Post-construction evaluation of the juvenile salmonid bypass system at Ice Harbor Dam, 1996

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Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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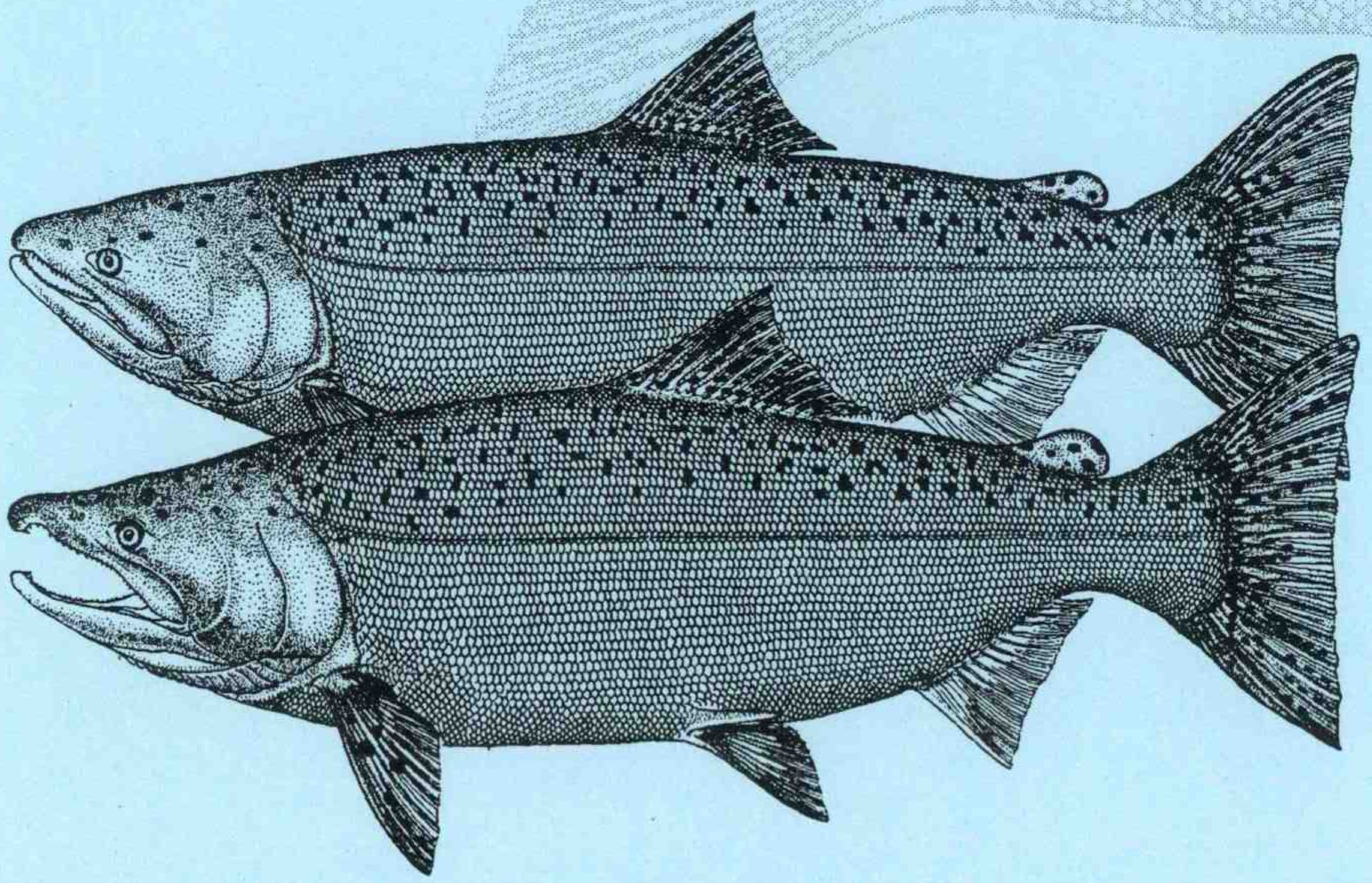

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EXECUTIVE SUMMARY

The Ice Harbor Dam juvenile salmonid sampling facility and bypass system was completed and ready for operation for the 1996 spring outmigration. This bypass system is similar to those at Lower Monumental, Little Goose, and McNary Dams, but does not include a raceway area to hold migrants for transportation purposes. Primary operation is to bypass fish around the dam and return them to the river just downstream from the tailrace area, but samples can be taken on an "as needed" basis. Prior to the facility being operated in the bypass mode, we evaluated the system by visually inspecting the entire fish passage system. We examined both juvenile and adult migrants for descaling and gross external injuries, and analyzed blood samples from juveniles for evidence of stress build-up. Our findings are summarized below:

1) We found no areas within the channel or piping where serious injury could occur. We did find minor, potentially abrasive areas within the outfall pipe that were removed prior to the beginning of the spring outmigration.

