	124-232	53.6	27.3	22-120.9
4/20/00	Night	BE	70	151	22.9	120-235	38.1	19.9	17.3-123.2
		AP	70	143.7	12.5	123-173	30.6	7.5	19.8-52
Overall:			272	157.2	25.4	118-235	42.9	23.1	17.3-123.2
Steelhead									
5/1/00	Day	BE	70	231.3	19.9	180-272	108.6	30.1	51.2-186.1
		AP	70	232.0	24.3	127-285	112.3	31.1	56.5-199.4
5/11/00	Night	BE	70	233.1	23.3	175-290	108.4	32.9	45.4-223.4
		AP	66	230.0	22.0	181-275	105.2	30.9	53.0-180.3
Overall:			276	231.6	22.4	127-290	108.7	31.2	45.4-223.4
Subyearling chinook									
6/30/00- 7/7/00	Day	BE	62	97.7	9.1	79-125	9.8	2.9	5.3-20.7
		AP	68	96.5	10.1	77-125	9.6	3.3	5.2-18.4
6/27/00	Night	BE	68	105.4	8.1	85-129	12.1	3.5	6.6-22.6
		AP	68	108.7	9.2	89-130	13.1	3.2	7.1-24.2
Overall:			266	102.2	10.6	77-130	11.2	3.5	5.2-24.2

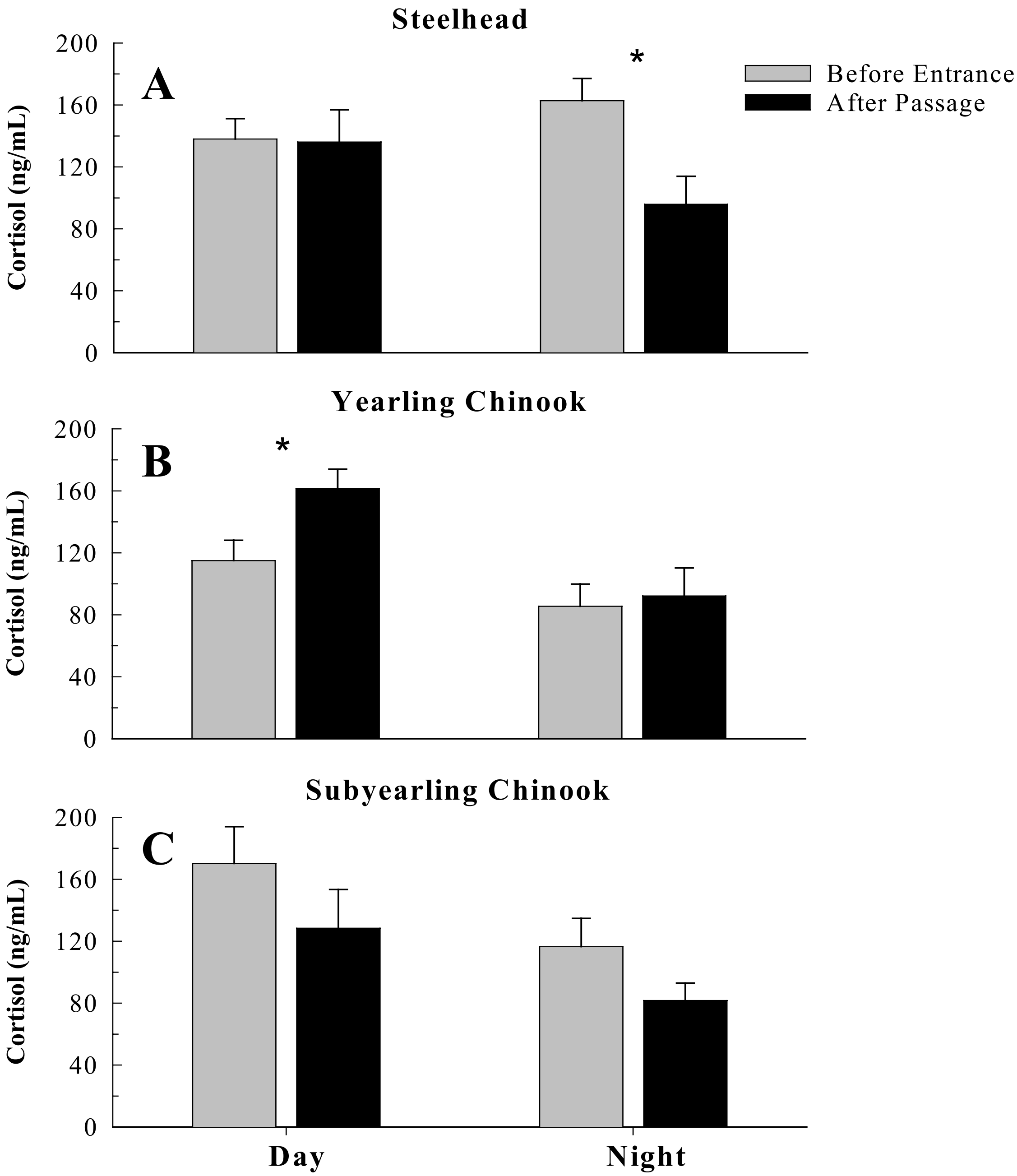

Figure 5. Mean (+ SE) plasma cortisol concentrations at time of capture of steelhead, yearling chinook and subyearling chinook before entrance and after passage through the conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Day and night experiments are shown. Sample sizes were 9-10 fish. Asterisks (*) indicate where mean cortisol concentrations differ significantly.

in the daytime samples, increasing from 115 to 162 ng·mL^{-1} (Figure 5B). Cortisol concentrations in subyearling chinook did not differ significantly after passage, although there was a decrease (170 to 128 ng·mL^{-1} in daytime; 117 to 82 ng·mL^{-1} at nighttime) after travel through the conveyance pipe (Figure 5C).

To determine if there was a diel difference in fish stress levels, we compared mean cortisol concentrations during daytime and nighttime sampling (Figure 6). Generally, cortisol concentrations did not differ significantly between fish sampled during daytime and nighttime, although most daytime levels of cortisol appeared slightly higher (Figure 6A). However, mean cortisol concentrations in yearling chinook after passage through the conveyance pipe indicated a difference between daytime and nighttime (Figure 6B). Cortisol concentrations were significantly higher ($P = 0.0063$) in yearling chinook sampled during the daytime (162 ng·mL^{-1}), compared to fish sampled at nighttime (92 ng·mL^{-1}). Mean cortisol concentrations in subyearling chinook showed a slightly higher stress level in fish during the daytime before and after passage through the pipe, although there was no significant difference (Figure 6C). Concentrations ranged from 128-170 ng·mL^{-1} during the daytime sampling, while concentrations during the nighttime ranged from 81-116 ng·mL^{-1}.

The two-way ANOVA for lactate at the time of capture of steelhead was significant ($P=0.0003$). Travel through the conveyance pipe had a significant effect ($P<.0001$) and we found no diel effect or significant interaction. In yearling chinook , the ANOVA was not significant. There was no effect from passage through the pipe or diel effect, but there was a significant interaction ($P=0.0337$) between pipe and diel. The two-way ANOVA for subyearling chinook was not significant ($P=0.0823$). There was a significant effect from travel through the conveyance pipe ($P=0.0495$), but no diel effect, and no significant interaction (Appendix 2).

Mean plasma lactate levels were significantly higher after travel through the conveyance pipe compared to samples collected prior to entering the pipe in one of six sampling comparisons, although most comparisons indicated a slight increase after passage (Figure 7). Among steelhead, mean lactate concentrations increased after passage, indicating a high likelihood that steelhead were swimming against the high velocities in the conveyance pipe

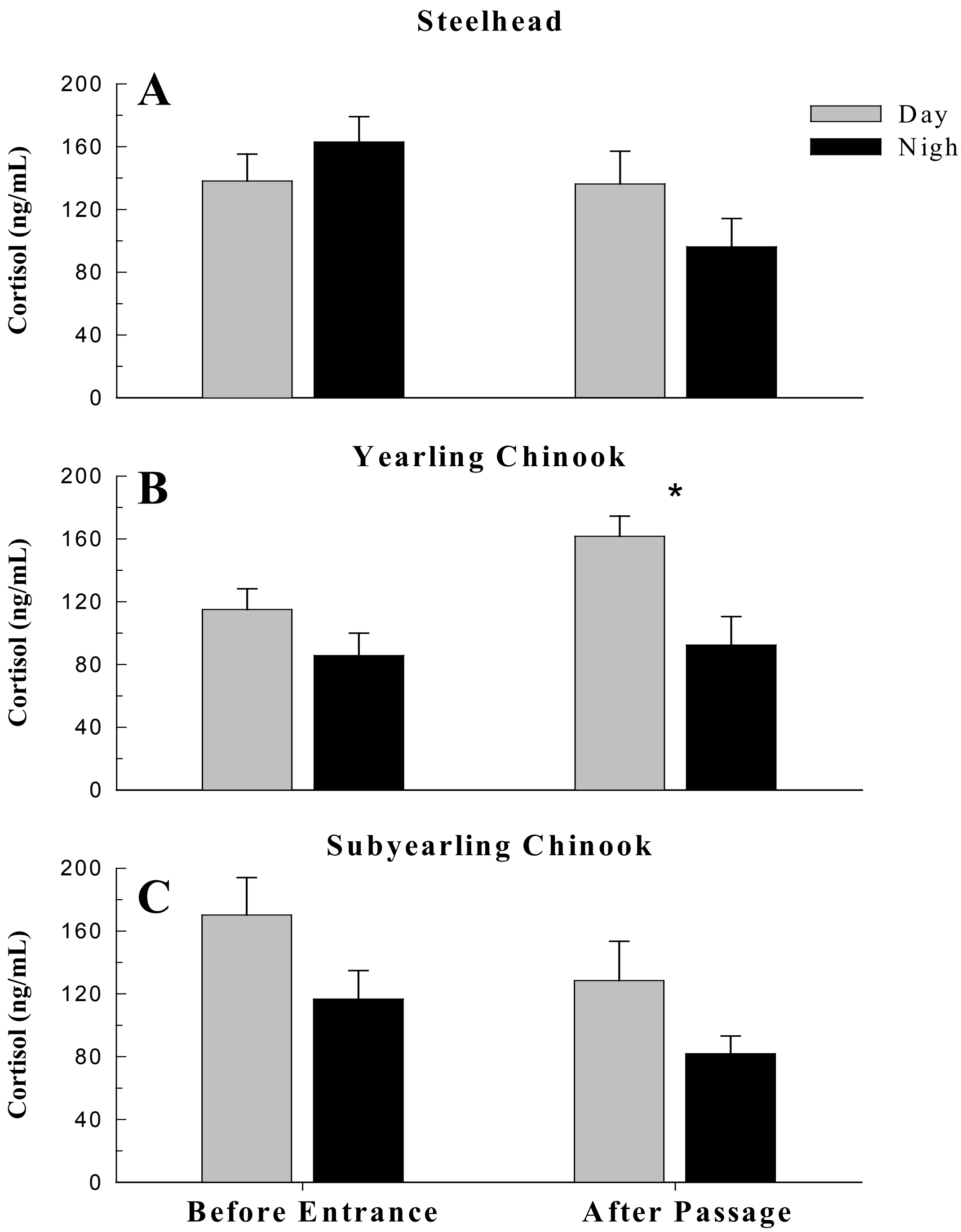

Figure 6. Mean (+ SE) plasma cortisol concentrations at time of capture of steelhead, yearling chinook and subyearling chinook during day and night through the conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Before entrance and after passage sampling locations are shown. Sample sizes were 9-10 fish. Asterisks (*) indicate where mean lactate concentrations differ significantly.

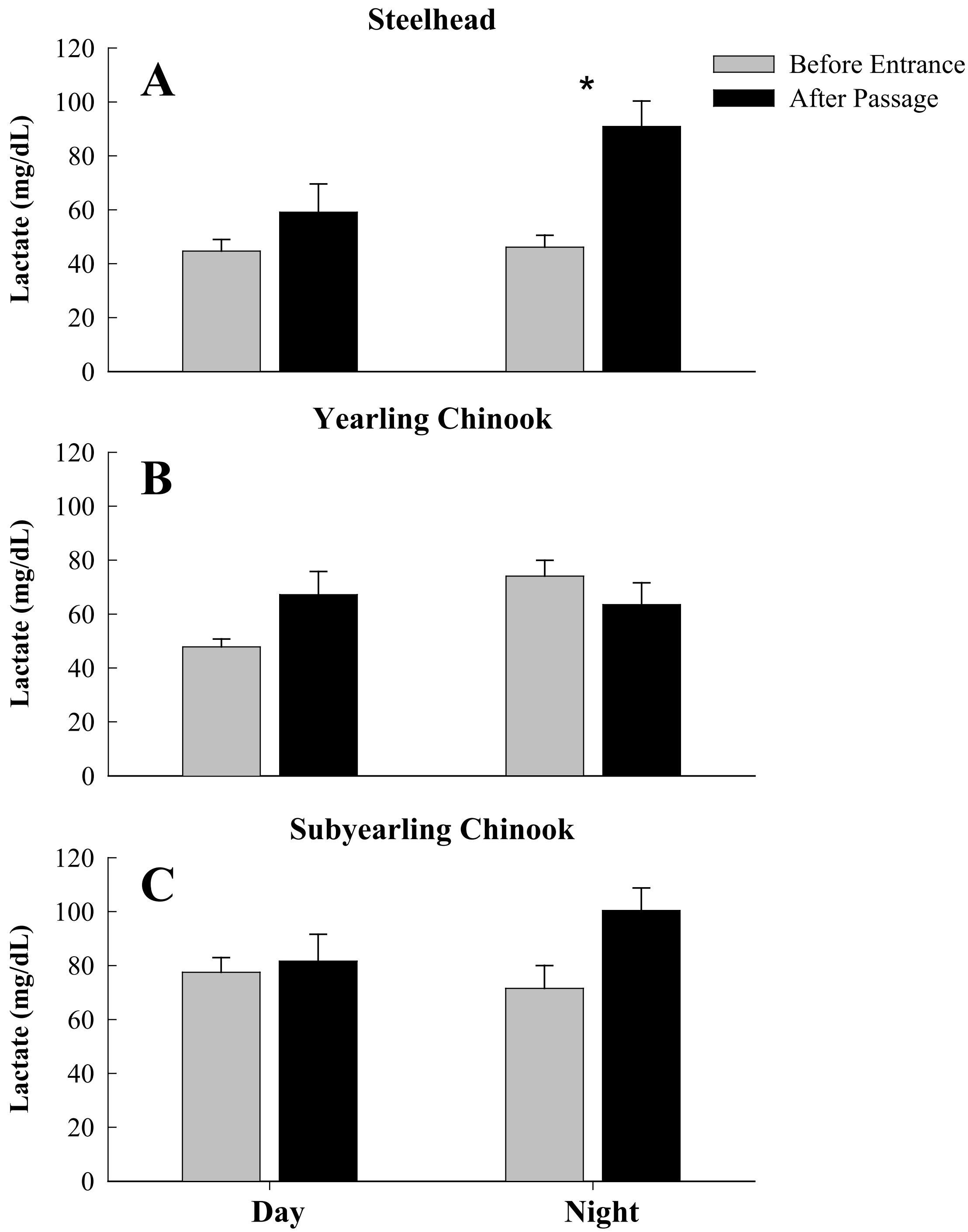

Figure 7. Mean (+ SE) plasma lactate concentrations at time of capture of steelhead, yearling chinook and subyearling chinook before entrance and after passage through the conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Day and night experiments are shown. Sample sizes were 9-10 fish. Asterisks (*) indicate where mean lactate concentrations differ significantly.

