Effects of Turbines Operating at Two Different Discharge Levels on Survival and Condition of Yearling Chinook Salmon at McNary Dam, 2002

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Report of research by

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201 North 3rd
Walla Walla, Washington 99362-1876
Contract W68SBV20655422

December 2003

EXECUTIVE SUMMARY

Survival of juvenile salmonids passing 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 juvenile salmonids. However, improving turbine survival can offer great benefits, especially in low flow years. Studies which estimate turbine survival under current and potential operating conditions need to be undertaken.

This study addresses turbine survival issues described in the National Marine Fisheries Service (NMFS) biological opinion and NMFS salmon research plan and is part of the U.S. Army Corps of Engineers Turbine Survival Program. There were two objectives of this study. The first was an initial evaluation of the condition of fish exposed to the gatewell environment at an operating load above the 1% peak efficiency band (16,400 ft^3/sec). PIT tags were used for evaluations under this objective because of the number of fish required and the capability to recapture PIT-tagged fish at the juvenile fish facility. The second objective was a relative survival evaluation comparing survival of fish released at an operating load of 11,200 ft^3/sec (within 1% of peak efficiency) to fish released at an operating load of 16,400 ft^3/sec. This evaluation was conducted with surgically-implanted radio tags to minimize the number of fish required to obtain statistical precision.

Initial evaluation of the gatewell conditions was conducted with hatchery yearling chinook salmon *Oncorhynchus tshawytscha* obtained from Leavenworth National Fish Hatchery. Four replicates of 300 fish per group were PIT tagged, and paired releases were made into Gatewell Slots 9B and 8B. Turbine Unit 9 was operated at 16,400 ft^3/sec, while Turbine Unit 8 was operated at 11,200 ft^3/sec. No differences in fish condition were found between fish released to the two gatewell environments.

We used radiotelemetry to evaluate the relative survival of run-of-river yearling chinook salmon passing through Turbine Unit 9 at McNary Dam under the two operating conditions of 11,200 and 16,400 ft^3/sec. Test fish were collected for this study at the McNary Dam juvenile fish facility, held for 24 h, and surgically tagged with a radio tag and a PIT tag. Test fish were held for an additional 24 h to monitor post-tagging mortality and tag loss. Three telemetry receivers and air antenna transects were used to detect radio-tagged fish as they migrated downstream.

Telemetry transects were located at Irrigon, East Crow Butte, and West Crow Butte, and were approximately 15, 41, and 46 km downstream from McNary Dam, respectively. PIT-tag detections of radio tagged fish at John Day and Bonneville Dams provided additional information.

Relative survival was estimated for releases through the turbine and from a site 2-km downstream from the tailrace of McNary Dam. Point estimates of relative survival were 85.5% (SE = 0.011) at a discharge rate of 16,400 ft^3/sec and 87.3% (SE = 0.013) at a rate of 11,200 ft^3/sec. We conclude that there was no difference in survival through Turbine Unit 9 when operated at 16,400 or 11,200 ft^3/sec.

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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. While other passage routes, such as spillways and bypass systems, typically result in higher survival rates for juvenile salmonids, improving turbine survival can offer great benefits, especially in low flow years such as 2001. Studies which estimate turbine survival under current and potential operating conditions need to be undertaken.

This study addresses turbine survival as prescribed by the National Marine Fisheries Service (NMFS) biological opinion on operation of the Federal Columbia River Power System (NMFS 2000, Appendix F, actions 59, 88-90) and the National Marine Fisheries Service Salmon Research Plan (NMFS 2003). This was part of the U.S. Army Corps of Engineers Turbine Survival Program, initiated as a result of the 1995 NMFS biological opinion to quantitatively evaluate juvenile salmonid passage through turbines with an emphasis on identifying turbine structures and operations responsible for injury to fish.

This study was conducted to evaluate total turbine mortality, including direct mortality associated with turbine passage and indirect mortality associated with possible delayed affects of turbine passage such as disorientation and an increased susceptibility to predation that may affect the longer term survival of fish. A concurrent balloon-tag study was conducted to evaluate direct turbine mortality and the causal mechanisms for mortality and injury (Normandeau Associates et al. 2003). There were two objectives for this study.

The first was an initial evaluation of the condition of fish exposed to the gatewell environment at an operating load (16,400 ft^3/sec) above the 1% peak efficiency band. PIT tags were used for this objective because of the number of fish required for statistical precision in the evaluation and because of the capability to recapture PIT-tagged fish at the juvenile fish facility.