2) No evidence of descaling or gross external injuries was observed with releases of hatchery steelhead and chinook salmon.

3) We found no evidence of descaling problems or gross external injuries for adult steelhead fall-backs that were released into the upper end of the collection channel and later collected at the sample facility.

4) For yearling chinook salmon, there were no significant differences in cortisol, glucose, or lactate levels among fish sampled from the gatewell, pre-separator, or pre-sample tank.

5) For steelhead, cortisol levels were significantly lower and glucose levels significantly higher in fish sampled from the gatewell than in fish sampled from the pre-separator or pre-sample tank.

INTRODUCTION

Bypass facilities for diverting juvenile salmonids (*Oncorhynchus* spp.) from turbine intakes have been in use at hydroelectric dams on the Snake and Columbia Rivers since the late 1970s. The early facilities did not always receive immediate evaluation for fish passage, and at times problems were detected (Matthews 1992). More recently, as new bypass systems have been completed, thorough evaluations have been conducted prior to salmonid passage (Marsh et al. 1996). The juvenile bypass system for Ice Harbor Dam was completed prior to the spring outmigration of 1996, and the National Marine Fisheries Service was engaged by the U.S. Army Corps of Engineers (COE) to conduct an evaluation of the facilities prior to operation.

The basic components of the Ice Harbor bypass system are similar to those in use at other Snake and Columbia River hydroelectric dams. A channel that runs the length of the powerhouse was constructed within the ice and trash sluiceway to accept flow from gatewell orifices (30.5-cm diameter). Flow within the channel runs from north to south, i.e., from Turbine Unit 6 to Unit 1. At the downstream (south) end of the channel is the primary dewatering screen, and from there migrants enter a corrugated steel pipe (91.4-cm diameter). This pipe leads to the main flume dewatering area and then to the wet-separator section where fish are diverted into a series of aluminum channels that lead either to the sampling facility or back to another section of the corrugated steel pipe. Downstream from the sampling facility, the corrugated steel pipe transitions to a smooth steel pipe (76.2-cm diameter) and from there to a plastic pipe of equal diameter (approximately 250-m long) that eventually releases fish into the river about 180 m downstream from the dam.

The overall goal of this project was to provide the COE, fisheries agencies, and tribes with information on the effects of the new bypass and sampling facility at Ice Harbor Dam on juvenile salmonids. Specific study objectives were: 1) inspect the interior of the outfall pipe to ensure that no problems existed that would hinder safe fish passage, 2) determine if mechanical problems existed within the bypass system and sampling facility that might affect salmonid passage, and 3) monitor the physiological effects of the bypass system on juvenile salmonids.

OBJECTIVE 1: INSPECT THE INTERIOR OF THE OUTFALL PIPE TO ENSURE SAFE FISH PASSAGE

Approach

The portion of the outfall pipe that leads from the collection facility and eventually returns fish to the river is approximately 300 m long, underground, and as such is not readily accessible for examination. In 1994, an unsuccessful attempt was made to evaluate a similar release structure at Lower Monumental Dam by releasing groups of marked fish and recapturing them with a floating net-pen at the exit point (Marsh et al. 1996b). Also in 1994, NMFS personnel tested the feasibility of purse seining the tailrace area at McNary Dam as a potential method of recapture (Marsh et al. 1996a). This method also was unsuccessful. Therefore, it was decided that the best method for the evaluation at Ice Harbor Dam would be a physical inspection of the pipe interior.

The outfall pipe was installed and ready for use before the system was watered up for the spring outmigration. While the primary contractor was still on site, we conducted two physical inspections of the pipe interior in early April. National Marine Fisheries

Service personnel conducted the inspections with the aid of ropes, lanterns, and battery-operated radios.

Results

During the first inspection, we found a few minor, potentially abrasive areas (sharp edges where two pieces of pipe were butted together) near the transition from smooth steel to plastic pipe. The contractor was notified of the problem areas, and in our final inspection we observed that these edges had been removed.

