Evaluation of Fish Condition with Prototype Vertical Barrier Screens at McNary Dam, 2004

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EXECUTIVE SUMMARY

We began a study in 2004 to evaluate the condition of yearling and subyearling Chinook salmon released into gatewells equipped with prototype vertical barrier screens (VBS) at McNary Dam. The prototype VBSs were designed to operate at turbine loads outside current guidelines, which specify operation within 1% of maximum turbine efficiency, or a discharge loading of approximately 60 MW. Planned improvements to McNary Dam will result in operations at a discharge loading of 80 MW or higher.

Groups of fish tagged with passive integrated transponder (PIT) tags were released into gatewells under the current operation (60 MW) and the higher discharge (80 MW). Fish were then recaptured using the separation-by-code (SbyC) system at the juvenile fish facility, which diverts fish based on PIT-tag code. We examined fish for descaling and injury and compared fish condition between release groups.

However, early in the study period we had to stop evaluations of the VBSs due to apparent increases in descaling and injury to river-run fish observed at the juvenile fish facility under the 80-MW loading. The prototype VBSs were left in place, but the remainder of the spring test period and the entire summer test period was devoted to determining if the injuries were occurring within the gatewell or at some point upstream from the gatewell.

To determine where the descaling had occurred, yearling Chinook salmon were released under both into 1) units operated at 60 and 80 MW loads 2) units operated at both 60 and 80 MW after trash racks had been raked, and 3) A and B slots of units operated at 80 MW. In addition, fish were collected by gatewell dipnetting from the orifice trap on slot 6B during both 60 and 80 MW loads and examined for injury and descaling.

Subyearling Chinook salmon were PIT tagged and released in different locations in the test gatewells to determine if release location affected fish condition. The first release compared the north and south ends of gatewells, while the second release compared the middle and north ends. To determine whether fish condition was being affected upstream from the collection channel (at the guidance screens, gatewell, or VBS), we also collected subyearling Chinook salmon in an orifice trap for examination at both 60 and 80 MW loads.

Results did not indicate a problem with fish condition for yearling Chinook salmon released into any of the gatewells. However, a moderate increase in descaling was noted for yearling Chinook collected in the orifice trap of slot 6B when the unit was operated at 80 MW. A moderate increase in descaling for yearling Chinook salmon was also observed in fish collected by gatewell dip net when the turbine unit had been operated at 80 MW. Taken together, results suggested that the relatively small increase in descaling observed when units operated at 80 MW occurred between the trash racks and deep in the gatewells (prior to fish being exposed to the VBSs).

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INTRODUCTION

Survival of juvenile salmonids that pass through turbines of hydroelectric projects on the Columbia River has long been lower than desired. Other routes past hydroelectric projects, such as spillways and bypass systems, typically provide higher survival rates for these fish. However, improving turbine survival can offer great benefits, especially in low flow years, and studies that estimate turbine survival under current and potential operating conditions need to be undertaken.

This study was conducted as part of the McNary Dam Modernization Program (USACE 2005), and was designed to evaluate bypass system components in anticipation of a planned increased in turbine loading with modernization of the powerhouse. The study also addresses turbine survival, as prescribed by the National Marine Fisheries Service (NMFS) Biological Opinion on Operation of the Federal Columbia River Power System (BiOp; NMFS 2000, Appendix F, Actions 59, 88-90) and by the NMFS Salmon Research Plan (NMFS 2003). It was also part of the U.S. Army Corps of Engineers Turbine Survival Program, initiated as a result of the 1995 NMFS BiOp to quantitatively evaluate juvenile salmonid passage through turbines, with an emphasis on identifying turbine structures and operations responsible for injuring fish.

More specifically, the study was designed to evaluate three prototype vertical barrier screens (VBS) operated at a load of 16,400 ft^3s^{-1} on fish condition. Prototype VBSs were located in the A slots of turbine units 2, 3, and 4 (Figure 1). Slot 2A was equipped with a profile-wire VBS with the wire oriented vertically; slot 3A was equipped with a profile-wire VBS with wire oriented horizontally; and slot 4A was equipped with a full-length traveling mesh VBS. All slots used after the study design was altered to evaluate descaling equipped with standard mesh VBSs (slots 3B, 5A, and 5B).