(Figure 7A). Lactate concentrations increased from 45 to 69 mg · dL^{-1} during the daytime and from 46 to 91 mg · dL^{-1} ($P = 0.0009$) during the nighttime sampling. Lactate concentrations in yearling chinook during daytime sampling were 47 mg · dL^{-1} prior to entering the pipe, then increased to a mean of 67 mg · dL^{-1}. Only during the nighttime sampling of yearling chinook did lactate levels decrease after passage through the conveyance pipe (74 mg · dL^{-1} decreased to 63 mg · dL^{-1} , Figure 7B). Mean lactate concentrations in subyearling chinook (Figure 7C) had a similar trend compared to the pattern observed among steelhead and yearling chinook (Figure 7A and B). Lactate concentrations sampled before entering the conveyance pipe ranged from 72-77 mg · dL^{-1} and increased after passage through the pipe to a range of 82-100 mg · dL^{-1}.

To determine if there was a diel difference in fish stress levels as they traveled through the conveyance pipe, we compared mean lactate concentrations during daytime and nighttime sampling (Figure 8). Lactate concentrations generally were not significantly different between fish sampled during the daytime compared to nighttime, although most nighttime levels of lactate were slightly higher. Mean lactate concentrations in steelhead were similar in daytime and nighttime samples prior to entering the conveyance pipe, 45 mg · dL^{-1} and 46 mg · dL^{-1}, as well as after passage through the conveyance pipe, 69 mg · dL^{-1} and 91 mg · dL^{-1} (Figure 8A). We found a diel difference in mean lactate concentrations in yearling chinook when they entered the conveyance pipe. Lactate concentrations were 47 mg · dL^{-1} during the daytime compared to 74 mg · dL^{-1} at nighttime ($P = 0.0015$). However, the difference between daytime and nighttime lactate levels in yearling chinook sampled after passage through the conveyance pipe was not significant (Figure 8B). Comparisons of lactate levels of subyearling chinook during daytime and nighttime sampling showed no diel differences (Figure 8C). Mean plasma lactate levels ranged from 72 mg · dL^{-1} to 100 mg · dL^{-1}.

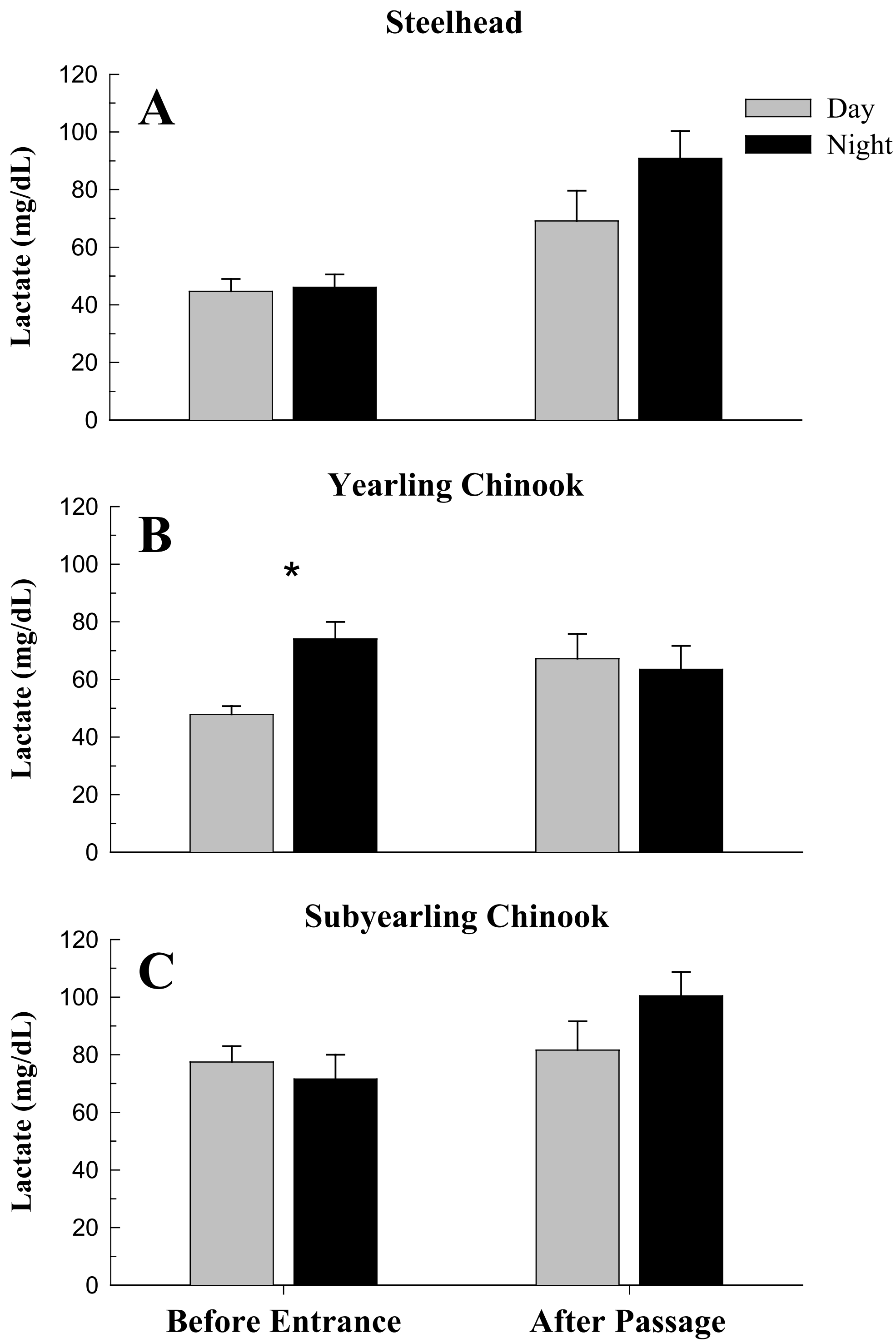

Figure 8. Mean (+ SE) plasma lactate concentrations at time of capture of steelhead, yearling chinook and subyearling chinook during day and night through the conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Before entrance and after passage sampling locations are shown. Sample sizes were 9-10 fish. Asterisks (*) indicate where mean lactate concentrations differ significantly.

Time Series

To assess the delayed endocrine stress response indicated by plasma cortisol and document recovery time after a stress event, we held fish in tanks and sampled them over a time period. Mean cortisol levels increased 1 and 3 h after capture and usually returned to concentrations similar to immediate sampling (time zero) within 24 h (Appendix 1, 2, 3). Mean cortisol concentrations in steelhead captured before entering the conveyance pipe during the daytime showed an increase from 138 $ng \cdot mL^{-1}$ to 233 $ng \cdot mL^{-1}$ at 1 h, then a gradual decrease, with concentrations decreasing to 99 $ng \cdot mL^{-1}$ 120 h after capture (Appendix 1A). A similar pattern was observed in mean cortisol levels during daytime sampling after passage through the conveyance pipe. Mean cortisol concentrations in steelhead during the nighttime were significantly higher ($P < 0.05$) between fish sampled before entering the conveyance pipe compared to fish sampled after travel through the conveyance pipe (Appendix 1B). This difference occurred throughout the entire time series experiment. An unexplainable change occurred between the 12 and 24 h samples, where cortisol levels increased in fish captured after passage, and levels decreased in fish captured before entrance to the pipe.

Mean cortisol levels of yearling chinook were significantly higher ($P = 0.0204$) immediately after passage through the conveyance pipe compared to levels observed before entrance to the pipe during the daytime (Appendix 2A). However, concentrations in the remaining time series did not differ between sample locations and we observed a gradual decrease in cortisol levels over time, with levels decreasing to 31-39 $ng \cdot mL^{-1}$ when sampled at 120 h after capture. Levels observed at 120 h were low compared to cortisol levels of yearling chinook at time of capture, when they were greater than 100 $ng \cdot mL^{-1}$. Cortisol concentrations in yearling chinook during nighttime sample showed a similar pattern in fish sampled before entrance and after passage to the pipe (Appendix 2B). Mean cortisol concentrations ranged at capture from 86-92 $ng \cdot mL^{-1}$, then increased to 198-210 $ng \cdot mL^{-1}$ at 1 h. Within 24 h, levels decreased to a range of 69-84 $ng \cdot mL^{-1}$ where levels remained. There was a distinct spike, rising to 307 $ng \cdot mL^{-1}$, 12 h after capture. It was unclear what caused this increase in cortisol concentrations, but it appeared to have been an isolated stressful event.

Plasma cortisol concentrations in subyearling chinook increased 1 and 3 h after capture, and then decreased within 24 h to concentrations observed during initial capture (Appendix 3). Cortisol concentrations in subyearling chinook during the nighttime series showed a parallel response for fish collected before entrance to the conveyance pipe and after passage through the pipe (Appendix 3B). Cortisol concentrations increased 1 and 3 h after capture, then decreased to levels similar to initial capture within 24 h. Levels continued to decrease in the 48 and 120 h samples.

Given that the fish had not yet been exposed to the conveyance pipe, we could not attribute the stress response that we observed in the time series to travel through the pipe. This indicated that the procedure of collecting and sequestering fish for the experiments had a physiological stress effect. Netting and capture procedures were similar before and after passage resulting in a similar stress response before and after passage, as seen in Appendix 3B. Once we determined that the stress response we observed was largely due to handling, we directed our emphasis toward the results of samples collected at recapture after passing through the pipe.

Plasma lactate concentrations in steelhead, yearling chinook, and subyearling chinook, during the time series showed an initial increase after capture, peaked at 1 h after capture, followed by a decrease throughout the remainder of the time series (Appendix 4, 5, 6). Mean lactate concentrations in steelhead sampled at time of capture showed a significant increase ($P < 0.0009$) after passage through the conveyance pipe during the nighttime experiment (Appendix 4B). Differences were still significant ($P < 0.0111$) after 1 h, then decreased to similar concentrations within 3 h. Once lactate concentrations decreased, they remained at low concentrations (29-40 $mg \cdot dL^{-1}$) throughout the remainder of the time series.

Lactate concentrations in yearling chinook increased 1 h after capture, then decreased within 3 h to below time of capture levels (Appendix 5). We observed a significant increase ($P < 0.0434$) after passage through the conveyance pipe at 1 h, although lactate levels had decreased by 3 h to levels below 40 $mg \cdot dL^{-1}$. Lactate concentrations in subyearling chinook were similar to levels in steelhead and yearling chinook (Appendix 6). Sample size varied among some time series groups due to a more protracted sampling, caused by changes in dam operating conditions. Lactate concentrations were similar before and after passage through the conveyance pipe. Levels were initially elevated, but decreased within 3 h after capture.

In all time series experiments lactate levels increased1 h after capture. We observed the same trends both before and after passage through the conveyance pipe, indicating fish experienced the same treatments at both locations. Because fish never exposed to travel through the conveyance pipe (before entrance) elicited a response, we cannot attribute increased lactate levels to travel through the pipe. The increase in lactate concentrations was likely caused by the stress of collecting and sequestering fish. Capture and sequester techniques were consistent between locations. Because lactate levels increased in samples obtained prior to entering the pipe, we can conclude that immediate increases in lactate were due to capture, rather than travel through the conveyance pipe.

Tailrace Egress Behavior

Methods

To determine the effects of passage through the JBS and conveyance pipe on tailrace egress behavior we monitored the movements of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon released from upriver telemetry studies and directly into the JBS. Fish movements were monitored using fixed-station telemetry receivers and boats equipped with telemetry antennas and receivers. Underwater telemetry antennas were positioned near the entrance and exit to the conveyance pipe (Figure 1). Four and six-element Yagi (aerial) antennas were positioned on the forebay side along the length of the dam, and on the tailrace side near the outfall (Figure 2). Monitoring stations were also placed downriver at river km 226 near Beacon Rock, river km 217 at Skamania Island, and river km 211 at Cape Horn (Figure 3) subsequently referred to as exit stations 1, 2, and 3, respectively. To determine which fish used the side channel behind the Ive's Island complex, a receiving station was placed near the Beacon Rock boat ramp. Antennas were connected to a Lotek SRX 400 data logging receiver. During monitoring of yearling chinook and steelhead, a Lotek Digital Spectrum Processor (DSP) was also used. The DSP allowed receivers to monitor all frequencies simultaneously. Receivers were downloaded to a laptop computer.

We monitored movements of radio-tagged fish released upriver from The Dalles and John Day dams, and at Rock Creek, Washington. Data from fish released upriver allowed us to determine travel time to the outfall through various reaches of the dam. These included the JBS and non-JBS passage routes such as the spillway and Powerhouse I. To compare travel times of fish moving through the conveyance pipe to water movement, we released a passive float into the conveyance pipe and recorded its travel time. We also compared tailrace behavior of fish that passed through the JBS to the behavior of fish that passed through other routes. Because of the type of transmitter, we were not able to determine passage route of subyearling chinook salmon.

As part of a juvenile salmon survival study conducted by the U.S. Geological Survey (Counihan et al. 2000), radio-tagged yearling chinook were released directly into the upstream end of the conveyance pipe. By monitoring the movements of these additional fish we were able to increase our sample size of radio-tagged fish that passed through the JBS. Fish were released during light diel periods, starting at 1000 hours, and dark diel periods starting at 2200 hours.

It is assumed that stressed fish or fish in compromised condition behave differently from unstressed-healthy fish. To assess whether or not fish were being stressed or harmed by passage through the conveyance pipe we compared the travel time and behavior of fish that passed through the conveyance pipe to groups of stressed fish and groups of unstressed fish that did not pass through the conveyance pipe. Radio-tagged fish were released into the upstream end of the conveyance pipe while radio-tagged stressed and unstressed fish were released into the downstream end near the outfall. After fish exited the bypass and plunged into the main river channel their movements were monitored using fixed site telemetry gear and boat tracking. To document differences between day and night behavior fish were released during hours of daylight or darkness.