OBJECTIVE 2: DETERMINE IF MECHANICAL PROBLEMS EXIST WITHIN THE BYPASS SYSTEM AND SAMPLING FACILITY THAT MIGHT AFFECT SALMONID PASSAGE

Approach

Juvenile Migrants

Our evaluation of the system entailed releasing groups of hatchery steelhead (*O. mykiss*) and yearling chinook salmon (*O. tshawytscha*) at different points within the collection channel and recovering them at the handling facility. In addition, all sections of pipes and flumes used for fish passage were thoroughly inspected for smoothness several times prior to the beginning of the spring outmigration.

For tests, steelhead from Dworshak National Fish Hatchery and yearling fall chinook salmon from the Washington Department of Fish and Wildlife, Lyons Ferry Hatchery were used. We transported the fish to Ice Harbor Dam in early April and held them at the dam in 1.3-m by 1.3-m by 6-m aluminum tanks with river water flow-through systems.

Equal numbers of each species were marked and released into the collection channel on 13 and 14 April. Points of release were the upper end of the collection channel near

Unit 6 and the lower end of the channel near Unit 1, just upstream from the primary dewatering screen. The fish were marked with a partial caudal clip (upper or lower lobe) corresponding to the point of release within the collection channel (e.g., upper lobe = upper channel). Only uninjured non-descaled fish were marked. On the day of release, fish were marked, held for recovery (a minimum of 2 hours), transported by truck to the forebay deck of the dam, and hand carried in 20-gallon plastic containers to release sites in the collection channel. All fish were recovered at the sampling facility where they were examined for fin clips, descaling, and any other signs of physical injury. Standard descaling criteria used at transportation sites were used for this evaluation (Ceballos et al. 1992).

Adult Migrants

Adult salmonid fall-backs have been monitored at Little Goose Dam during the spring outmigration (Monk et al. 1992) and at Lower Monumental Dam during the fall (Marsh et al. 1996). Both of these bypass systems are operated on a continuous basis, so these evaluations were done with naturally occurring fall-backs as they arrived at the collection facility. The fish were examined, marked, and released into gatewells at each of these projects. When recaptured, the fish were again examined for descaling/injury. Neither of these studies detected any evidence of serious injury problems, but the results of both indicated passage time through the system could vary considerably.

For our evaluation of adult migrants at Ice Harbor Dam, we used hatchery steelhead from the Lyons Ferry Hatchery. These fish had arrived at the hatchery in late summer and were being held for spawning in late fall. We used these fish for the evaluation because the sampling facility at Ice Harbor is not operated on a continuous basis and therefore could not provide a consistent supply of test fish. Also, we wanted to limit the handling of naturally migrating fall chinook salmon adults as much as possible during our evaluation.

The adult steelhead were transported by truck from Lyons Ferry Hatchery to Ice Harbor Dam. At the dam, any external injuries were noted and recorded for each fish as it was marked for identification. The fish were then released into the upper portion of the collection channel (Unit 6). We released 10 adults on 7 and 10 October. We also recorded the condition of naturally migrating adult steelhead fall-backs that were collected at the sampling facility during this portion of the facility evaluation.

Results

Juvenile Migrants

We began operating the sampling facility at 1600 h on 13 April, and operated it continuously through 2200 h on 14 April for a total of 30 hours. We recovered nearly 95% of the test fish. Table 1 shows the marked and recovered numbers for each release group of steelhead and yearling chinook salmon. The recovery rate was lowest for steelhead released at the upper end of the collection channel (84.4%). Each of the other three groups of marked fish were recovered at rates of ≥97%. A lower return rate for one group of steelhead may have resulted from closure of orifices in Unit 5 (this unit was not operated during the sample period). For these steelhead, their downstream movement through the collection channel may have been delayed when they encountered the area of reduced flow near Unit 5. Descaling and mortality were very low for all of the marked fish, with only one fish descaled and one mortality for each species.

Table 1. Numbers of hatchery steelhead and yearling chinook salmon marked at the upper (near Unit 6) or lower (near Unit 1) end of the collection channel, released, and recaptured during the evaluation of the juvenile bypass system at Ice Harbor Dam, 13-14 April 1996.