The second objective was a relative survival evaluation comparing survival of fish released at an operating load of 11,200 ft^3/sec to fish released at an operating load of 16,400 ft^3/sec. This evaluation was conducted with surgically-implanted radio tags to minimize the number of fish required to obtain statistical precision.

OBJECTIVE 1: Evaluation of Gatewell Fish Condition under Two Turbine Operating Levels

Methods

To determine if gatewell conditions were detrimental to juvenile salmonids when turbines were operated outside peak efficiency, we released one group of yearling chinook salmon *Oncorhynchus tshawytscha* into a gatewell at McNary Dam with the turbine operated at 16,400 ft^3/sec and another group with the turbine operated near 11,200 ft^3/sec (within 1% of peak efficiency). Hatchery yearling chinook salmon were obtained from Leavenworth National Fish Hatchery and held in a transport tank supplied with flow-through river water prior to tagging. Test fish ranged from 95 to 192 mm in length (median 121 mm).

Paired groups of 300 fish each were tagged with passive integrated transponder (PIT) tags prior to release. Tagged fish were held 20 h to recover from the effects of anesthesia and to monitor potential tagging mortality. Fish were transferred from the holding tank to a release canister (Absolon and Brege 2003) shortly before release. The fish were released in the center of the gatewell slot approximately 9.1 meters (30 feet) below water level. Four paired releases were made into Gatewell Slot 9B, operating at 16,400 ft^3/sec, and Slot 8B, operating near 11,200 ft^3/sec (within 1% of peak efficiency). All releases were made in the morning between 0700 and 0800.

The separation-by-code capability of the PIT-tag monitoring equipment at the juvenile fish facility was utilized to recapture tagged fish. Additional fish were recaptured in the smolt monitoring sample. Recaptured fish were examined for signs of descaling or injury using Fish Transportation Oversight Team criteria (Ceballos et al. 1993), wherein fish are classified as descaled when cumulative scale loss is 20% or more on one side of the body. After examination, all fish were allowed to recover from the anesthesia prior to release into the river.

Differences in descaling and injury between fish released into Gatewell Slot 9B at 16,400 ft^3/sec and those released into Slot 8B operating within 1% of peak efficiency (near 11,200 ft^3/sec) were noted. In addition, gatewell residence times were compared between the two release groups. Statistical analysis of gatewell residence times was done with a paired *t*-test for each 10-percentile increment (10th-100th percentile) of gatewell residence time.

Detections of study fish at downstream sites that were not recaptured at McNary Dam provided evidence that these fish survived passage through the project. Detection sites downstream included John Day and Bonneville Dams and the surface-trawl detection system in the estuary (Ledgerwood et al. 2003).

Results and Discussion

Fish were released from 11 to 15 April and recaptured from 11 to 18 April. Of the 1,202 fish released into Gatewell Slot 9B, 1,090 were re-examined, and of the 1,180 fish released into Gatewell Slot 8B, 1,070 were re-examined. We observed descaling (≥ 20% descaled on either side of fish body) on a total of two fish (0.2%) released into Gatewell Slot 9B and three fish (0.3%) released into Gatewell Slot 8B. A total of 12 fish released into Gatewell Slot 9B had minor levels of descaling (< 20% of body) and 10 fish released into Gatewell Slot 8B had minor levels of descaling. We observed eye injury (popeye) on one fish from each slot. Two fish from Gatewell Slot 9B and three fish from Gatewell Slot 8B were dead when recaptured.

In this evaluation with hatchery yearling chinook salmon, we found no differences in fish condition between fish released into the two test gatewells. Descaling rates were low for fish released in both gatewells. Numbers of fish with minor descaling, other injuries, and mortalities were low and very similar for fish released into both gatewells.

These results differed from descaling test results of the vertical barrier screen (VBS) conducted in 1997, when significantly higher descaling rates were noted for run-of-river yearling chinook salmon released at a load of 16,000 ft^3/sec than fish released at 12,000 ft^3/sec with both the existing VBS and a test VBS (Brege et al. 1998).

A total of 222 fish were not re-examined after release into gatewell slots. Of these, 14 were not detected at any downstream site after release. Six of these fish had been released into Gatewell Slot 8B and eight into Gatewell Slot 9B. Of the remaining 208 fish, 79 were detected at a downstream site or at detectors (full-flow detectors) on the large-diameter juvenile fish transport pipe located 77.7-98.7 m downstream from the powerhouse (Axel et al. 2003). These detections indicated that these 79 fish did leave the gatewell and bypass system, but were not detected at the juvenile fish facility. They (Gatewell Slot 9B, n = 53; Gatewell Slot 8B, n = 26) probably exited the bypass system during periods of primary bypass.