There were two objectives for this study. The first was to evaluate the effects of the newly designed VBSs on the condition of steelhead, yearling Chinook, and sockeye salmon released into gatewells of turbine units operated above 1% peak efficiency. These turbine units were operated at a load of approximately 80 megawatts (MW) which is about 16,400 ft^3s^{-1}. The second objective was to repeat the evaluation with subyearling Chinook salmon during summer.

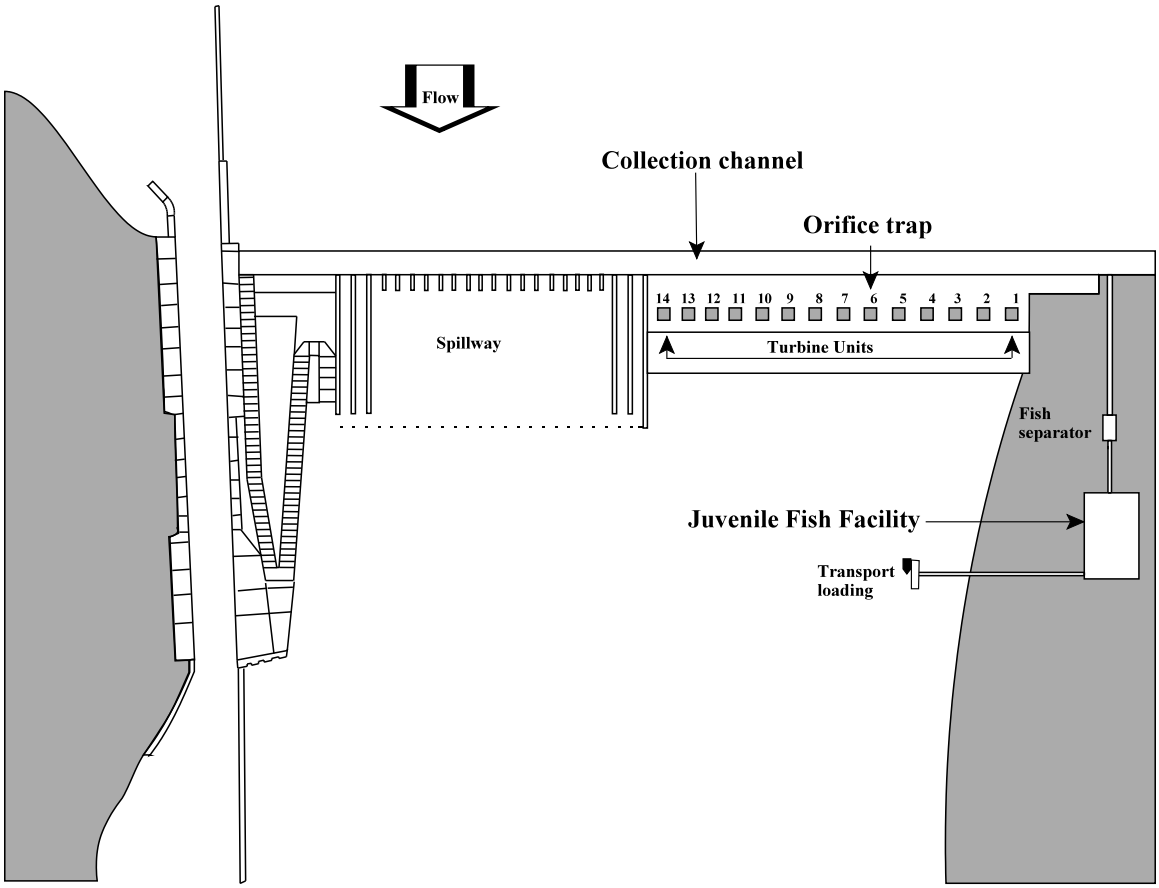

Figure 1. Overhead view of McNary Dam showing approximate locations of turbine units 2, 3, 4, and 5; orifice trap at unit 6; collection channel; and the juvenile fish facility (JFF).