	Steelhead		Yearling Chinook	
	Upper	Lower	Upper	Lower
Number released	500	500	500	500
Number recovered	422	485	492	499
Percent recovered	84.4	97.0	98.4	99.8
Number descaled	1	0	0	1
Percent descaled	0.2	0.0	0.0	0.2
Number mortalities	1	0	1	0
Percent mortality	0.2	0.0	0.2	0.0

Adult Migrants

We operated the fish sampling facility continuously, beginning at 1200 h on 7 October, and terminating at 1200 h on 22 October. We recovered 15 of the 20 adult steelhead released into the collection channel. The initial recovery occurred just 19 minutes after the first release. However, this fish was dropped (without apparent physical injury) during tagging, which may have contributed to its rapid movement through the bypass system. The final recovery occurred at 1415 h on 15 October (Table 2). The average time from release to recovery was 29.8 hours. Condition of the majority of the recovered fish was considered good, with no new descaling or abrasions. The condition of two fish was judged to be fair, as both fish had minor, new injuries (one was slightly descaled and the other had an abrasion on the nose). Appendix Table 1 lists the incidental salmonid catch for the 15 days we operated the sampling facility during this portion of the evaluation. On 16 December, we recovered three of the five missing adult steelhead from the collection channel when it was dewatered at the end of the fish passage season.

Table 2. Release and recovery data for adult steelhead to evaluate passage through the fish bypass and collection facility at Ice Harbor Dam, October 1996.

Date	Time released	Time recovered	Total hours	Fish condition
7 October	1300	1900	102.0	good
	1300	1830	29.5	good
	1300	0300	14.0	good
	1330	not recovered		
	1330	2200	56.5	good
	1330	1830	5.0	good
	1330	1630	3.0	fair
	1400	2030	6.5	good
	1400	1530	1.5	good
	1400	1420	0.3	good
10 October	1230	not recovered		
	1230	1430	2.0	fair
	1230	not recovered		
	1230	0400	15.5	good
	1300	2020	55.3	good
	1300	not recovered		
	1300	1415	121.3	good
	1300	1700	4.0	good
	1330	2000	30.5	good
	1330	not recovered		

OBJECTIVE 3: MONITOR THE PHYSIOLOGICAL EFFECTS OF THE BYPASS SYSTEM ON JUVENILE SALMONIDS

Approach

The physiological effects of the juvenile bypass system were evaluated by monitoring stress and fatigue indices in naturally migrating yearling chinook salmon and steelhead smolts. The test design consisted of collecting blood samples (15 fish each species) on four separate occasions at three locations within the bypass system: 1) gatewell (baseline levels), 2) pre-sample tank, and 3) pre-separator tank. The samples were then assayed for plasma cortisol, glucose, and lactate.

Sampling at Ice Harbor Dam occurs on an "as needed" basis. On each sampling day, flow must be diverted into the sampling facility. To reduce the possibility of introducing a sampling bias, we used a set procedure for the 4 sample days. At the start of each sample day (0700 h), COE personnel diverted the collection channel flow into the sample facility. This allowed smolts to accumulate in the wet-separator section (as is the general tendency). Personnel from the Washington Department of Fish and Wildlife were contracted to take the blood samples. Around 0900 h, our crew began dipnetting fish from the gatewell and collecting blood samples from this group. When these baseline data were collected, the crew moved to the next sample site, the pre-sample tank, and collected fish with small dip nets after they volitionally exited the wet-separator, just prior to entering the sample tank. The last sample site was the pre-separator tank; small dip nets were used to collect fish as they exited the main sample flume and just before they entered the collection hopper with the underwater separator bars.

After collection, all fish were immediately sacrificed in a 200-mg/L solution of MS-222. This concentration does not significantly alter any of the blood indices being measured (Black and Conner 1964, Strange and Schreck 1978). The caudal peduncle was severed and the blood sample collected with a 0.25-ml ammonium-heparinized capillary tube. Blood samples were centrifuged, the plasma was removed and sealed in plastic vials, and the vials were immediately frozen with dry ice. The blood samples were analyzed at the Oregon Cooperative Fisheries Research Unit, Oregon State University. Thawed plasma was assayed for cortisol using a radioimmunoassay, for glucose using the σ-toluidine method, and for lactate using a fluorimetric enzyme reaction (Barton et al. 1986, Barton and Schreck 1987).

Sample means of the 11 replicates (3 gatewell plus 4 pre-separator and pre-sample tank) were analyzed by randomized block analysis of variance (RBANOVA) with each replicate day considered a block. Significant changes between locations were then examined with Fisher's Protected Least Significant Difference (FPLSD) multiple comparisons technique (Petersen 1985).

Results

Only three sets of gatewell samples were recorded because our initial gatewell sample had insufficient numbers of fish. Mean cortisol, glucose, and lactate levels for the three sample locations at Ice Harbor Dam are shown in Table 3, and results of the RBANOVA are in Table 4. Appendix Table 2 summarizes the individual sample values for all of the sacrificed fish.