To induce stress, we transferred two radio-tagged fish into a perforated bucket inside a second bucket filled with water. We then removed the perforated bucket allowing the water to drain out. Fish were exposed to hypoxia, struggling, and mild agitation for 30 s. The fish were then transferred back to the holding tank. Blood plasma cortisol concentrations peak approximately 1 h after a stress event and can be cumulative from multiple stress events (Mesa 1994). We repeated the stressor 1 h after the first event. Fish were then released 1h after the second stressor.

Yearling chinook, steelhead, and subyearling chinook to be implanted with radio transmitters and released into the JBS were obtained from the Downstream Monitoring Facility operated by the Pacific States Marine Fisheries Commission at PH I. Fish were held 12-24 h at the facility to allow for stomach content evacuation and then transported to PH II for tagging and release. Transmitters were gastrically implanted following procedures described by Adams et al. (1998). Steelhead and yearling chinook were implanted with digitally-coded transmitters. Steelhead transmitters measured 8.2 mm (diameter) x 18.9 mm and weighed 1.75 g in air. Yearling chinook transmitters measured 7.3 mm (diameter) x 18 mm and weighed 1.4 g in air. Because of their smaller size, subyearling chinook were implanted with smaller pulse-coded transmitters. Subyearling chinook transmitters measured 6.0 mm (diameter) x 15 mm and weighed 1.1 g in air. After tagging, fish were placed in 20 or 32 gallon holding tanks, two fish per tank, and supplied with circulating river water. Fish were held for 12-24 h, checked for mortalities and regurgitated tags, then released directly into the JBS (Figure 1).

Fish released directly into the JBS or from upriver telemetry studies were mobile tracked from the outfall to the first downriver exit stations using boats equipped with six-element Yagi antennas and telemetry receivers. When the boat was in close proximity to the fish, a GPS unit was used to georeference its position. Approximately four positions per fish were recorded between the outfall and the exit station. To maximize contacts with fish released from upriver studies, mobile tracking was performed during dawn (0300-1100 hours) and dusk (1500-2300 hours) crepuscular periods when concentrations of migrating salmonids were highest.

To further characterize the migrational behavior of migrating salmonids and determine if their behavior was discernable from the movements of dead fish being passively transported, dead radio-tagged fish were released into the main river channel near the outfall and tracked downriver. Radio-tagged yearling chinook and steelhead were placed in 5 L of water with 200 mg/L of tricain methanesulfonate for 30 min. A wire mesh screen was placed in the holding tank below water level to prevent fish from gulping air at the water surface for buoyancy compensation. Dead fish were released two at a time from a boat at mid channel. Personnel in boats equipped with telemetry equipment started tracking fish immediately after release.

To test for differences in median travel time among passage routes and treatments we used a non-parametric test that would address assumptions of normality. Variances were tested for homogeneity using a Bartlett's test. A Wilcoxon rank test was used when comparing two travel times and the Kruskal-Wallis test was used when comparing more than two. The Kruskall-Wallis test may be applied when the population variances are somewhat heterogeneous (Zar 1996). All statistical tests were conducted at a 95% confidence level.

To describe how water movement and hydraulic conditions in the tailrace influenced fish movement we released a free-drifting drogue equipped with a global positioning system (GPS) while mobile tracking. Relative positions of the fish and drogue were monitored and their spatial relationship over time was determined. We used a metal drogue (1.2 x 0.5 m) attached to a PVC cylinder equipped with a global positioning system (GPS) which recorded its path and chronological history. Drogues were released at the first contact position of the fish concurrently being tracked and allowed to drift downriver to the exit site where the drogue was retrieved. Complete drogue drift paths and associated fish positions were plotted using Arcview geographic information system (GIS) software to determine the relation of fish and drogue movement.

Results

Upriver Releases

Between 15 April and 15 May USGS personnel conducting radio telemetry studies released 1,193 radio-tagged steelhead, and 2,075 radio-tagged yearling chinook salmon at Rock Creek, WA, John Day Dam, and The Dalles Dam. Actively migrating yearling chinook salmon and steelhead released upriver took longer to reach the outfall site when passage occurred through the JBS when compared to fish that passed the dam through non-JBS routes such as the spillway and PH I (Table 2). We obtained travel times from the forebay to the outfall for 998 yearling chinook and 522 steelhead. Of these, 12% of the chinook and 15% of the steelhead used the JBS, and 88% of the chinook and 85% of the steelhead passed the dam through non-JBS routes. Yearling chinook had a median travel time of 121 min from the forebay to the outfall area via the JBS. Steelhead had a median time of 81 min. Because of the type of transmitter

Table 2. Median and mean travel time (min) through Bonneville Dam's Powerhouse II juvenile bypass system (JBS) and non-JBS routes of radio-tagged yearling chinook salmon, steelhead, and subyearling chinook salmon released from upriver telemetry studies. Conveyance pipe refers to time from the upstream end of the pipe to the downstream end. Entire JBS and non-JBS routes refers to travel time from the forebay to the outfall.

Species	Passage route	N	Median travel time (min)	Mean travel time (min)	SD	Range
Yearling chinook						
	Dam non JBS	875	30.1	125.1	562.1	20.1-10505.9
	Dam JBS	123	121.4	233.8	311.0	46.3-2085.7
	Conveyance pipe	127	41.3	103.0	386.8	33.0-3978.2
Steelhead						
	Dam non JBS	446	31.6	279.4	1083.3	20.1-13220.5
	Dam JBS	76	80.6	224.8	422.7	43.0-3174.4
	Conveyance pipe	80	47.7	91.0	189.8	32.7-1149.1
Subyearling chinook						
	Conveyance pipe	24	36.5	83.7	223.4	33.0-1132.1
Passive float						
	Conveyance pipe	4	32	32	0.0	32.0-32.0

used we were unable to make this comparison with subyearling chinook salmon. For more information on dam passage route of upriver fish see Evans et al. (2001).

Yearling chinook had a median travel time of 81 min from the forebay to the start of the conveyance pipe, and 41 min from the start of the conveyance pipe to the outfall (Table 2), indicating much of the time spent in the entire JBS occurred before fish entered the conveyance pipe. Steelhead had a median travel time of 33 min from the forebay to the start of the conveyance pipe and took 48 min (median) to travel through the conveyance pipe. Subyearling chinook took 37 min (median) to travel through the conveyance pipe. A passive float released into the conveyance pipe had a median travel time of 32 min to reach the separator bars just upstream of the fish facility and telemetry monitoring station. This indicated that steelhead and yearling chinook resisted transport within the conveyance pipe and subyearling chinook were transported passively or were unable to resist the current in the pipe. This was likely due to the larger size of the yearlings and their greater swimming ability.

We compared travel times from the outfall to the downriver exit stations of fish that passed through the JBS to fish that passed through non-JBS routes. In general, fish that passed through the JBS had slightly longer tailrace travel times compared to fish that passed through non-bypass routes (Table 3). We found no significant difference in travel time to the first and third exit stations for yearling chinook, and there were no significant differences in travel times to the first and second exit stations among steelhead. Appendix 13 shows the distribution of yearling chinook travel times to downriver exit stations. The Ive's Island antenna site, located in the side channel, detected 141 yearling chinook. Approximately 14% of these had passed through the JBS. Of the steelhead that were detected at the Beacon Rock site 15% had been detected passing through the JBS.

During mobile tracking, fish that passed through JBS and non-JBS routes moved downriver in the main channel and rarely entered the side channels behind Ives Island (Figure 9). We contacted 86 fish released from upriver studies. Of these, two (2%) were believed to be consumed by predatory fish, three (3%) used the side channel behind Ives Island, and 6 (7%) delayed before moving downriver. Determination of predation was based on fish remaining in low velocity water such as an eddy or side channel, or fish rapidly moving back upriver.

Table 3. Median and mean travel times (min) and travel rate (km/h) of radio-tagged yearling chinook and steelhead from the outfall antenna to the downriver exit stations (Exits 1-3), 2000. Fish were released from upriver studies and passed through the Powerhouse II bypass system (JBS) or through non-JBS routes such as Powerhouse I or the spillway. Asterisk (*) indicates variances were heterogeneous.

Species/ Exit station/	Release type	N	Median travel time (min)	Median travel rate (km/h)	Mean travel time (min)	SD	Range
Yearling chinook							
Exit 1	JBS	120	36.6^{A}	9.59	58.4	*140.6	20.3-1554.3
	Non JBS	1002	35.6^{A}	9.86	46.7	139.4	20.0-4092.2
Exit 2	JBS	115	170.0^{A}	4.81	204.4	*161.9	115.9-1702.3
	Non JBS	1001	162.3^{B}	5.06	196.1	243.3	60.7-5036.0
Exit 3	JBS	120	294.1^{A}	3.88	328.2	*166.8	209.0-1809.1
	Non JBS	1008	287.7^{A}	3.96	318.1	186.0	179.0-5205.6
Steelhead							
Exit 1	JBS	69	30.5^{A}	11.51	33.5	*14.4	20.7-124.6
	Non JBS	555	31.0^{A}	11.32	33.9	16.3	20.3-214.1
Exit 2	JBS	68	157.0^{A}	5.24	163.6	*41.6	101.3-317.5
	Non JBS	554	146.2^{A}	5.62	166.4	140.9	65.7-3191.7
Exit 3	JBS	73	280.0^{A}	4.07	295.3	*59.0	209.3-535.4
	Non JBS	572	264.6^{B}	4.31	282.9	146.9	142.3-3349.6

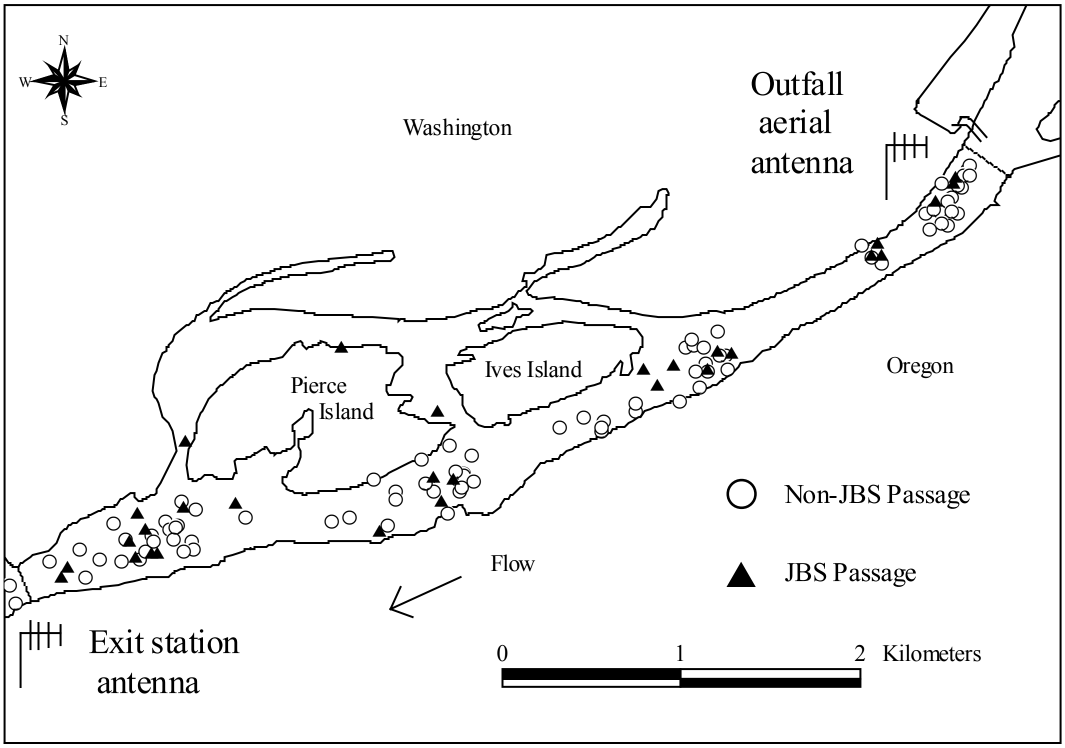

Figure 9. Mobile tracking locations of radio-tagged yearling chinook released from upriver studies that passed Bonneville Dam through the JBS and through non-JBS routes, 2000.

Additional JBS Releases

From 3 May through 27 May USGS personnel conducting survival studies at Bonneville Dam released 250 yearling chinook salmon, in groups of 21 to 29, directly into the upstream end of the conveyance pipe during light and dark diel periods. Of these, 58 yearling chinook were detected at both the upstream and downstream antenna in the conveyance pipe. These took 42 min (median) to pass through the conveyance pipe. As these fish exited the bypass and moved downriver, we detected 164 (64%) at the outfall antenna and exit stations 1 and 2 , and 169 (68%) at the outfall and exit station 3 (Table 4). Median travel time from the outfall to exit station 1 was 36 min. Of the fish we contacted, 93% passed exit station 1 within 90 min and less than 2% took more than 200 min. Median travel time from the outfall to exit station 2 was 177 min, and 314 min to exit station 3. Boat tracking was not performed on these fish.

Stressed and Unstressed fish

On four different days between 13 May to 19 May, we released groups of approximately 25 yearling chinook or steelhead into the upstream end of the conveyance pipe (Table 5). We simultaneously released 25 stressed and 25 unstressed fish of the same species into the downstream end of the conveyance pipe near the outfall. From 11 July to 18 July this procedure was repeated using subyearling chinook. We determined travel times between the outfall and the first downriver exit station for 92% of the steelhead released into the JBS, 85% of the unstressed steelhead and 76% of the stressed steelhead released near the outfall.

Travel times of steelhead released into the upstream end of the JBS were not significantly different from unstressed steelhead released near the downstream end (Table 6, Appendices 11 and 12). However, stressed steelhead took significantly longer to reach all three exit sites compared to JBS released and unstressed steelhead. This indicated that the behavior of steelhead was effected by the induced stress, and that steelhead that passed through the JBS did not experience equivalent stress. Also, 24% of the stressed steelhead were detected in the side channel at Beacon Rock compared to only 7% of the unstressed steelhead and 8% of the JBS steelhead.

Table 4. Median and mean travel time (min) and travel rate (km/h) of radio-tagged yearling chinook salmon released into the Bonneville Dam's Powerhouse II juvenile bypass system as part of a separate survival study, 2000.

Exit station	N	Median travel time (min)	Median travel rate (km/h)	Mean travel time (min)	SD	Range
Exit 1	188	36.3	9.8	58.0	181.5	21.2 - 2498.1
Exit 2	187	178.7	4.6	220.0	163.8	100.9 - 1910.4
Exit 3	193	314.3	3.6	372	201.4	146.7 - 2050.6

Table 5. Mean fork length and weight of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon released into the Bonneville Dam's Powerhouse II juvenile bypass system (JBS), 2000. JBS fish were released into the upstream end of the conveyance pipe; Stressed and Unstressed fish were released into the downstream end of the conveyance pipe.