OBJECTIVE 1: Evaluate the Effects of Three Prototype Vertical Barrier Screens on the Condition of Yearling Chinook Salmon

Methods

We evaluated three prototype vertical barrier screens and their effects on fish condition with turbine units operating above 1% peak efficiency. To accomplish this, we released groups of PIT-tagged yearling Chinook salmon *Oncorhynchus tshawytscha* into gatewells and recaptured them using the separation-by-code (SbyC) system at the McNary Dam juvenile fish facility (JFF).

The test units were operated in a randomized two-day block design to accommodate the requirements of other studies. In addition, the JFF was in primary bypass on odd-numbered days, so we could only recapture study fish on even-numbered days. Due to these restrictions, we were able to release groups of test fish only on approximately every fourth day.

Fish Collection, Tagging, and Release

We collected fish for tagging by dipnetting the gatewells (Swan et al. 1979) at McNary Dam (Figure 2). We selected yearling Chinook salmon that were not injured or descaled at the time of collection for tagging. This allowed us to positively identify any descaling or injury as having occurred as a result of the test conditions.

After PIT tagging, fish were routed to a tank and held overnight. All other juvenile salmonids were routed to a recovery tank and allowed to recover from the anesthetic before being released back into a gatewell. Equal numbers of fish were tagged into each of the required number of tanks. Prior to release, the holding tanks were examined, and any loose tags and mortalities were removed.

Fish were released in the morning into the selected gatewells using a canister designed specifically for release of fish into gatewells (Absolon and Brege 2003). Fish were recaptured using the SbyC system at the McNary Dam JFF. Recaptured fish were anesthetized and examined for injury and descaling. Descaling was estimated according to Standard Fish Transport Oversight Team (FTOT) descaling criteria (Ceballos et al. 1993), with a fish that was missing at least 20% of the scales on at least one side considered descaled. After reexamination, fish were allowed to recover from anesthesia and then returned to the river.