No significant differences among locations were found in cortisol, glucose, or lactate levels for yearling chinook salmon or in lactate levels for steelhead, but there were significant differences in cortisol and glucose levels for steelhead. Mean cortisol for steelhead was significantly lower at the gatewell than at the pre-separator or pre-sample tank (101, 166, and 189 ng/ml, respectively). Mean glucose for steelhead was significantly higher at the gatewell than at the pre-separator or pre-sample tank (131, 118, and 112 mg/dl, respectively). One explanation for the interspecies differences in cortisol and glucose levels could be that steelhead may hold in the collection channel longer than yearling chinook salmon. This would tend to increase cortisol and reduce glucose levels for steelhead, but would also result in a subsequent increase in lactate levels. Steelhead did show a general increase in lactate, but it was not a statistically significant change.

Protracted steelhead passage within juvenile fish bypass systems is not uncommon. To date we have no blood chemistry data that suggest a delay of a few hours in the bypass system is harmful to these fish.

Table 3. Mean cortisol, glucose, and lactate levels for steelhead and yearling chinook salmon at sample locations in the new juvenile bypass system at Ice Harbor Dam, May 1996.

	Gatewell	Pre-Separator Tank	Pre-Sample Tank
Steelhead			
Cortisol (ng/ml)	100.7	165.7	189.3
Glucose (mg/dl)	131.1	117.7	112.4
Lactate (mg/dl)	51.3	71.1	65.6
Yearling Chinook			
Cortisol (ng/ml)	141.5	140.2	135.9
Glucose (mg/dl)	105.8	95.0	97.2
Lactate (mg/dl)	54.0	59.1	60.2

Table 4. Results of randomized block analysis of variance comparing mean cortisol, glucose, and lactate levels for steelhead and yearling chinook salmon at locations in the new juvenile bypass system at Ice Harbor Dam, May 1996.

	F	P	FPLSD[a]
Steelhead			
Cortisol	12.23	0.0119	40.2 (ng/ml)
Glucose	9.33	0.0205	10.4 (mg/dl)
Lactate	5.67	0.0518	
Yearling Chinook			
Cortisol	0.07	0.9368	
Glucose	0.19	0.8300	
Lactate	1.36	0.3375	

a Fisher's Protected Least Significant Difference; only shown for significant F-tests.

CONCLUSIONS

1. No areas within the collection channel and pipes were found that could cause serious injury to juvenile salmonid migrants.
2. No evidence of descaling problems was observed at the sample facility.
3. No evidence of serious injury or descaling was found in any of the adult steelhead examined during the evaluation of the juvenile bypass and collection facility.
4. For yearling chinook salmon, there was no significant difference in cortisol, glucose, or lactate levels among fish sampled from the gatewell, pre-separator, or pre-sample tank.
5. For steelhead smolts, cortisol levels were significantly higher and glucose levels significantly lower in fish sample from the gatewell than in fish sampled from the pre-separator or pre-sample tank.

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REFERENCES

Barton, B. A., and C. B. Schreck. 1987. Metabolic costs of acute physical stress on juvenile steelhead. Trans. Am. Fish. Soc. 116:257-263.

Barton, B. A., C. B. Schreck, and L. A. Sigismondi. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile chinook salmon. Trans. Am. Fish. Soc. 115:245-251.

Black, E. C., and A. R. Conner. 1964. Effects of MS-222 on glycogen and lactate levels in rainbow trout. J. Fish. Res. Board Can. 21:1539-1542.

Ceballos, J. R., S. W. Pettit, and J. L. McKern. 1992. Fish Transportation Oversight Team. Annual Report - 1991. Transportation operations on the Columbia and Snake Rivers. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWR-29. 77 p. plus Appendix.

Marsh, D. M., B. H. Monk, B. P. Sandford, and G. M. Matthews. 1996a. Preliminary evaluation of the new juvenile collection, bypass, and sampling facilities at McNary Dam, 1994. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H-0034, 39 p. + Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Marsh, D. M., L. K. Timme, B. P. Sandford, S. Achord, and G. M. Matthews. 1996b. Preliminary evaluation of the new juvenile collection, bypass, and sampling facilities at Lower Monumental Dam, 1994. Annual report of research to the U.S. Army Corps of Engineers, Contract DACW68-84-H-0034, 54 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Matthews, G. M. 1992. Potential of short-haul barging as a bypass release. Unpublished issue paper. 56 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard E., Seattle, WA 98112-2097.)