Species/ release date	Diel period	Release location	N	Fork length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
Yearling chinook									
5/17/00	Day	JBS	26	148.3	18.5	124-195	35.2	15.5	22.3-79.8
		Stressed	23	148.3	18.9	122-187	35.3	15.7	18.1-73.1
		Unstressd	24	156.7	22.1	129-205	42.9	21.0	22.9-90.4
5/19/00	Night	JBS	25	154.7	21.7	121-203	41.1	20.4	19.9-96.6
		Stressed	24	167.4	23.2	134-200	53.3	21.1	23.6-88.3
		Unstressd	24	147.7	26.1	124-215	37.4	24.7	20.3-101.1
Overall:			146						18.1-101.1
Steelhead									
5/13/00	Day	JBS	25	232.5	24.5	185-290	108.3	35.4	50.5-187.1
		Stressed	25	231.2	22.7	183-272	107.5	30.1	54.8-178
		Unstressd	23	232.8	22.6	205-300	115	39.7	68.1-225
5/15/00	Night	JBS	24	229.6	25.1	172-275	106.9	36.3	41.1-193.9
		Stressed	24	236.1	18.7	200-270	113.7	28.9	60.7-170.7
		Unstressd	23	226.6	22.1	175-268	99.5	32.2	46.9-176
Overall:			144			172-300			41.1-225

Table 5 (continued). Mean fork length and weight of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon released into the Bonneville Dam's Powerhouse II juvenile bypass system (JBS), 2000. JBS fish were released into the upstream end of the conveyance pipe; Stressed and Unstressed fish were released into the downstream end of the conveyance pipe.

Species/ release date	Diel period	Release location	N	Fork length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
Subyearling chinook									
7/11/00	Day	JBS	14	121.3	4.0	116-130	19.3	2.3	15.6-23.5
		Stressed	12	123.7	8.3	115-144	21.0	5.0	14.3-31.8
		Unstressd	12	123.7	10.2	111-150	20.6	3.9	14.5-29.6
7/12/00	Night	JBS	13	122.2	9.7	114-147	21.3	5.1	15.5-33.9
		Stressed	12	119.3	6.7	112-138	19.9	2.9	16.8-26.9
		Unstressd	12	119.8	6.7	112-132	19.7	3.2	15.6-25.5
7/17/00	Day	JBS	14	128.8	9.3	120-150	22.5	5.5	15.7-33.8
		Stressed	12	129	9.4	120-145	23.0	5.3	16.6-32.4
		Unstressd	12	122.5	2.6	120-126	18.8	1.2	16.9-21.3
7/18/00	Night	JBS	13	126.1	9.2	117-147	21.8	5.3	15.9-31.8
		Stressed	12	125.8	9.9	111-145	22.2	6.2	14.3-34.2
		Unstressd	12	121.3	3.7	117-130	19.4	2.3	16.9-24.7
Overall:			150			111-150			14.3-342

Table 6. Median and mean travel time (min) and travel rate (km/h) of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon from the juvenile bypass system (JBS) outfall to downriver exit stations, 2000. Median travel times with letters in common were not significantly different within an exit station. Asterisks (*) indicate variances within an exit station were heterogeneous.

Species/ Exit station/ Release type		N	Median travel time (min)	Median travel rate (km/h)	Mean travel time (min)	SD	Range
Yearling chinook							
Exit 1	JBS	44	35.8 [A]	9.80	42.3	*16.7	26.0 -105.4
	Unstressed	35	37.4 [A]	9.39	41.2	17.5	28.1 - 124.5
	Stressed	41	36.6 [A]	9.59	42.8	25.6	23.8 - 186.3
Exit 2	JBS	45	180.3 [A]	4.56	180.3	*71.1	122.2 - 449.3
	Unstressed	36	182.0 [A]	4.52	182.0	40.9	118.8 - 281.1
	Stressed	35	203.2 [A]	4.05	203.2	546.5	138.3 - 3410.5
Exit 3	JBS	46	331.4 [AB]	3.44	331.4	*1050.6	237.7 - 7444.3
	Unstressed	37	312.3 [A]	3.65	312.3	48.2	233.2 - 445.8
	Stressed	34	334.2 [B]	3.41	334.2	113.1	272.3 - 735.0
Steelhead							
Exit 1	JBS	45	30.7 [A]	11.43	38.2	*17.0	26.2 - 94.6
	Unstressed	39	34.4 [A]	10.20	51.7	63.4	25.7 - 396.8
	Stressed	37	53.6 [B]	6.55	223.9	882.1	23.8 - 5426.5
Exit 2	JBS	46	169.7 [A]	4.84	201.6	*93.1	114.1 - 622.1
	Unstressed	39	180.3 [A]	4.56	254.8	246.7	114.0 - 1536.7
	Stressed	33	252.0 [B]	3.26	423.1	926.9	121.9 - 5550.5
Exit 3	JBS	48	330.0 [A]	3.45	362.5	*128.0	227.4 - 929.3
	Unstressed	40	317.6 [A]	3.59	396.1	245.9	217.6 - 1656.5
	Stressed	36	427.2 [B]	2.67	641.2	971.2	252.2 - 5645.1
Subyearling chinook							
Exit 1	JBS	25	44	7.98	47.9	15.0	37.9 - 110.9
	Unstressed	38	46	7.63	48.7	14.0	33.0 - 115.9
	Stressed	30	42	8.36	45.2	11.1	21.0 - 72.0

The effects of induced stress on yearling chinook were not as apparent. We determined travel times to exit station 1 for 86% of the yearling chinook released into the JBS, 73% of the unstressed chinook and 85% of the stressed chinook released near the outfall. Travel times for yearling chinook released into the JBS from the outfall to exit stations 1 and 2 were not significantly different from travel times of stressed or unstressed yearling chinook. However, median travel times to exit station 3 were closer to median travel times of stressed fish than to unstressed fish. Only 2% of the stressed yearling chinook were detected in the side channel near Beacon Rock compared to 7% of the unstressed chinook and 8% of the yearling chinook released into the upstream end of the conveyance pipe. Subyearling chinook were only monitored to the first exit station and showed no significant differences in travel times for JBS, stressed, and unstressed fish (Table 6). Median travel times to exit station 1 ranged from 42 to 46 min. No subyearlings were detected behind Ives Island. Low water prevented us from accessing and maintaining the receiver station and power levels of the battery power supply may have dropped below the minimum operating threshold. However, while mobile tracking no subyearling chinook were detected behind the Ives Island Complex.

During hours of daylight, travel times of yearling chinook released into the JBS were not different from stressed and unstressed fish released near the outfall. Stressed and unstressed steelhead took longer to reach the exit stations than steelhead released into the JBS. There were no differences in subyearling chinook travel times to the first exit station. After dark, stressed yearling chinook took longer than JBS and unstressed fish. Steelhead released into the JBS after dark took less time to reach the first two exits than stressed and unstressed steelhead released near the outfall. When travel times during daylight hours were compared to travel times during darkness, yearling chinook released into the JBS traveled faster during daylight (Appendices 9 and 10). Stressed yearling chinook took longer during darkness. Steelhead released into the JBS traveled faster during darkness. Unlike yearling chinook, stressed steelhead traveled faster during darkness. Stressed, unstressed, and JBS subyearling chinook traveled slightly faster during darkness.

During mobile tracking of yearling chinook, fish passing the JBS and stressed and unstressed groups released at the outfall used the main river (Figures 10, 11, and 12). However,

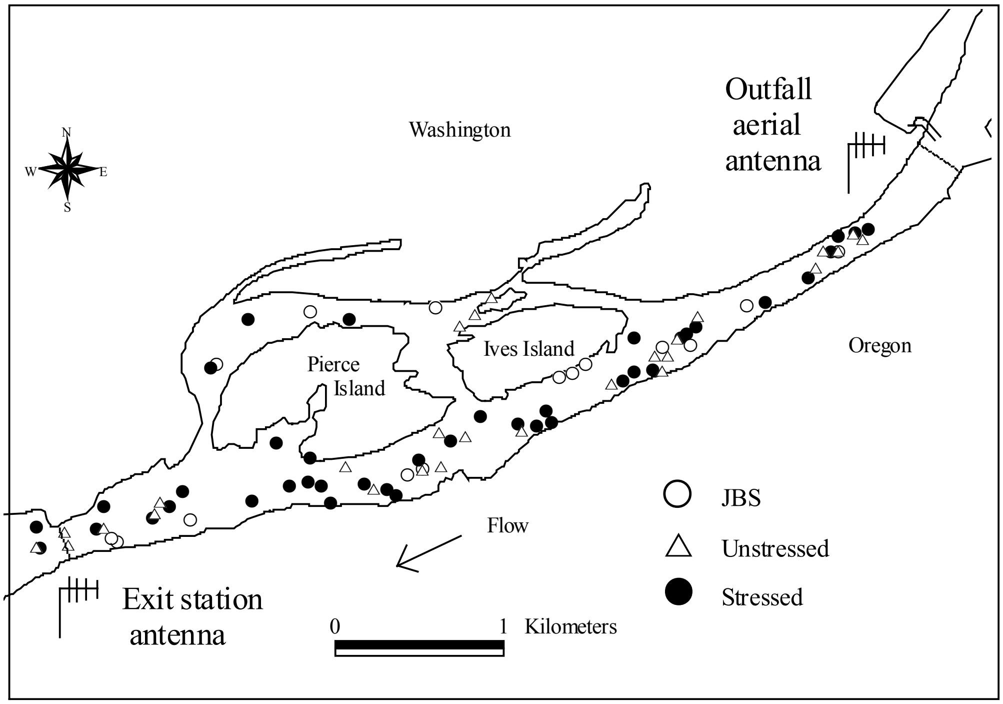

Figure 10. Mobile tracking locations of radio-tagged yearling chinook salmon released into Bonneville Dam Powerhouse II juvenile bypass system (JBS), 2000. JBS fish were released into the upstream end of the conveyance pipe. Stressed and unstressed fish were released into the downstream end of the conveyance pipe.

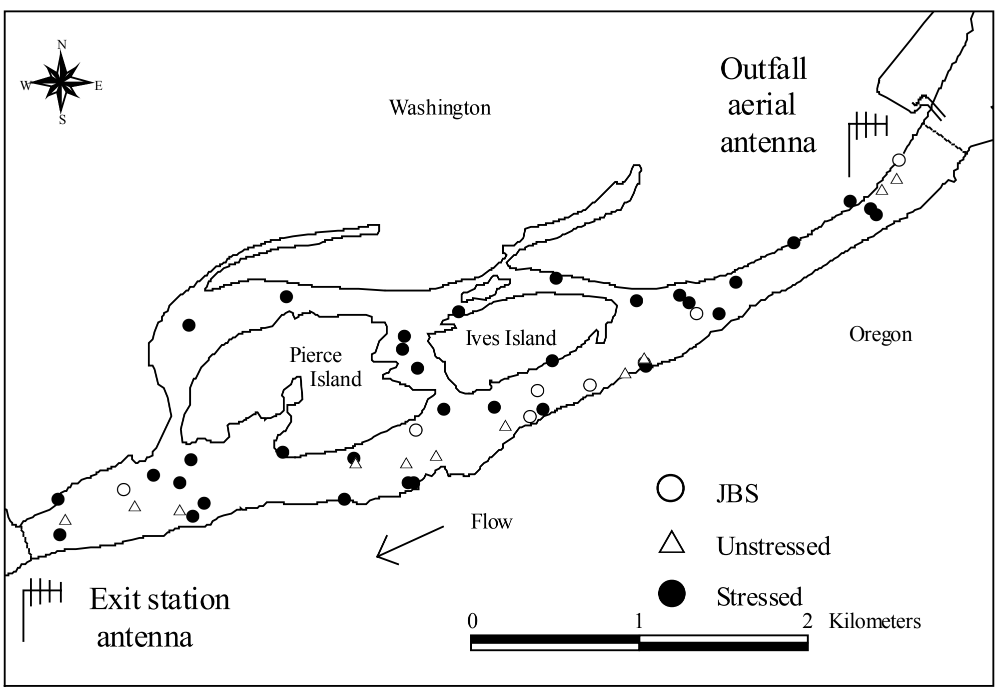

Figure 11. Mobile tracking locations of radio-tagged yearling steelhead released into Bonneville Dam Powerhouse II juvenile bypass system (JBS), 2000.

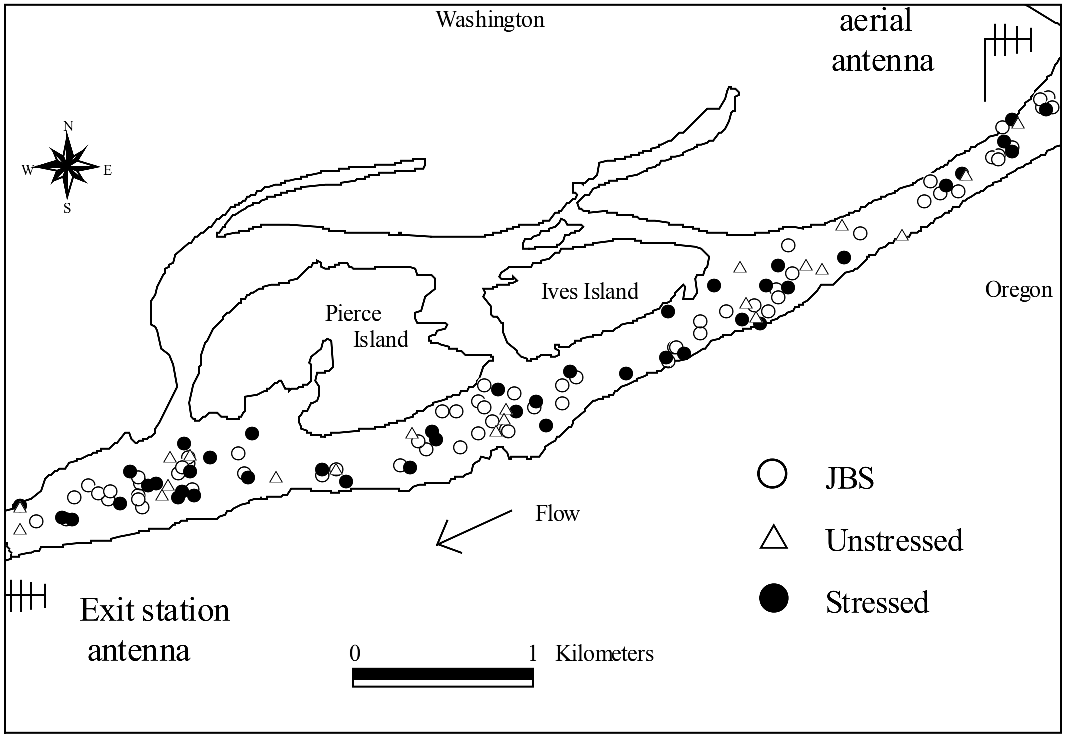

Figure 12. Mobile tracking locations of radio-tagged subyearling chinook salmon released into Bonneville Dam Powerhouse II juvenile bypass system (JBS), 2000.

one yearling chinook salmon from each group was contacted in the side channel (Table 6).