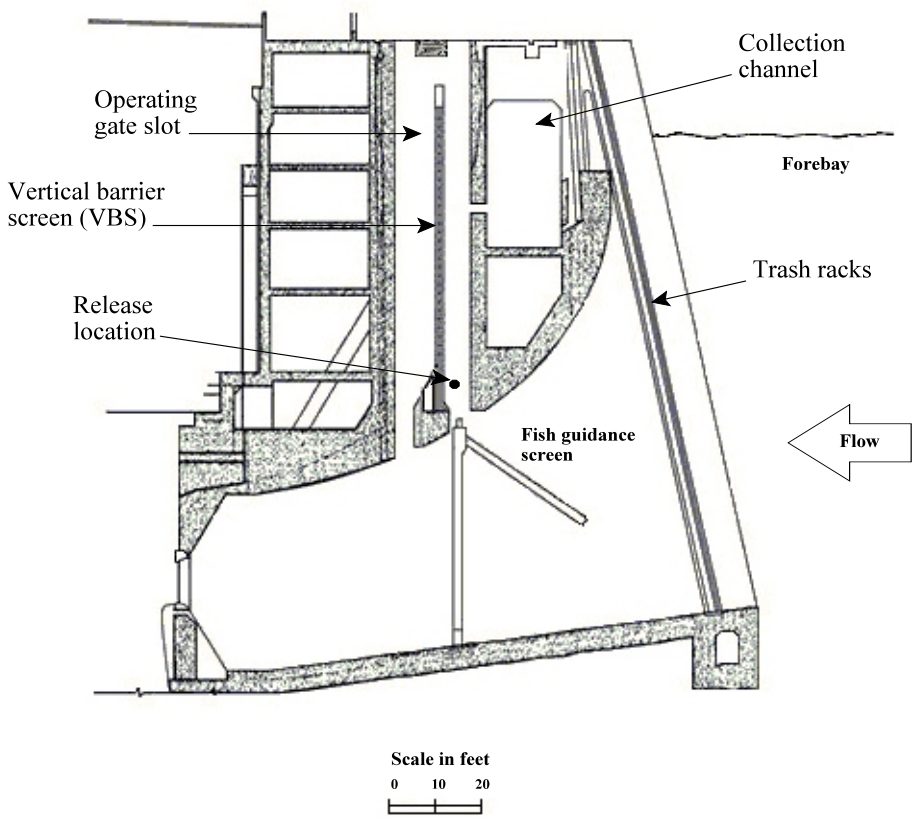

Figure 2. Cross-section of McNary Dam showing approximate location of the vertical barrier screens (VBS), gatewell release location, guidance screen, and trash racks.

Differences in descaling and injury between groups released into each location were noted. In addition, gatewell residence times were compared in 10-percentile increments among groups using a paired *t*-test (i.e., the 10th through 90th percentiles were compared).

Evaluations of River-Run Fish

In addition to collecting fish for the PIT-tag release groups to evaluate the prototype VBSs, we collected river-run fish by dip net from gatewells to evaluate the condition of juvenile salmonids exposed to the gatewell under the 80-MW operating level. To accomplish this, the turbine unit was operated for at least 12 hours at the 80-MW load prior to dipnetting.

Just prior to dipping the gatewells, unit load was reduced to 60 MW, and the gatewell orifice was closed. The gatewell was then fished three to four times by dip net to capture as many fish as possible. As soon as dipnetting was completed, the orifice was opened, and the unit load was returned to 80 MW. Collected fish were then anesthetized and examined for descaling and injury using standard FTOT criteria. After examination, fish were allowed to recover from anesthesia and were then released into a gatewell.

A gatewell orifice trap, which was located on the south orifice of gatewell slot 6B (McComas et al. 1997), was also used to collect run-of-river fish for evaluation at both the 60- and 80-MW loads. The orifice trap was operated three to four times during the 2-day period that turbine unit 6 was operated at each load. Typically, this occurred in mornings and evenings for the length of time necessary to either collect at least 200 fish or up to 4 hours of operation.

As fish were collected, they were anesthetized and examined. After examination, fish were allowed to recover from the anesthesia before being released into the collection channel. When it was determined that a sufficient number of fish had been collected, the orifice trap was closed as the north orifice was reopened. All remaining fish were examined for descaling and injury.

Results and Discussion

Releases were made with PIT-tagged yearling Chinook salmon from 24 April through 18 May. The median length of tagged fish was 145 mm, ranging from 104 to 216 mm. The JFF was operated on even-numbered days, starting at 0700 PDT and ending at the same time the following day. Our releases were made at about 0900 on the days the JFF was being operated. We were unable to recapture many of the test fish because they exited the powerhouse more than about 22 h after release, when the facility had been switched to primary bypass. Some additional fish were not recaptured because they were either not detected by the SbyC detectors, were missed by the SbyC gate, or exited through the adult passage route.

Releases at 60 and 80 MW

The first releases were made on 24 April into slots 2A, 3A, and 4A, with those units running at 80 MW. These releases were followed by a release on 28 April into slots 2A, 3A, 4A, and 5A operating at 80 MW. Releases in all slots were made at a depth of approximately 35 ft (10.7 m). This did not allow fish to be exposed to the full length of the prototype VBSs. However, we were unable to release fish deeper than 35 ft because cables had been placed in slot 4A for another study: we were concerned that our release frame could catch on the cables and either hang up the frame or break the cables. We were also concerned with disturbing the power and pendant cables for the extended-length submersible bar screen (ESBS). The first two releases were made with the units operated at 80 MW. We saw little descaling or mortality for the fish we reexamined (Table 1).

During the 2-day block when units were operated at 80 MW for our first two releases, increased descaling and mortality were observed in river-run fish at the JFF. This caused suspension of the 80-MW operation until the situation could be discussed within regional management agencies, and the likely cause determined and corrective action taken.