Monk, B. H., B. P. Sandford, and J. G. Williams. 1992. Evaluation of the juvenile fish collection, transportation, and bypass facility at Little Goose Dam, 1990. Annual report of research to the U.S. Army Corps of Engineers, Contract E86900057, 131 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard E., Seattle, WA 98112-2097.)

Petersen, R. G. 1985. Design and Analysis of Experiments. Marcel Dekker, New York. 429 p.

Strange, R. J., and C. B. Schreck. 1978. Anesthetic and handling stress on survival and cortisol concentration in yearling chinook salmon (*Oncorhynchus tshawytscha*). J. Fish. Res. Board Can. 35:345-349.

APPENDIX TABLES

Appendix Table 1. Identification of fall-back adult salmonids during the evaluation of the new juvenile salmonid bypass system at Ice Harbor Dam, October 1996.

Date	Steelhead	Chinook	Jacks[a]
07 October	3	1	0
08 October	7	2	0
09 October	4	7	0
10 October	3	1	0
11 October	8	1	0
12 October	4	2	0
13 October	7	1	0
14 October	11	2	0
15 October	7	3	2
16 October	11	1	0
17 October	7	0	1
18 October	6	1	1
19 October	4	1	0
20 October	7	3	0
21 October	9	1	0
22 October	1	0	0

[a]In this instance, jacks were one-ocean chinook salmon.

Appendix Table 2. Plasma cortisol, glucose, and lactate levels for migrating yearling chinook salmon and steelhead collected at the new juvenile salmonid bypass system at Ice Harbor Dam, May 1996.

Sample Site	Yearling Chinook Cortisol (ng/ml)	Yearling Chinook Glucose (mg/dl)	Yearling Chinook Lactate (mg/dl)	Steelhead Cortisol (ng/ml)	Steelhead Glucose (mg/dl)	Steelhead Lactate (mg/dl)
First Replicate (7 May 1996)						
Pre-separator tank	117.5	109.5	46.7	188.3	95.0	41.0
	185.9	82.2	60.9	158.1	110.7	34.5
	83.0	68.4	41.6	169.1	87.2	46.2
	112.8	57.2	55.9	179.0	70.7	72.8
	120.0	59.1	53.9	247.3	104.8	63.7
	93.9	101.4	63.8	338.0	340.2	69.4
	106.9	72.9	52.7	228.1	102.3	33.0
	225.1	89.0	70.4	191.9	137.1	61.5
	44.6	69.8	46.7	211.4	105.4	37.9
	137.8	109.9	70.1	98.1	108.9	60.9
	24.9	69.5	44.5	173.8	106.1	61.5
	47.9	76.9	76.1	245.1	131.6	52.7
	131.4	75.8	34.5	143.9	117.7	57.6
	121.3	77.8	46.7	205.1	75.8	84.8
				181.3	72.3	94.8
Pre-sample tank	194.0	99.4	51.9	240.7	106.4	55.6
	218.6	78.3	45.3	145.5	119.4	32.2
	111.6	70.5	38.5	265.1	83.9	56.9
	128.8	84.2	50.4	198.5	77.5	139.4
	123.8	96.6	45.1	194.7	101.6	43.4
	76.9	69.4	48.8	202.2	122.7	56.5
	184.6	81.9	70.3	232.1	76.1	61.9
	152.5	83.3	53.4	228.9	107.2	79.6
	186.7	83.0	53.0	-	146.7	43.0
	192.4	99.8	60.9	126.3	138.4	45.1
	38.2	45.5	44.0	262.7	163.7	52.6
	168.4	87.7	43.6	209.2	92.2	80.7
	28.1	45.5	47.7	190.8	123.2	72.1
	157.2	96.9	57.3	225.9	94.1	96.0
	64.1	100.4	64.6	266.8	107.2	115.5

Appendix Table 2. Continued.