Dead Fish Releases

On 30 May 2000, we radio tagged and released 15 dead chinook and 15 dead steelhead, and on 31 May we released 12 dead chinook and 14 dead steelhead (Table 7). Contact with dead fish was maintained for approximately 100 m downriver from the release location. After that, contact was lost presumably from dead fish sinking to the bottom. However, one steelhead was tracked downriver to the first exit station and its migrational characteristics were similar to those of a live fish. An additional two steelhead were detected by downriver exit stations bringing the total to three (11.5%) dead steelhead that were transported downriver. No chinook salmon were tracked downriver or detected by exit stations. Dead subyearling chinook were not released. For additional information regarding these dead fish see Counihan et al. (2000).

Drogue Releases

Downriver from the outfall, the thalweg follows the south side of the channel. Between the western edge of the Ives Island complex and exit station 1 the river becomes wider. Depths behind the Islands range from 1 to 3 m. Water velocity data obtained using an acoustic Doppler current profiler in 1999 show that water velocities were higher in the thalweg (2 to 4 m/s) compared to shallower sections near the Washington shore and behind the islands (<2 m/s). During spring, when Bonneville Dam project discharge ranged from 184 to 319 kcfs, all of the 23 drogues followed the thalweg on the south side of the river (Table 8). During 10 (43%) of the drogue drifts, fish traveled over the thalweg, 8 (35%) traveled mid-channel north of the thalweg, and 3 (13%) traveled on the north side of the river. During the drogue drifts, the drogue and fish would be in close proximity until they both reached the downstream end of the Ives Island complex. As the thalweg widened, fish and drogue paths separated. Some drogue paths were incomplete due to GPS signal interference caused by high mountains on both sides of the river. Figures 13 and 14 provide examples of drogue and fish movement paths along with concurrent drogue and fish positions.

Table 7. Dead radio-tagged yearling chinook and steelhead released mid channel near the juvenile bypass system outfall, 2000.

Species	Date	N	Exit station detections N (%)
Yearling chinook	5/30/00	15	0 (0%)
	5/31/00	12	0 (0%)
Steelhead	5/30/00	15	1 (7%)
	5/31/00	14	2 (14%)
Overall		56	3 (5%)

Table 8. Summary of drogue drift paths and concurrent fish positions during mobile tracking below Bonneville Dam's Powerhouse II juvenile bypass system, 2000.

Path of fish	Path of drogue	Upriver yearling chinook	Upriver steelhead	Upriver subyearling chinook
south channel	south channel	3	3	
north channel	south channel	1		
south channel then midchannel	south channel then midchannel	1		2
south channel then midchannel	south channel	1	2	
north channel then midchannel	north channel		1	
north channel then midchannel	south channel	1		
mid channel	south channel	3	5	2
mid channel	mid channel			1
Overall:		10	11	5

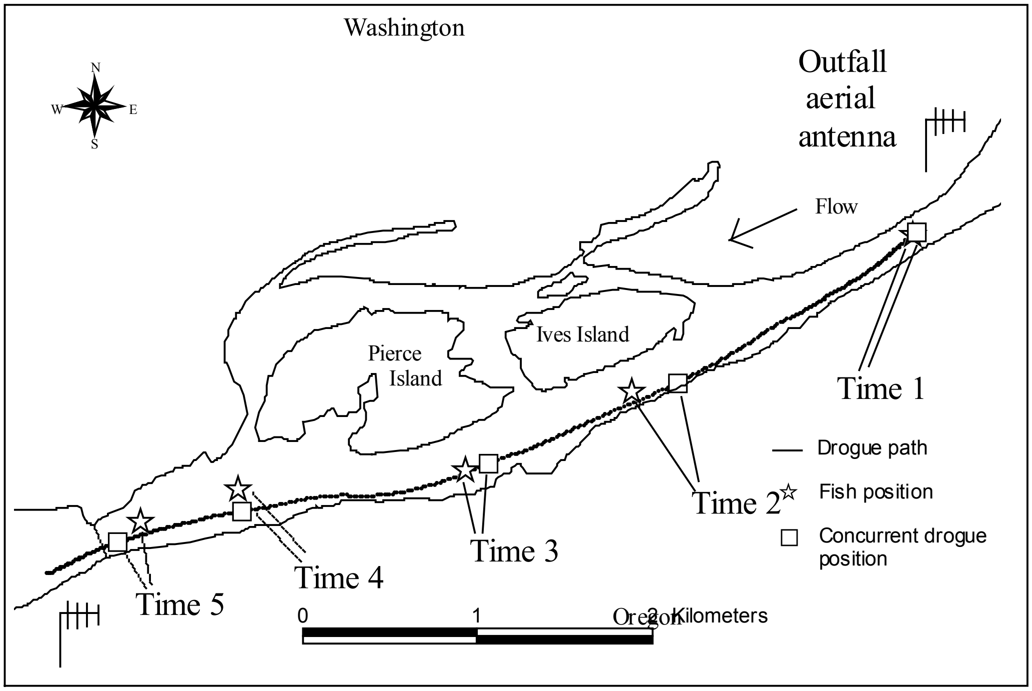

Figure 13. Path of drogue drift and associated fish positions below Bonneville Dam Powerhouse II juvenile bypass system (JBS) and outfall. Fish positions are for radio-tagged yearling steelhead released upriver from Bonneville Dam on 8 May, 2000.

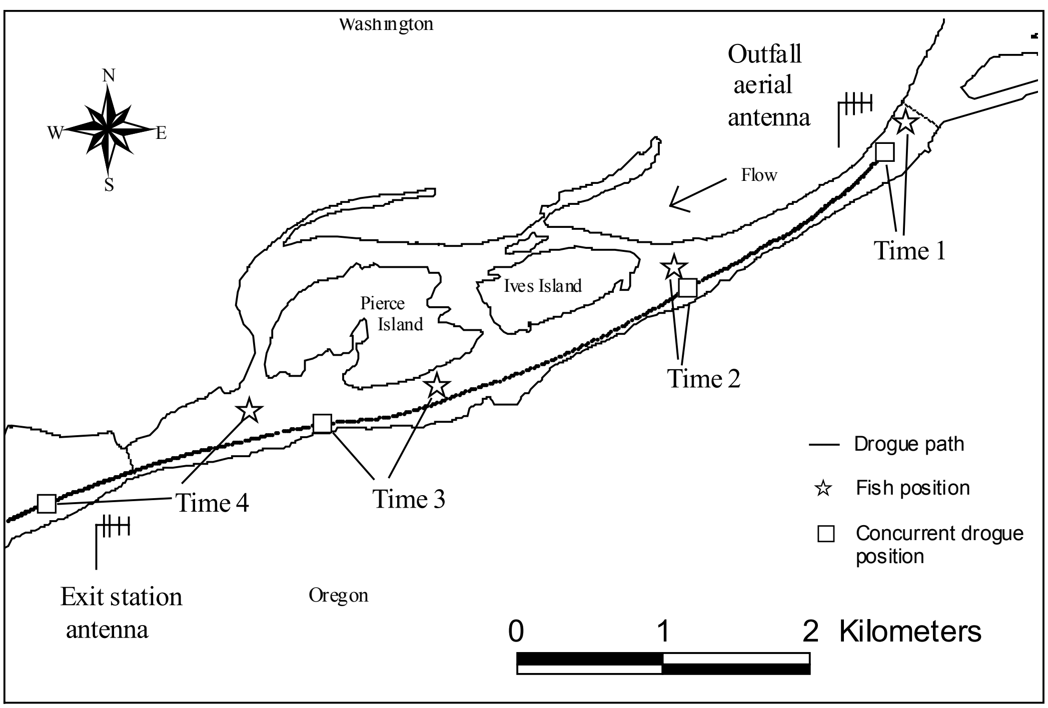

Figure 14. Path of drogue drift and associated fish positions below Bonneville Dam Powerhouse II juvenile bypass system (JBS) and outfall. Fish positions are for radio-tagged yearling chinook salmon released upriver from Bonneville Dam on 24 May, 2000.

Discussion

We found no evidence of direct mortality caused by travel through the JBS. These findings concur with a physical injury and descaling study conducted by the National Marine Fishery Service (Gilbreath and Downing 2000). Results of the survival through the JBS and non-JBS areas of the dam will be available in Counihan et al. (2000).

Plasma cortisol and lactate are well known indicators of physiological stress (Barton et al. 1986; Mesa et al. 2000). Cortisol concentrations indicate a primary or endocrine stress response, while lactate concentrations indicate a secondary or metabolic response. Cortisol and lactate concentrations we measured were relatively high compared to most laboratory studies. The increased plasma cortisol concentrations we observed may have been due to a rise in baseline cortisol, that occurs with the onset of smoltification (Hoar and Randall 1988). ATPase, often used as an indicator of smoltification, was not measured. Also, cortisol and lactate levels may have already been elevated prior to sampling, due to stressors encountered between the Powerhouse II forebay and the entrance to the conveyance pipe.

Comparisons of mean plasma cortisol levels indicated that passage through the conveyance pipe had a minimal stress on fish. During two of our six comparisons of fish collected at time of capture, we found a significant difference between fish sampled before and after passage through the pipe. One experiment showed an increase after passage, while the other showed an unexplained decrease. Throughout the remaining tests, no significant increases in mean cortisol levels were found, indicating that travel through the conveyance pipe was fairly benign.

Comparisons of lactate levels before and after passage through the pipe showed an increase in lactate concentrations after fish passed through the conveyance pipe. This indicated that fish traveling through the conveyance pipe were probably swimming against the water velocity. The increase in lactate levels after fish passed through the pipe was most pronounced in steelhead. Elevated lactate levels showed the high likelihood that fish were swimming, possibly resisting, the water velocities (approximately 1.5 m/s) encountered in the conveyance pipe. Burst-style or prolonged swimming at high velocities could cause fish to incur oxygen debt, and therefore, increase lactate concentrations in the blood. The steelhead in our tests had a mean fork length of 232 mm and ranged in size from 127-290 mm. At this size, the larger steelhead would be capable of swimming against high velocities and maintaining their position for longer than the smaller chinook. This is consistent with radio-telemetry data that showed that steelhead spent a longer time (48 min) in the conveyance pipe than yearling chinook (41 min) or subyearling chinook (37 min), indicating that steelhead were more likely to either swim against the current or hold in various locations in the pipe. Mean lactate concentrations in yearling chinook and subyearling chinook were also elevated after passing through the conveyance pipe. Although this increase in lactate indicated anaerobic metabolism, we are uncertain about the detrimental effects of passage through the pipe. In the time series, we observed a decline in lactate levels within 3 h, after the additive effect of capturing and handling, which indicated that fish were capable of recovering in a short period of time. We presume that once the fish re-entered the river, their lactate concentrations would drop to levels found in fish prior to entering the conveyance pipe.

Results from the time series experiments indicated that collecting and sequestering the fish caused physiological stress. We observed similar responses in fish sampled before entering the conveyance pipe compared to fish sampled after passage through the conveyance pipe. We found that regardless of whether or not fish traveled through the pipe, they exhibited a stress response. Stress associated with capture undoubtedly contributed to increases in cortisol and lactate. In our time series samples, we observed a stress response in both cortisol and lactate. Therefore, we have put greater emphasis on our cortisol and lactate levels of fish collected and sampled at time of capture to conclude actual stress caused by the travel through the conveyance pipe. However, the time series experiments allowed us to see how capable fish were of responding to stressors and enabled us to determine that they were not already at their maximal stress response. Although passage through the pipe did not seem to elicit a stress response, it did appear that even a relatively minor event (capture) elicited a substantial response. If the conveyance pipe was a major stressor, we would have observed a large increase in cortisol levels in fish sampled at the time of capture after passage. Since results at time of capture showed little difference, we conclude that the conveyance pipe alone was not eliciting a serious stress response. In addition to assessing a stress response, our time series allowed us to evaluate recovery time after a stress event. A period of 12-24 h was required for steelhead, yearling chinook, and subyearling chinook to recover from collection stress.

During the radio-telemetry evaluation, radio-tagged fish traveling from the forebay to the outfall area took longer when traveling through the JBS compared to fish that passed the dam through non-JBS routes, most likely due to the longer distance of the pipe and minimal delay associated with passing over the spillway. The small delays should not be detrimental to fish if predation in the immediate tailrace is reduced.

Once in the conveyance pipe, radio-tagged fish moved quickly. However, comparisons of median travel time of radio-tagged fish to a passive object indicated that yearling chinook, and to a greater degree steelhead, resisted transport in the flow. Pacific States Marine Fisheries Commission personnel cleaning the separator bars observed steelhead holding position in the transport flume near the fish facility between the primary and secondary dewatering systems. This may have led to increased lactate levels and longer median travel times in steelhead compared to yearling and subyearling chinook. Longer delays of yearling chinook before entering the conveyance pipe indicated they were holding in the collection channel, and their lactate levels may have already increased prior to sampling at the upstream end of the pipe. This would explain why lactate levels did not increase dramatically for yearling chinook during travel through the pipe.

Once in the main river channel, fish moved downriver and exited the study area quickly. Fish that had passed through the JBS exhibited similar behavior to fish that passed the dam through other routes, and travel time to the first exit station was the same for both groups (median = 36 min for spring chinook and 31 min for steelhead). These travel times were approximately equal to travel times recorded in 1999.

The fixed receiver station at Beacon Rock allowed us to determine side channel use with much greater efficiency than if using boat tracking alone. During mobile tracking, the percentage of fish that delayed (7%) or were believed to be lost to predation (2%) was low for both JBS and non-JBS passed fish, and the percentage of fish using the side channel behind Ives Island was less than 3%. However, data collected from the fixed antenna station at Beacon rock increased our estimates of side channel use to 8% for both yearling chinook and steelhead. This number was similar to the 10% estimate reported by Snelling and Matson (1995). We attribute the small difference to either a difference in flows or a difference in behavior due to the methods of Snelling and Matson (1995).

It appeared that steelhead were more affected by the introduced stress than yearling or subyearling chinook. In all three species, the fish that passed through the JBS behaved like the unstressed group although there was no significant difference in chinook. Because most fish stayed near the thalweg where water velocities were highest it appeared that these fish were healthy and actively migrating downriver. Disappearance of dead fish helped us to characterize the movements of live fish and indicated that fish we monitored were not dead or being passively transported downriver.