While this process was occurring, we released fish into units operated at 60 MW. Releases were made into slots 2A, 3A, 4A, and 5A on 4 May, with turbine units operated at 60 MW. We again saw little descaling or injury during these tests (Table 2).

Table 1. Release and recapture data for initial gatewell releases of yearling Chinook salmon into turbine units operated at 80 MW.

Release		Number of fish					
Date	Slot	Released	Detected[a]	Reexamined	Minor descaling[b]	Descaled	Mortality
24 April	2A	200	200	152	15	0	0
	3A	195	165	161	9	3	1
	4A	153	150	119	7	1	2
28 April	2A	97	97	63	2	0	5
	3A	146	146	111	5	1	0
	4A	149	146	124	13	2	3
	5A	93	91	68	2	0	1

a Number detected are those fish detected at the full-flow PIT-tag detectors, indicating the fish left the powerhouse.
b Number of fish recorded having minor descaling are those fish that were descaled more than 3% but less than 20% on at least one side.

Table 2. Release and recapture data for gatewell releases of yearling Chinook salmon into gatewells of turbine units operated at 60 MW.

Release		Number of fish					
Date	Location	Released	Detected[a]	Reexamined	Minor descaling[b]	Descaled	Mortality
4 May	2A	150	149	118	5	1	1
	3A	151	151	136	8	1	0
	4A	151	148	133	6	0	2
	5A	151	151	100	1	0	1

a Number detected are those fish detected at the full flow PIT tag detectors, indicating the fish left the powerhouse.
b Number of fish recorded having minor descaling are those fish that were descaled more than 3% but less than 20% on at least one side.

Effect of Debris Removal from Trash Racks (at 60 and 80 MW)

During the time that operations at 80 MW were suspended, trash racks were raked on the test units, and a large amount of debris was removed from nearly all of them (Brad Eby, U.S. Army Corps of Engineers, personal communication). It was decided that two of the four test units could operate at 80 MW so that testing could continue, and the removal of debris from the trash racks would minimize potential negative impacts to migrating juvenile salmonids. The next releases were made on 8 May into slots 3A and 5A operated at 80 MW and slots 2A and 4A operated at 60 MW. As occurred during previous releases, descaling and injury rates were low for all of these releases (Table 3).

Table 3. Release and recapture data for gatewell releases of yearling Chinook salmon into gatewells of turbine units 2 and 4 operated at 60 MW and turbine units 3 and 5 operated at 80 MW.

Release		Number of fish					
Date	Location	Released	Detected[a]	Reexamined	Minor descaling[b]	Descaled	Mortality
8 May	2A	149	147	107	1	0	0
	4A	150	150	124	1	2	0
	3A	150	148	107	3	0	0
	5A	152	151	107	4	0	4

a Number detected are those fish detected at the full flow PIT tag detectors, indicating the fish left the powerhouse.

b Number of fish recorded having minor descaling are those fish that were descaled more than 3% but less than 20% on at least one side.

Evaluation of Gatewell B Slots

Since we had not observed high descaling or mortality in any of the gatewell releases to this point (all releases had been to the A slots), we considered that the descaling and mortality seen at the JFF may have resulted from fish passing through the B slots of units operated at 80 MW. In turbines at McNary Dam, the A slots have the highest flow and water velocity, so it is assumed that these slots present the "worst case" hydraulic conditions for fish among the A, B, and C gatewell slots associated with each turbine unit. Our releases on 14 May were made in the A and B slots of units 3 and 5.

We also released these fish at a depth of approximately 50 ft (15.2 m) in an attempt to determine if the injuries seen at the juvenile facility resulted from conditions deeper in the gatewell. The greater release depth was possible in slots 3A and 5A because they had fewer cables than slot 4A, so that our release frame was not as likely to become entangled with cables at the 50-ft depth. However, descaling and mortality did not differ markedly for fish released into the A and B slots of either turbine unit 3 or 5 (Table 4).

Table 4. Release and recapture data for gatewell releases of yearling Chinook salmon into the A and B slots of turbine units 3 and 5.