Sample Site	Yearling Chinook Cortisol (ng/ml)	Yearling Chinook Glucose (mg/dl)	Yearling Chinook Lactate (mg/dl)	Steelhead Cortisol (ng/ml)	Steelhead Glucose (mg/dl)	Steelhead Lactate (mg/dl)
Second Replicate (8 May 1996)						
Gatewell	148.6	261.3	55.2	201.1	170.0	36.2
	241.9	139.8	77.1	39.9	114.7	34.8
	190.5	149.9	54.7	175.0	109.9	35.3
	27.8	84.5	50.8	45.1	124.0	51.0
	105.6	109.9	49.7	-	-	-
	14.3	96.7	29.0	-	-	-
	57.7	108.6	25.9	66.3	103.6	39.4
	128.2	83.3	41.1	43.6	113.0	50.4
	77.5	44.9	41.6	101.0	86.0	50.1
	185.9	114.2	43.9	74.3	99.6	35.0
	197.3	110.1	45.1	55.3	106.1	39.1
	149.7	108.0	39.4	199.8	144.2	60.2
	89.0	137.2	51.0	12.0	76.0	51.6
	60.7	98.9	47.9	82.2	133.5	41.6
	60.4	87.1	50.8	87.1	138.5	46.1
				24.3	118.9	56.1
Pre-separator tank	224.8	94.7	52.6	222.4	126.5	129.7
	165.3	86.2	36.5	175.7	147.0	68.8
	147.0	89.1	90.8	196.3	128.8	42.5
	130.7	91.5	59.2	166.4	92.8	61.5
	107.2	93.2	66.1	186.8	124.0	71.7
	150.7	89.0	55.4	155.8	115.9	48.2
	196.0	81.8	60.2	230.8	97.3	49.4
	194.9	71.7	54.6	89.0	113.9	80.0
	196.9	80.7	65.7	196.4	74.2	49.9
	183.5	86.8	41.0	232.1	105.1	41.0
	111.1	73.1	77.3	132.1	138.0	73.8
	128.6	78.6	56.5	195.3	104.2	77.1
	137.9	110.5	62.6	144.9	89.6	52.6
	119.6	114.2	75.3	174.5	139.8	93.8
	198.5	107.6	76.9			
Pre-sample tank	111.5	81.4	71.2	221.4	91.9	66.2
	122.2	106.5	57.5	137.9	104.8	62.9
	94.3	75.2	61.2	177.5	69.2	52.7
	132.3	89.6	50.8	135.6	98.8	109.6
	136.3	76.9	68.1	75.7	110.8	39.8
	99.3	125.1	51.4	187.7	104.9	33.0
	183.1	122.4	73.9	186.3	121.9	39.1
	91.6	96.0	48.3	217.6	109.9	60.9
	349.0	271.3	108.0	187.7	83.9	68.1
	74.7	47.1	68.8	179.2	113.7	109.7
	52.8	67.3	60.5	119.2	120.0	57.8
	135.0	53.7	99.2	213.3	118.1	83.3
	128.6	78.7	54.3	145.9	95.6	36.1
	155.8	93.2	51.1	200.0	122.1	50.4
	152.4	65.4	36.7	175.2	114.6	75.1

Appendix Table 2. Continued.

Sample Site	Yearling Chinook Cortisol (ng/ml)	Yearling Chinook Glucose (mg/dl)	Yearling Chinook Lactate (mg/dl)	Steelhead Cortisol (ng/ml)	Steelhead Glucose (mg/dl)	Steelhead Lactate (mg/dl)
Third Replicate (14 May 1996)						
Gatewell	190.6	93.7	54.5	103.1	95.4	38.8
	148.6	96.6	35.9	126.9	131.8	38.8
	166.6	203.7	70.1	138.5	103.1	38.5
	193.1	125.1	58.6	244.4	88.6	46.5
	180.9	82.5	61.5	163.3	418.2	64.6
	120.1	104.2	38.8	83.5	127.0	67.2
	96.9	99.5	44.2	113.8	104.8	59.5
	170.4	66.5	44.0	200.5	256.1	71.2
	133.7	95.5	42.2	176.9	125.1	45.4
	124.2	138.2	58.4	128.5	177.0	74.4
	116.4	93.7	51.0	62.9	71.7	51.0
	152.2	57.2	49.0	96.8	166.5	79.0
	151.5	110.1	41.8	106.4	108.9	49.0
	181.4	65.3	32.5	88.4	56.6	76.8
	130.5	101.9	46.7	11.7	115.9	59.2
Pre-separator tank	170.0	94.8	65.4	175.4	103.2	50.7
	212.2	80.7	35.4	162.1	137.9	74.8
	133.3	91.2	60.2	190.9	226.1	70.2
	164.5	119.4	56.4	201.5	112.4	56.4
	144.2	88.6	69.2	131.4	89.3	53.9
	162.8	83.3	61.8	137.4	131.6	75.3
	194.6	99.0	64.4	176.9	171.9	88.8
	76.1	90.0	52.7	139.0	125.1	67.5
	96.1	84.6	53.7	183.1	87.4	55.6
	114.8	72.5	55.8	133.6	93.2	94.5
	124.8	84.2	70.0	163.5	113.0	88.1
	119.6	56.1	52.6	129.2	130.4	68.1
	153.4	97.9	61.8	57.6	59.5	61.8
	149.0	104.2	87.5	105.4	99.8	160.6
	90.8	77.2	74.8	93.5	173.2	143.5
Pre-sample tank	198.9	104.8	76.1	132.7	111.8	42.8
	62.0	90.9	73.8	211.1	142.3	50.1
	206.1	69.4	55.4	128.3	123.5	54.9
	141.5	76.9	47.7	198.3	104.3	49.4
	118.4	83.9	51.7	114.2	139.8	50.2
	178.1	114.2	64.3	263.7	124.6	37.9
	152.6	101.9	57.2	170.1	108.2	74.8
	99.5	86.0	61.2	166.4	90.1	43.6
	151.2	119.6	63.9	156.3	94.4	42.8
	81.2	72.9	45.0	233.7	78.0	54.7
	63.0	85.1	69.5	173.4	120.6	109.7
	167.6	65.6	62.1	171.2	88.1	50.2
	153.6	259.2	95.2	163.8	214.5	59.2
	158.4	94.8	80.2	199.8	105.4	108.9
	138.8	76.9	63.8	124.2	106.7	60.9