Acknowledgments

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Appendix 1. Analysis of variance summary for blood plasma cortisol of steelhead, yearling chinook, and subyearling chinook subjected to the conveyance pipe (before entrance and after passage) and diel (daytime and nighttime) treatments. Summary reflects data taken immediately at capture (time-zero). Asterisk (*) denotes $P<0.05$.

Steelhead

Source	df	MS	F-ratio
Before_after	1	11806.10	3.61
Diel	1	576.08	0.18
Before_after x Diel	1	10530.03	3.22
Error	36	3271.04	

Yearling Chinook

Source	df	MS	F-ratio
Before_after	1	7115.56	3.29
Diel	1	24378.91	11.27*
Before_after x Diel	1	3974.04	1.84
Error	36	2163.27	

Subyearling Chinook

Source	df	MS	F-ratio
Before_after	1	14270.17	3.63
Diel	1	24478.35	6.23*
Before_after x Diel	1	115.94	0.03
Error	35	3927.18	

Appendix 2. Analysis of variance summary for blood plasma lactate of steelhead, yearling chinook, and subyearling chinook subjected to the conveyance pipe (before entrance and after passage) and diel (daytime and nighttime) treatments. Summary reflects data taken immediately at capture (time-zero). Asterisk (*) denotes P<0.05.

Steelhead

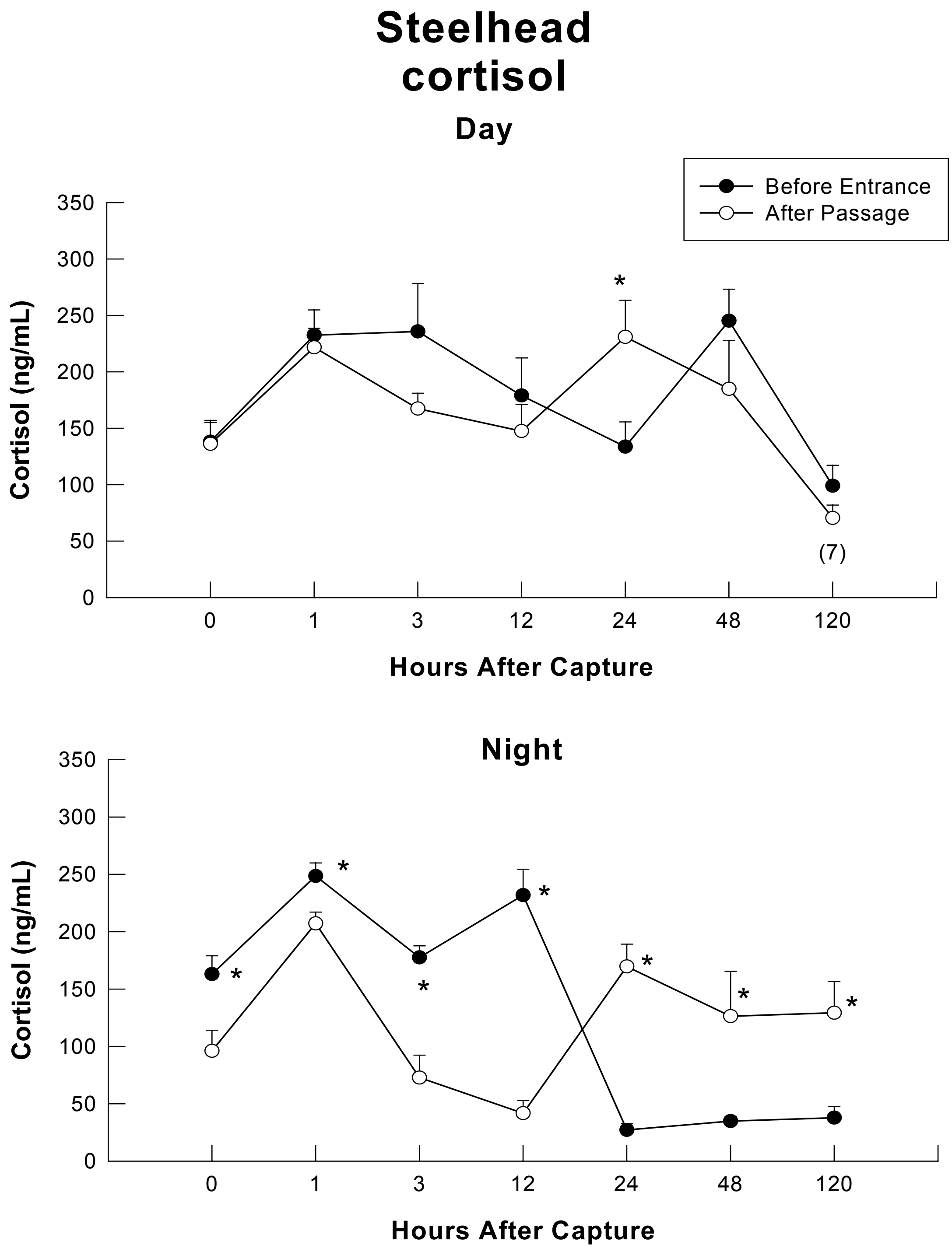
Source	df	MS	F-ratio
Before_after	1	11974.71	20.18*
Diel	1	1352.22	2.28
Before_after x Diel	1	1040.71	1.75
Error	36	593.49	

Yearling Chinook

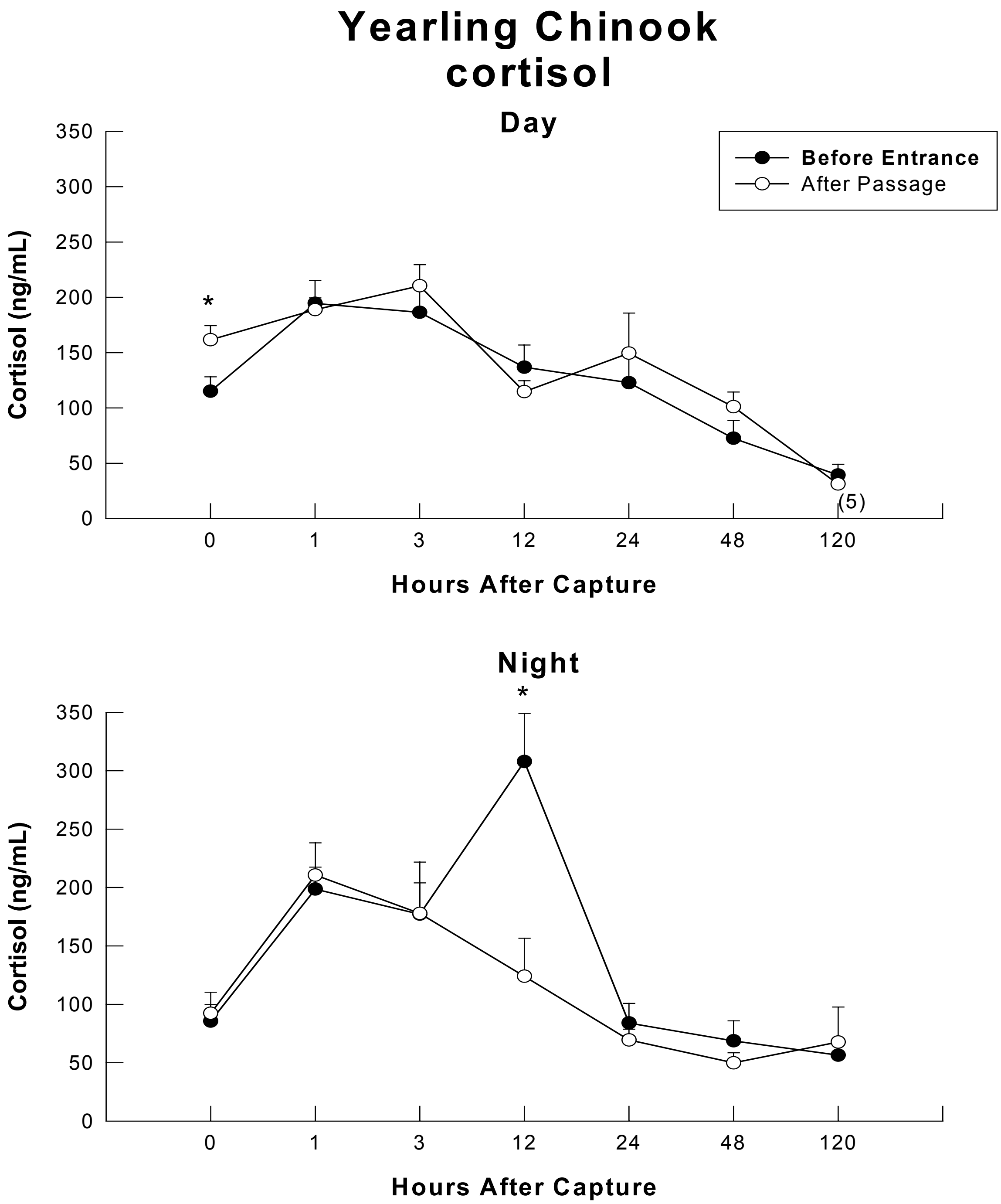
Source	df	MS	F-ratio
Before_after	1	191.36	0.42
Diel	1	1272.05	2.77
Before_after x Diel	1	2239.96	4.88*
Error	36	459.24	

Subyearling Chinook

Source	df	MS	F-ratio
Before_after	1	2578.48	4.15*
Diel	1	392.21	0.63
Before_after x Diel	1	1439.93	2.32
Error	34	621.24	

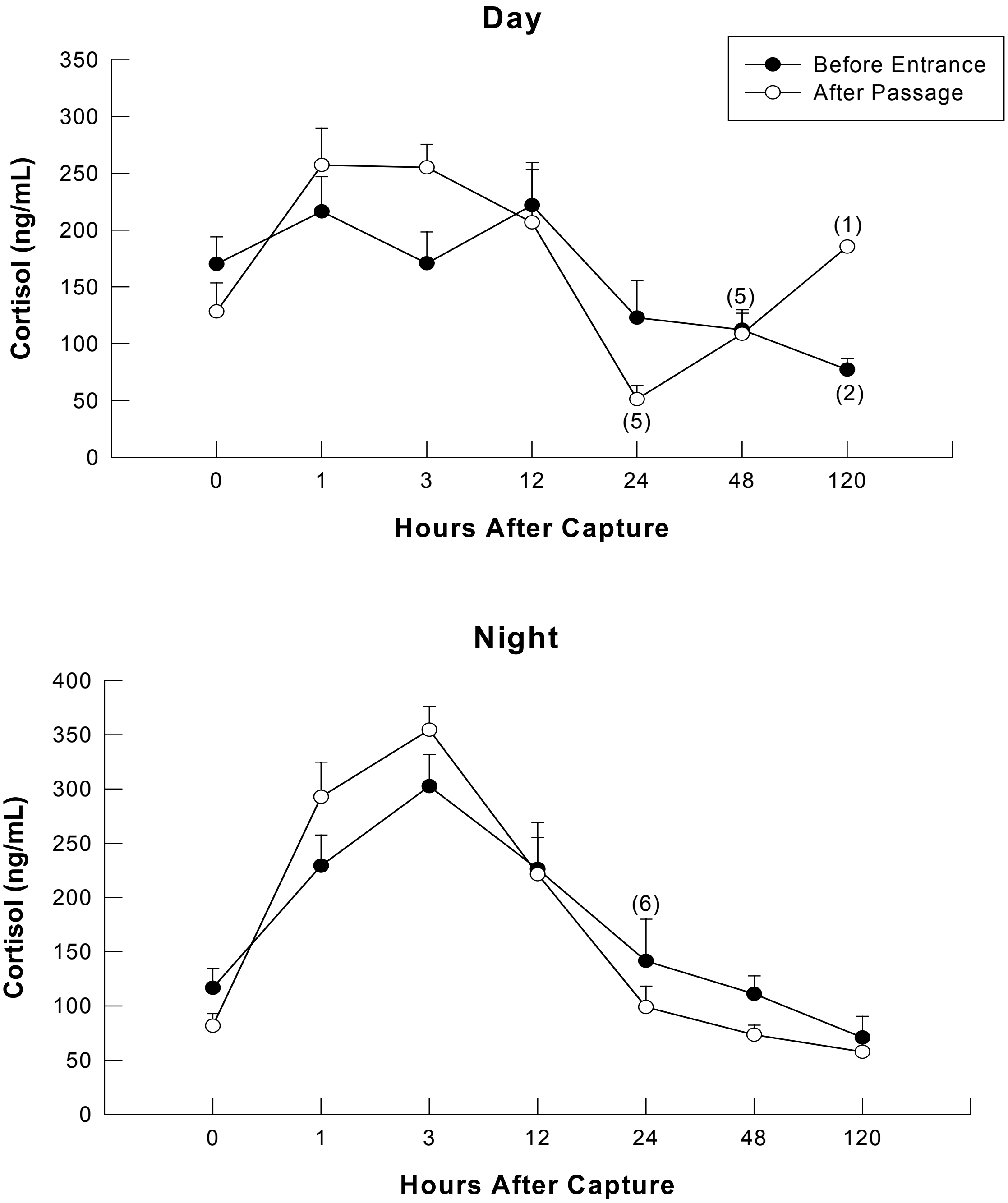


Appendix 1. Mean (+ SE) plasma cortisol concentrations over time series in steelhead before entrance and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample size. Asterisks (*) indicate where before entrance and after passage values differ significantly.



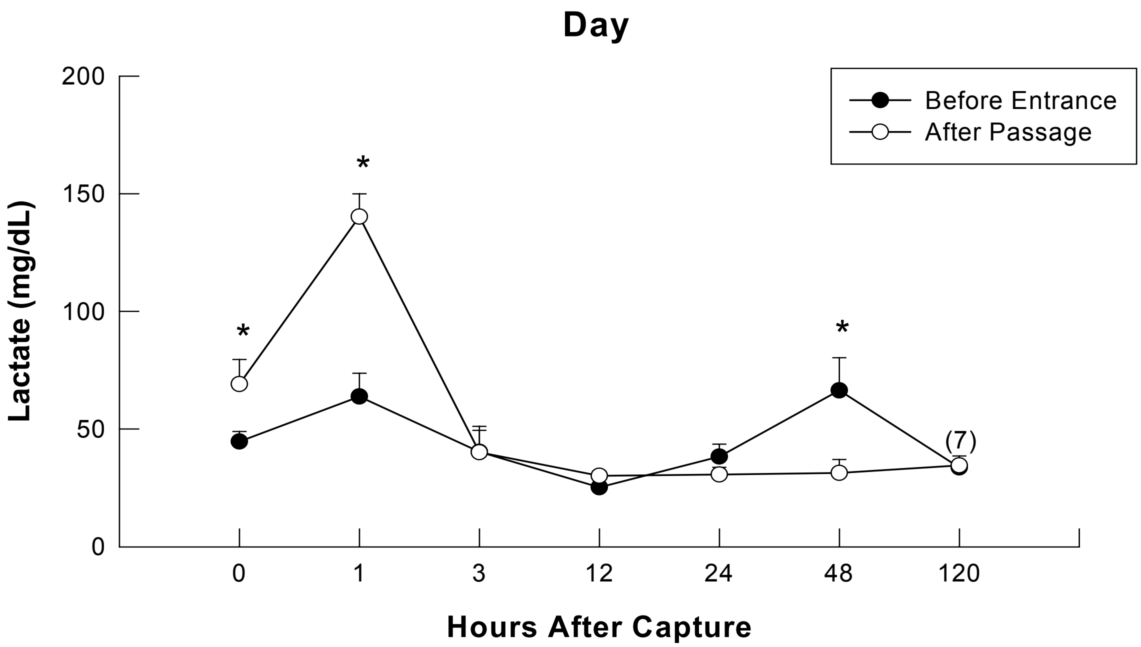
Appendix 4. Mean (+ SE) plasma cortisol concentrations over time series in yearling chinook before entrance and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for most points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample size. Asterisks (*) indicate where before entrance and after passage values differ significantly between time series groups.