Release		Number of fish					
Date	Location	Released	Detected[a]	Reexamined	Minor descaling[b]	Descaled	Mortality
14 May	3A	148	148	134	4	0	0
	3B	151	146	116	8	1	4
	5A	152	151	138	3	1	1
	5B	148	148	137	1	0	0

a Number detected are those fish detected at the full-flow PIT-tag detectors, indicating the fish left the powerhouse.

b Number of fish recorded having minor descaling are those fish that were descaled more than 3% but less than 20% on at least one side.

We released fish on 18 May into the same gatewells under the same operating conditions as on 14 May, but this replicate was compromised by the necessity to clean the VBSs in slots 3B, 5A, and 5B about 6 hours after fish were released. The results of this release are shown in Table 5. The numbers of fish detected and reexamined were both lower in some cases than had occurred in previous releases because the VBSs were raised for cleaning, which allowed fish to escape through the turbine units. Descaling and mortality rates were again low for the fish we were able to recapture and examine.

Table 5. Release and recapture data for gatewell releases of yearling Chinook salmon into the A and B slots of turbine units 3 and 5.

Release		Number of fish					
Date	Location	Released	Detected[a]	Reexamined	Minor descaling[b]	Descaled	Mortality
18 May	3A	147	146	109	6	0	0
	3B	151	130	95	2	1	0
	5A	149	144	106	5	0	0
	5B	150	150	130	4	0	0

a Number detected are those fish detected at the full flow PIT tag detectors, indicating the fish left the powerhouse.

b Number of fish recorded having minor descaling are those fish that were descaled more than 3% but less than 20% on at least one side.

Passage Timing

We analyzed the elapsed time it took fish to travel from release in the gatewells to detection at the full-flow detectors between groups released into units operating at 80 vs. 60 MW (Table 6). No difference in travel times were observed for groups released under the two operating conditions (Table 7).

Table 6. Yearling Chinook salmon travel times (in days) from point of release to detection at the full-flow PIT-tag detectors for releases at 80 and 60 MW.

Release		Number of fish		Passage percentile		
Date	Location	Released	Detected[a]	10th	50th (median)	90th
80 MW						
24 April	2A	200	200	0.106	0.405	1.639
	3A	195	195	0.030	0.279	1.095
	4A	153	150	0.035	0.401	1.435
28 April	2A	97	97	0.039	0.653	3.324
	3A	146	146	0.015	0.434	1.747
	4A	149	146	0.008	0.033	0.380
	5A	93	91	0.091	0.488	2.449
8 May	3A	150	148	0.061	0.452	3.197
	5A	152	151	0.177	0.581	2.968
14 May	3A	148	148	0.055	0.294	1.217
	3B	151	146	0.170	0.549	4.270
	5A	152	151	0.122	0.378	0.823
	5B	148	148	0.011	0.163	1.017
18 May	3A	147	146	0.118	0.343	1.592
	3B	151	130	0.252	0.392	2.076
	5A	149	144	0.137	0.346	2.276
	5B	150	150	0.034	0.260	0.949
Mean				0.086	0.379	1.909
60 MW						
4 May	2A	150	149	0.065	0.436	2.351
	5A	151	151	0.096	0.519	2.054
	3A	151	151	0.046	0.356	1.375
	4A	151	148	0.050	0.469	1.673
8 May	2A	149	147	0.061	0.875	3.339
	4A	150	150	0.109	0.391	1.709
Mean				0.071	0.507	2.083

Table 7. Statistical comparison of travel time percentiles between yearling Chinook salmon released in gatewells at 80 vs. 60 MW.