Appendix Table 2. Continued.

Sample Site	Yearling Chinook Cortisol (ng/ml)	Yearling Chinook Glucose (mg/dl)	Yearling Chinook Lactate (mg/dl)	Steelhead Cortisol (ng/ml)	Steelhead Glucose (mg/dl)	Steelhead Lactate (mg/dl)
Fourth Replicate (15 May 1996)						
Gatewell	202.5	119.4	42.5	118.6	126.5	29.7
	143.1	121.3	62.1	130.3	120.2	31.5
	207.0	118.7	60.9	57.5	104.8	45.3
	156.7	111.8	96.0	154.9	369.3	42.4
	202.9	92.2	50.6	144.1	101.0	37.3
	176.4	87.1	80.7	175.4	307.9	50.3
	179.9	51.9	67.2	90.5	83.3	56.0
	184.3	133.5	53.3	126.9	85.2	41.9
	81.7	121.9	67.5	34.9	130.6	52.7
	105.9	76.3	82.2	28.1	87.2	54.7
	154.0	75.2	74.7	120.1	90.0	65.1
	97.1	51.3	70.3	74.8	93.0	61.2
	63.8	101.3	58.5	54.3	136.0	62.2
	262.4	130.6	64.3	64.2	75.5	76.0
				18.0	86.2	70.1
Pre-separator tank	172.3	100.7	43.6	156.7	163.7	93.9
	157.8	125.9	53.6	58.3	190.3	52.3
	201.7	151.1	53.3	185.9	83.6	73.1
	197.9	164.2	103.4	231.7	186.3	121.0
	19.2	64.3	46.7	167.4	114.6	61.6
	179.8	111.2	75.9	161.1	136.5	58.9
	175.4	197.8	75.1	162.7	91.5	48.0
	223.3	244.1	58.0	214.6	106.7	76.4
	30.4	70.6	49.1	136.2	125.3	107.7
	13.5	110.8	54.7	79.2	136.3	73.5
	225.2	93.8	38.8	155.5	95.0	98.7
	219.8	85.1	36.5	98.2	73.2	66.1
	73.1	102.3	68.9	134.9	77.8	64.6
	220.3	69.9	58.3	70.5	69.9	56.3
	138.9	135.2	60.0	114.0	79.3	122.1
Pre-sample tank	145.4	109.9	60.6	278.5	98.2	73.1
	73.6	107.1	68.8	203.9	168.1	52.0
	199.6	117.5	66.9	173.6	110.8	61.9
	127.1	108.6	57.7	153.8	118.1	59.8
	201.7	105.9	57.5	191.9	100.0	69.4
	114.5	94.2	64.3	203.0	162.5	51.3
	126.1	125.9	50.7	159.1	75.4	82.4
	124.1	117.1	54.5	188.9	146.2	81.3
	34.4	109.2	34.2	225.0	97.3	50.3
	135.9	101.8	52.1	191.8	95.4	33.4
	133.2	93.2	65.8	245.5	141.5	67.2
	159.1	161.8	73.8	224.9	114.2	88.8
	164.7	78.1	65.5	132.8	137.9	104.4
	166.1	110.8	74.8	191.2	97.3	71.0
	130.4	116.5	62.6	221.4	125.9	99.0