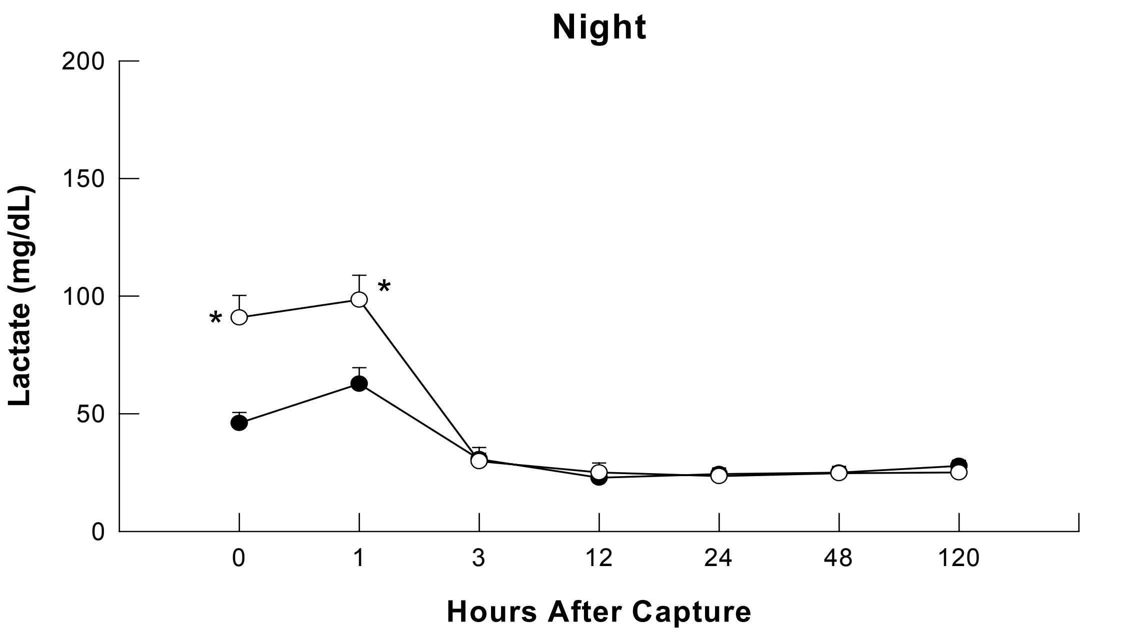
Subyearling Chinook cortisol



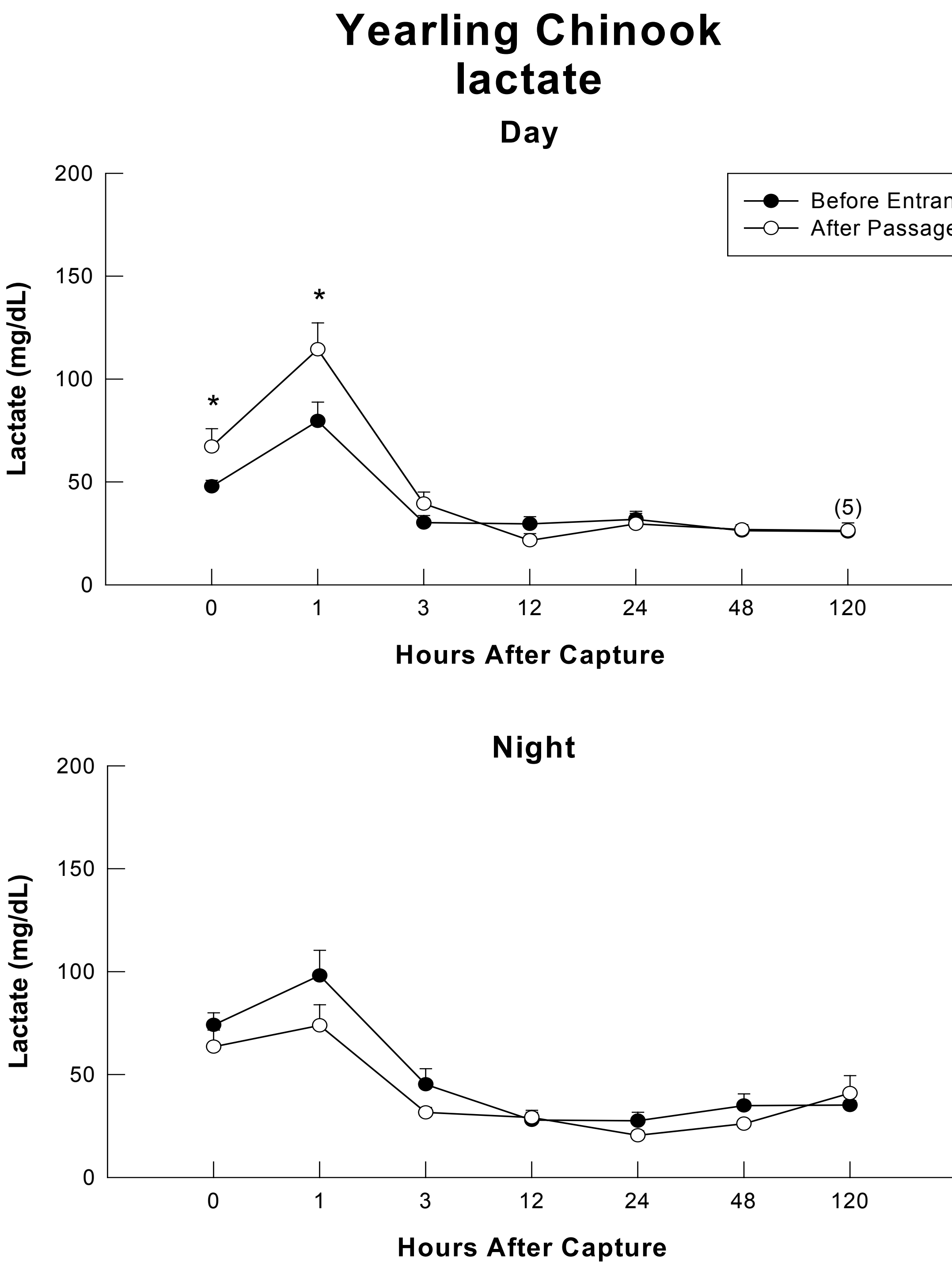
Appendix 5. Mean (+ SE) plasma cortisol concentrations during time series in subyearling chinook before entrance and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample sizes.

Steelhead lactate

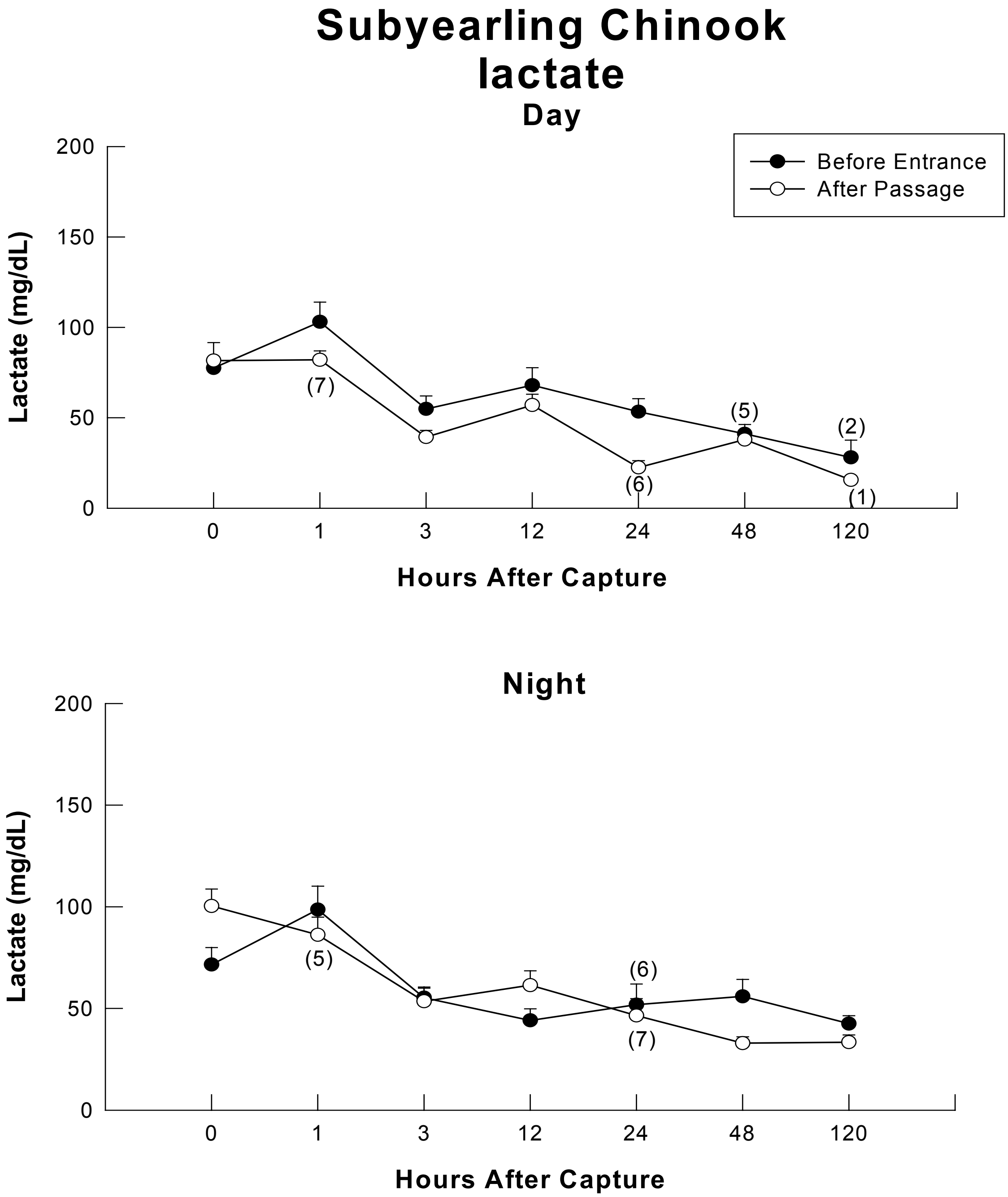




Appendix 6. Mean (+ SE) plasma lactate concentrations over time series in steelhead before entrance to conveyance pipe and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample size. Asterisks (*) indicate where before entrance and after passage values differ significantly.



Appendix 7. Mean (+ SE) plasma lactate concentrations over time series in yearling chinook before entrance and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample size. Asterisks (*) indicate where before entran and after passage values differ significantly.



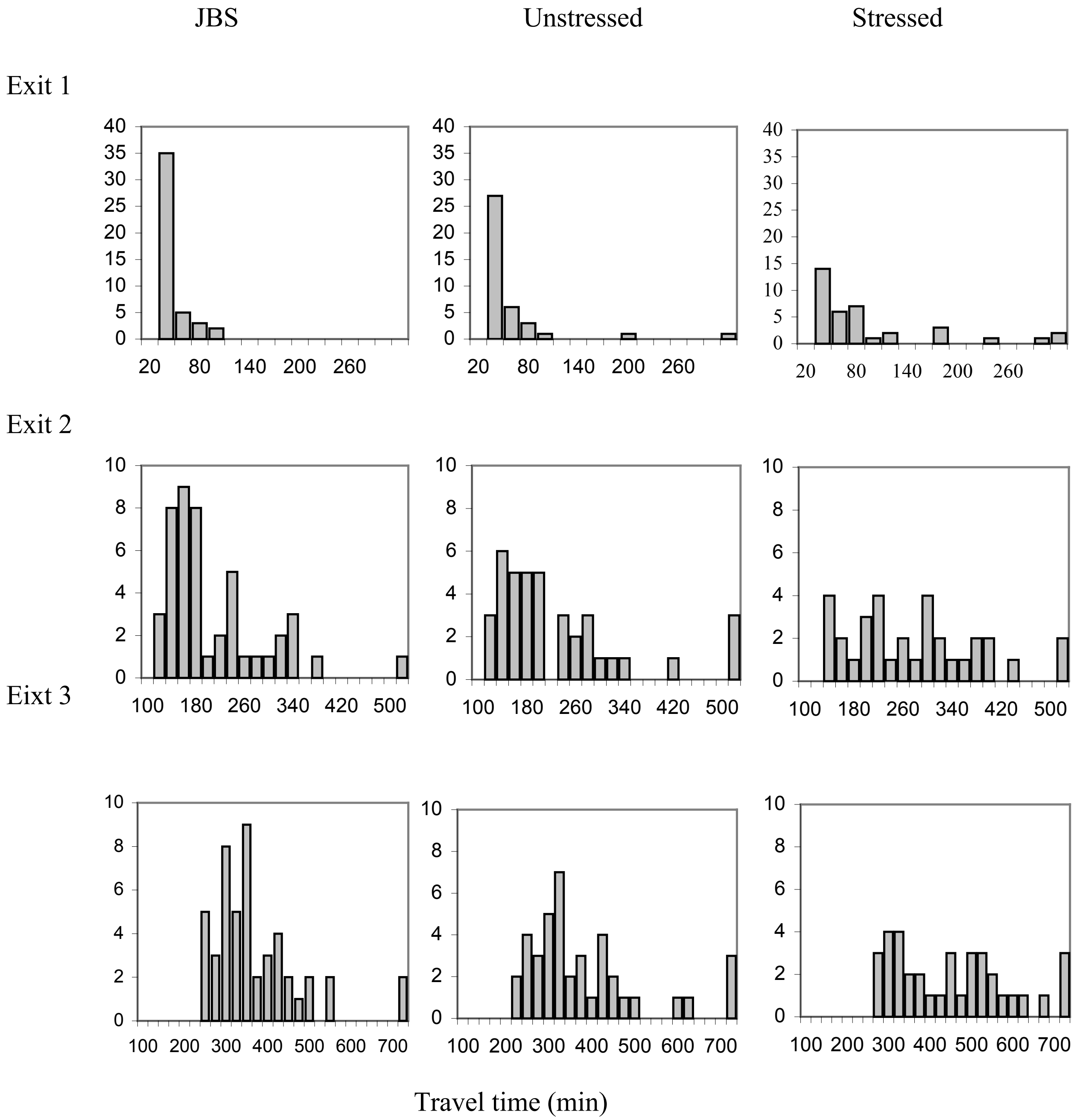
Appendix 8. Mean (+ SE) plasma lactate concentrations over time series in subyearling chinook before entrance to conveyance pipe and after passage through conveyance pipe at Bonneville Dam's Powerhouse II juvenile bypass system, 2000. Sample size for points was 8-10, unless otherwise indicated. Numbers in parentheses denote smaller sample size. Asterisks (*) indicate where before entrance and after passage values differ significantly. Plasma samples taken over one week period.