	Percentile arriving at full-flow detectors								
	10	20	30	40	50	60	70	80	90
					80 MW				
Mean	0.086	0.166	0.239	0.306	0.379	0.500	0.707	1.071	1.909
SE	0.017	0.021	0.026	0.031	0.037	0.056	0.098	0.144	0.254
Min	0.008	0.011	0.018	0.026	0.033	0.051	0.109	0.162	0.380
Max	0.252	0.284	0.397	0.482	0.653	1.043	1.579	2.287	4.270
					60 MW				
Mean	0.071	0.156	0.228	0.351	0.507	0.677	0.961	1.294	2.083
SE	0.011	0.028	0.026	0.028	0.077	0.128	0.248	0.257	0.286
Min	0.046	0.073	0.139	0.244	0.356	0.433	0.478	0.758	1.375
Max	0.109	0.269	0.312	0.439	0.875	1.117	2.027	2.479	3.339
t	0.746	0.285	0.316	1.073	1.501	1.265	0.950	0.757	0.455
df	21	21	21	21	21	21	21	21	21
p	0.464	0.779	0.755	0.296	0.148	0.220	0.353	0.458	0.654

Gatewell and Orifice Evaluations

Because the release of PIT-tagged fish on 18 May was compromised by the cleaning of the VBSs, it was decided to dipnet gatewells to evaluate the condition of river-run fish after the turbine units had been running at 80 MW. We dipnetted gatewell slots 5A and 5B on the evening of 18 May, after turbine unit 5 had been operating at 80 MW for about 12 h. We also dipnetted slots 3A, 5A, and 5B on the morning of 19 May, after turbine units 3 and 5 had been operating at 80 MW for about 26 h. The combined descaling was 5.8% for yearling Chinook salmon for this effort. Results for all river-run juvenile salmonids collected and examined on these dates are shown in Table 8.

The last evaluation conducted with yearling Chinook salmon was the operation of the orifice trap located on the south orifice of slot 6B. The trap was operated periodically on 24 and 25 May while the unit was operating at 60 MW and on 26 through 28 May with the unit operated at 80 MW. The trap was operated up to 4 h or until at least 200 yearling Chinook salmon were collected. Descaling was consistently about twice as high when the unit was operated at 80 MW (Table 9).

Because of the descaling and injury problems encountered at the JFF during the initial spring tests and the resultant changes in the study design in an attempt to isolate the problem, we were unable to evaluate the three prototype VBSs as proposed. The cumulative results of the different evaluations we conducted indicated that the descaling and injury seen at the JFF occurred prior to the fish arriving at our release location in the gatewells.

Table 8. Condition of river-run juvenile salmonids dipnetted under 80 MW load for river-run juvenile salmonids dipnetted.

	Yearling Chinook		Subyearling Chinook		Steelhead		Coho		Sockeye	
Slot	Desc*	Normal	Desc	Normal	Desc	Normal	Desc	Normal	Desc	Normal
					18 May					
5A	85	1,233	4	25		19		20	33	144
5B	11	196		1		2		2	1	20
					19 May					
3A	72	1,000	1	22	1	38	5	165	38	150
5A	28	576	2	3	1	14	2	47	18	118
5B	24	537		22		13		58	42	189

*Abbreviation: Desc = descaled.

Table 9. Descaling results for yearling Chinook salmon collected with the orifice trap in Slot 6B.

Date	Time	Load (MW)	Number of fish examined	Percent descaled
24 May	1905-2300	60	131	2.3
25 May	0815-1200	60	74	4.1
	1815-2300	60	189	2.6
		Totals:	394	2.8
26 May	1900-2100	80	136	5.1
27 May	0805-0900	80	274	6.9
	1702-1715	80	492	5.7
28 May	0813-0933	80	367	7.9
		Totals:	1,269	6.5

OBJECTIVE 2: Evaluate the Effects of Three Prototype Vertical Barrier Screens on the Condition of Subyearling Chinook Salmon

Methods

Evaluations of the prototype VBSs with subyearling Chinook salmon followed a course similar to that encountered during spring testing. For evaluation of the VBS, we had proposed to release fish into units operating at 80 MW and to operate the orifice trap at 80 MW, but permission for this plan could not be obtained, and all plans to release fish under the 80 MW load were abandoned. All subyearling Chinook salmon evaluations were conducted with the test units operated at 60 MW. The prototype VBSs were left in place, but releases were made primarily in an attempt to isolate the location where injury and descaling had occurred in river-river run fish seen at the JFF the previous spring.

The first evaluation we conducted during the summer test period was to isolate the effects of the orifice trap. The trap was operated for up to three hours or until at least 200 fish were collected. As fish were being collected, they were periodically examined for descaling and injury. After examination, they were allowed to recover from the anesthesia before being released into the collection channel. At the conclusion of each collection period, all remaining fish were examined for descaling and injury.

PIT-tag releases were also made to evaluate different horizontal release locations in the gatewell. The frame that we used to hold the release canister was modified to allow placement of the canister toward either the end of the frame. By rotating the frame, releases could be made at either end of the gatewell. We were able to make one release to compare the north and south ends of the gatewell and another to compare the middle to the north end of the gatewell.

The evaluations comparing gatewell release locations were conducted by PIT tagging run-of-river subyearling Chinook salmon collected by gatewell dipnetting, as had been done with yearling migrants in spring. Only fish with very little to no descaling were PIT tagged.

During “summer-like” conditions, the JFF is operated differently than in spring. As a result, we were unable to use the B side of the SbyC system to recapture our tagged study fish due to the necessity of having to use the flume during barge loading periods; hence, we were limited to recapturing about half as many of our tagged fish as was possible during spring testing.

Results and Discussion

The orifice trap was operated at 60 MW on 9, 10, 15, and 16 June. Little descaling or injury was observed (Table 10). Plans to operate and test the orifice trap at 80 MW on 17 and 18 June were dropped after regional agreement could not be reached on this issue.

We made the first releases of PIT-tagged subyearling Chinook salmon into slots 3A and 5A into both the north and south ends of each slot on 1 July. On 7 July, PIT-tag releases were made into the middle and north ends of slots 3A and 5A. The median fork length of tagged fish was 88mm, ranging from 68 to 128 mm. No descaling was noted in any of the release groups, and mortality was un-remarkable given the relatively small sample sizes (Table 11).

A meaningful evaluation of the prototype VBSs on the condition of subyearling Chinook salmon could not be accomplished this summer due to the problems encountered during the spring evaluation. A very limited evaluation of different release locations in gatewells was attempted; however JFF operation procedures during the summer resulted in the recapture of relatively low numbers of study fish and little information was therefore gained. Further testing of the prototype VBSs on subyearling Chinook salmon are necessary and planned for 2005. We will use a modified study design to avoid repeating the problems encountered this year.

Table 10. Descaling results for subyearling Chinook salmon collected with the orifice trap in slot 6B.

Date	Time	Load (MW)	No. examined	Percent descaled
9 June	0915-1215	60	210	2.9
	1715-1730	60	730	1.6
10 June	0815-1115	60	52	0.0
15 June	1815-2200	60	116	2.6
16 June	0805-1130	60	108	1.9
	1710-2010	60	396	4.8
Totals			1,612	2.6

Table 11. Descaling and mortality results for subyearling Chinook salmon PIT-tagged released into gatewells at McNary Dam during summer 2004.

Release date	Release location	No. released	No. reexamined	Descaling (%)	Mortality (%)
1 July	3A-north	200	71	0.0	5.6
	3A-south	198	57	0.0	3.5
	5A-north	192	44	0.0	0.0
	5A-south	203	62	0.0	1.6
7 July	3A-north	202	68	0.0	0.0
	3A-middle	204	75	0.0	1.3
	5A-north	205	69	0.0	1.4
	5A-middle	205	78	0.0	0.0

CONCLUSIONS AND RECOMMENDATIONS

1. The overall condition of PIT-tagged yearling Chinook salmon released into gatewells operated at 80 MW does not appear to be markedly different than that of fish released at 60 MW; however limited replication was accomplished during this study year.

2. Travel time for each 10th percentile from point of release to detection at the full-flow PIT-tag detectors was similar for yearling Chinook salmon released at 60 and 80 MW.

3. A vigorous evaluation of the effects on fish condition prototype VBSs in gatewells of turbines operated at 80 MW load needs to be undertaken with yearling and subyearling Chinook salmon.

4. A similar evaluation should also be undertaken with juvenile steelhead and sockeye salmon.

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