Appendix 9. Median and mean travel time (min) and travel rate (km/h) of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon from the juvenile bypass system (JBS) outfall to downriver exit stations during hours of daylight, 2000. Median travel times with letters in common were not significantly different within an exit station. Asterisks (*) indicate variances within an exit station were heterogeneous.

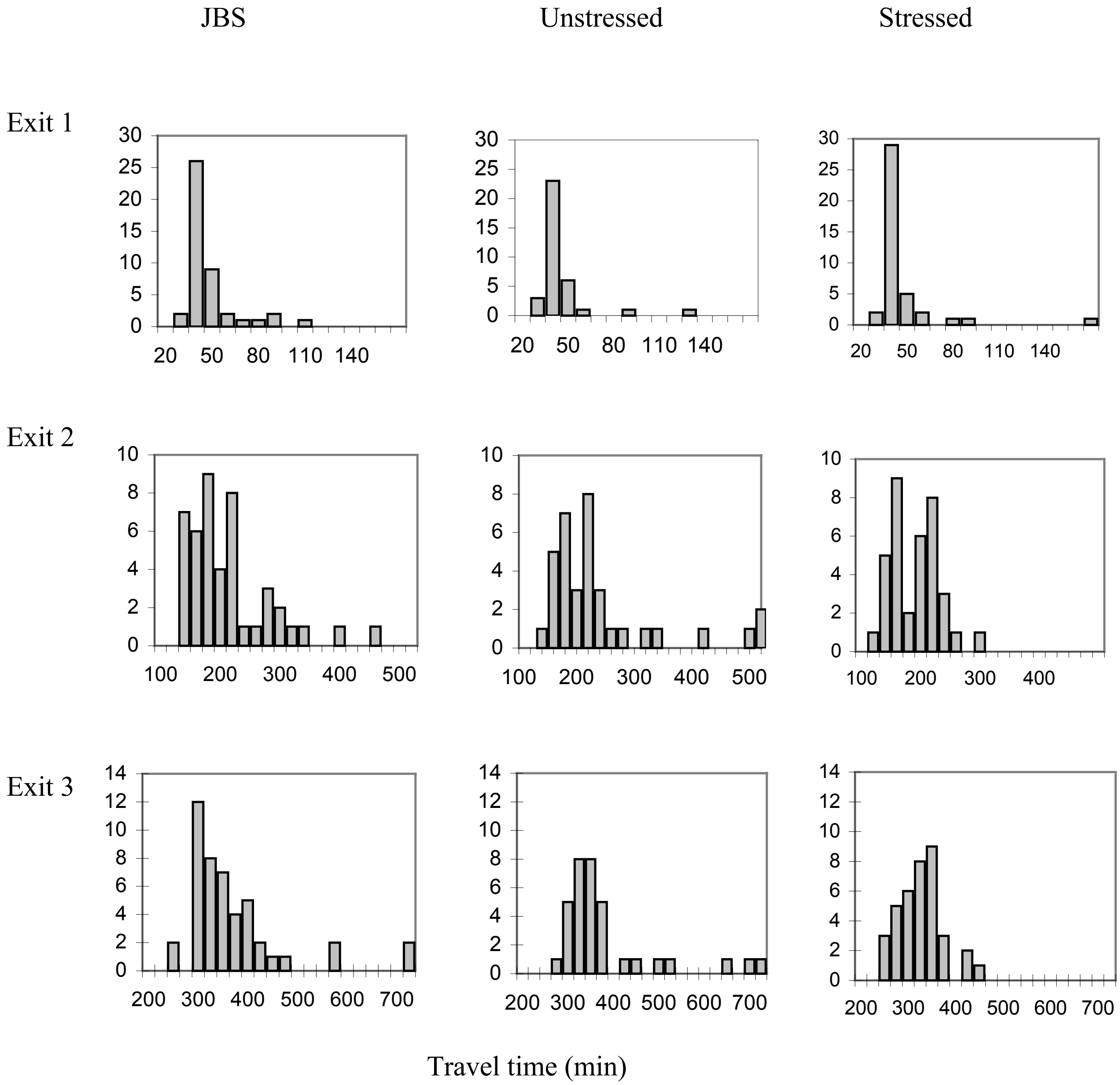
Species/ exit station/ release type		N	Median travel time (min)	Median travel rate (km/h)	Mean travel time (min)	SD	Range
Yearling chinook							
Exit 1	JBS	24	37.6^{A}	9.34	45.1	20.7	26.0-105.4
	Unstressed	21	37.5^{A}	9.36	41.5	19.7	28.1-124.5
	Stressed	19	34.8^{A}	10.09	38.4	13.6	23.8-88.0
Exit 2	JBS	23	198.7^{A}	4.14	211.6	*84.9	124.3-449.3
	Unstressed	21	181.6^{A}	4.53	184.5	43.8	125.6-281.1
	Stressed	18	199.3^{A}	4.12	390.7	758.3	138.3-3410.5
Exit 3	JBS	24	340.1^{A}	3.35	375.7	*135.8	245.9-893.8
	Unstressed	21	325.9^{A}	3.50	320.6	48.5	248.1-412.3
	Stressed	18	331.6^{A}	3.44	352.4	83.9	285.7-639.5
Steelhead							
Exit 1	JBS	24	31.4^{A}	11.18	41.0	*20.7	26.6-94.6
	Unstressed	19	38.5^{A}	9.12	68.6	88.2	25.7-396.8
	Stressed	16	85.0^{B}	4.13	108.5	77.7	29.5-286.8
Exit 2	JBS	24	177.2^{A}	4.64	226.8	*105.6	137.1-622.1
	Unstressed	18	254.7^{A}	3.23	353.6	335.9	139.3-1536.7
	Stressed	13	307.7^{B}	2.67	310.3	126.8	121.9-649.8
Exit 3	JBS	25	328.5^{A}	3.47	364.1	*106.2	275.5-740.5
	Unstressed	19	408.6^{A}	2.79	500.5	321.2	278.6-1656.5
	Stressed	16	489.7^{B}	2.33	642.9	653.6	278.8-3048.7
Subyearling chinook							
Exit 1	JBS	15	44.0^{A}	7.98	44.6	7.1	37.9-67.0
	Unstressed	19	44.9^{A}	7.82	50.6	18.4	33.0-115.9
	Stressed	13	42.0^{A}	8.36	43.0	10.4	21.0-67.0

Appendix 10. Median and mean travel time (min) and travel rate (km/h) of radio-tagged yearling chinook, steelhead, and subyearling chinook salmon from the juvenile bypass system (JBS) outfall to downriver exit stations during hours of darkness, 2000. Median travel times with letters in common were not significantly different within an exit station. Asterisks (*) indicate variances within an exit station were heterogeneous.

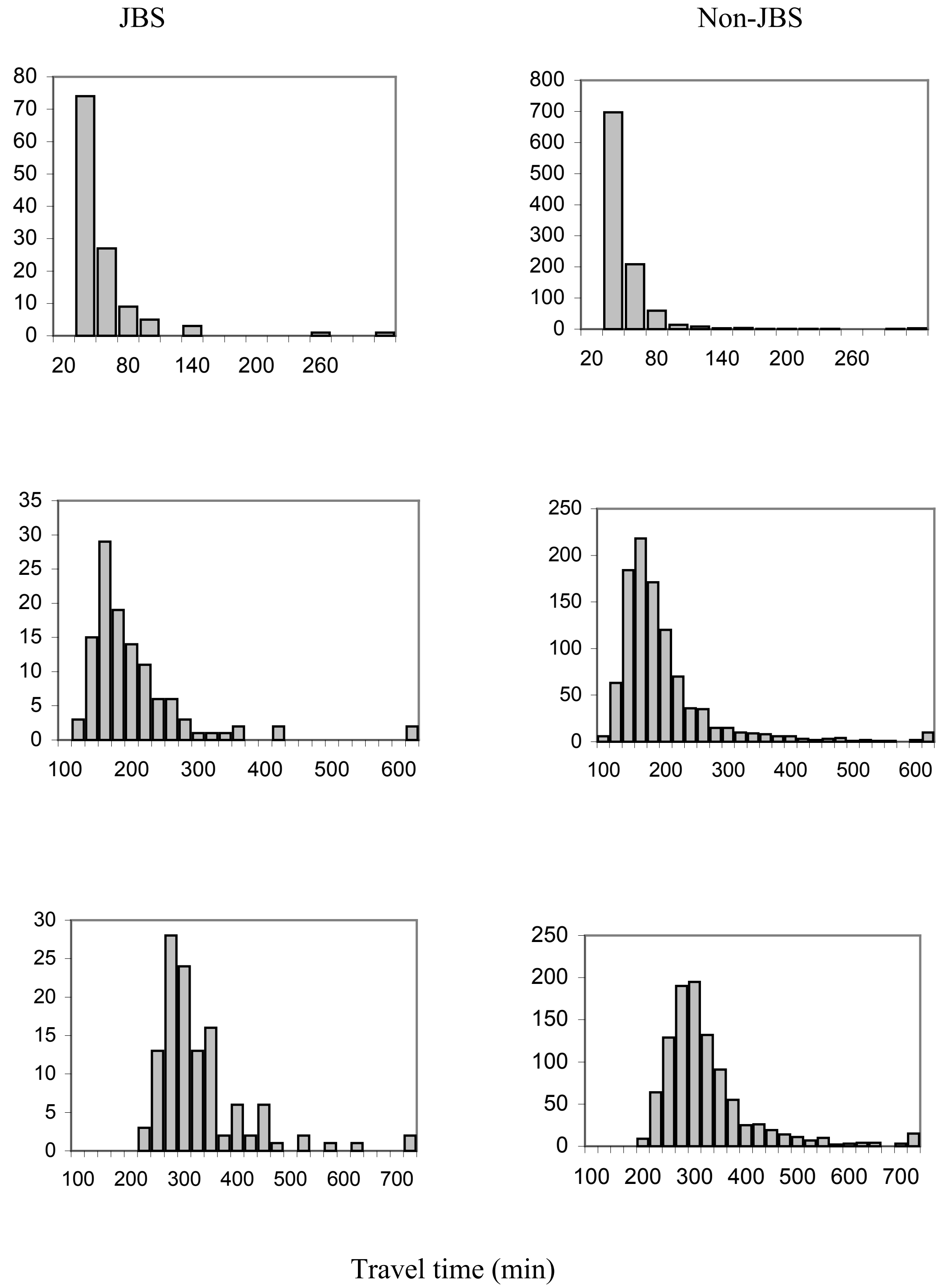
Species/ Exit station/	Release type	N	Median travel time (min)	Median Travel Rate (km/h)	Mean travel time (min)	SD	Range
Yearling chinook							
Exit 1	JBS	20	35.7^{A}	9.83	39.0	*9.7	30.6-68.8
	Unstressed	14	36.4^{A}	9.64	40.6	14.2	29.9-84.9
	Stressed	22	38.7^{A}	9.07	46.6	32.5	31.9-186.3
Exit 2	JBS	22	174.3^{A}	4.72	191.7	*53.3	122.2-337.4
	Unstressed	15	182.4^{A}	4.51	175.5	37.4	118.8-223.8
	Stressed	17	207.3^{A}	3.97	236.6	102.7	140.3-542.2
Exit 3	JBS	22	326.0^{A}	3.50	653.7	*1517.	237.7-7444.3
	Unstressed	16	308.7^{A}	3.69	309.5	48.6	233.2-445.8
	Stressed	16	343.3^{A}	3.32	393.2	138.7	272.3-735.0
Steelhead							
Exit 1	JBS	21	30.4^{A}	11.55	311.8	*11.2	26.2-69.9
	Unstressed	20	32.3^{A}	10.87	35.1	10.8	26.2-66.8
	Stressed	21	33.3^{A}	10.54	35.7	1173.6	23.8-5426.5
Exit 2	JBS	22	141.4^{A}	5.81	174.1	*69.6	114.1-333.8
	Unstressed	21	151.5^{A}	5.43	170.0	58.4	114.0-337.7
	Stressed	20	211.2^{B}	3.89	496.4	1192.6	124.7-5550.5
Exit 3	JBS	23	333.5^{AB}	3.42	360.6	*150.5	227.4-929.3
	Unstressed	21	290.0^{A}	3.93	301.6	73.2	217.6-486.7
	Stressed	20	337.4^{B}	3.38	639.8	1183.3	252.2-5645.1
Subyearling chinook							
Exit 1	JBS	10	48.0^{A}	7.31	53.5	*22.5	39.9-110.9
	Unstressed	19	47.0^{A}	7.47	46.8	7.5	34.9-65.0
	Stressed	17	44.0^{A}	7.98	46.8	11.7	26.9-72.0



Appendix 11. Travel times of JBS- released, unstressed, and stressed the steelhead between outfall and downriver exits, 2000.



Appendix 12. Travel times of JBS- released, unstressed, and stressed yearling chinook between the outfall and downriver exits, 2000.



Appendix 13. Travel times from the outfall to downriver exits of yearling chinook released upriver,that passed through JBS and non-JBS routes, 2000.

Appendix 14. Mean fork length and weight of dead radio-tagged yearling chinook and steelhead released mid channel near the outfall to Bonneville Dam's Powerhouse II juvenile bypass system, 2000.

Species/ Release date	N	Fork length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
Yearling chinook							
5/30/00	15	156.3	17.8	136-200	40.3	13.9	27.6-79.6
5/31/00	12	146.8	10.0	127-163	32.7	7.0	23.9-48.4
Steelhead							
5/30/00	15	221.1	31.3	136-258	102.9	28.0	60.1-141.6
5/31/00	14	224.4	32.2	177-283	102.6	40.7	43.2-180.6