The remaining 129 fish (Gatewell Slot 9B, n = 51; Gatewell Slot 8B, n = 78) were observed by at least one of the PIT-tag detectors at the juvenile fish facility, but were not recaptured. They were either missed by the separation-by-code slide gates, observed only at the exit coils, or exited the powerhouse after diversion ended on 18 April.

Travel time was estimated from time of release in the gatewell to time of detection at the full-flow detection system. Median travel time for fish released into Gatewell Slot 9B (operated at 16,400 ft^3/sec) was 0.58 h, and travel time ranged from 0.07 to 136.6 h. Median travel time for fish released into Gatewell Slot 8B (operated within 1% of peak efficiency) was 18.7 h and ranged from 0.02 to 276.0 h (Table 1).

Neither turbine unit was operated continuously during the study period, which may have affected travel time. Differences in orifice passage efficiency (OPE) may also explain some of the differences between the two operating conditions. Significantly higher OPE was noted for yearling chinook salmon released into slots operated at 16,000 ft^3/sec compared to those operated at 12,000 ft^3/sec in 1997 (Brege et al. 1998). A turbine unit bias may have also been a factor in the differences. Unit bias was observed in a 2001 study of gatewell residence time in subyearling chinook salmon (Axel et al. 2002).

Table 1. Gatewell residence time percentiles for PIT-tagged hatchery yearling chinook salmon released into Gatewell Slots 8B and 9B at McNary Dam, 2002.

Release	Percentile								
Date	10	20	30	40	50	60	70	80	90
					Gatewell Slot 8B				
4/11	0.002	0.313	0.910	0.941	1.082	1.701	1.885	2.404	3.158
4/12	0.048	0.414	0.650	0.778	0.919	1.388	1.677	2.020	2.342
4/13	0.118	0.243	0.420	0.528	0.541	0.579	0.633	0.867	1.280
4/15	0.043	0.221	0.406	0.538	0.634	0.868	0.968	2.296	3.362
Mean	0.053	0.298	0.597	0.696	0.794	1.134	1.290	1.897	2.535
					Gatewell Slot 9B				
4/11	0.004	0.004	0.006	0.007	0.009	0.011	0.021	0.029	0.044
4/12	0.004	0.005	0.006	0.007	0.011	0.028	0.040	0.048	0.056
4/13	0.004	0.008	0.012	0.017	0.081	0.190	0.473	0.796	1.932
4/15	0.006	0.013	0.068	0.090	0.114	0.155	0.194	0.213	0.274
Mean	0.005	0.007	0.023	0.030	0.054	0.096	0.182	0.272	0.576
					Difference				
4/11	-0.002	0.309	0.904	0.934	1.073	1.690	1.864	2.375	3.114
4/12	0.044	0.409	0.644	0.771	0.908	1.360	1.637	1.972	2.286
4/13	0.114	0.235	0.408	0.511	0.460	0.389	0.160	0.071	-0.652
4/15	0.037	0.208	0.338	0.448	0.520	0.712	0.774	2.083	3.088
Mean	0.048	0.290	0.574	0.666	0.740	1.038	1.109	1.625	1.959
SE	0.024	0.045	0.128	0.113	0.149	0.297	0.394	0.525	0.891
Lo 95% CI	-0.028	0.147	0.166	0.305	0.267	0.093	-0.145	-0.045	-0.877
Hi 95% CI	0.125	0.434	0.981	1.027	1.214	1.982	2.362	3.296	4.795
Paired *t*	2.01	6.45	4.48	5.88	4.97	3.50	2.81	3.10	2.20
P	0.138	0.008	0.021	0.010	0.016	0.040	0.067	0.054	0.115

OBJECTIVE 2: Radiotelemetry Estimation of Relative Survival Through Turbines Under Two Operating Conditions

Methods

We obtained run-of-river hatchery yearling chinook salmon from the McNary Dam smolt monitoring sample. Test fish were held in 113-L containers with flow-through river water for 24 h prior to tagging. Before being tagged, test fish were examined and any fish that were injured and/or heavily descaled were rejected. Radio tags were surgically implanted using the procedure described in Eppard et al. (2000).

Radio tags with a 30.5-cm antenna were supplied by Advanced Telemetry Systems Inc.† They measured 17 mm in length by 6 mm in diameter and weighed 1.4 g in air. Tags were pulse-coded for unique identification of individual fish and were designed to cease operation after a period of 6 days, so that tag frequencies could be repeated weekly. Pulse rate of the tags was 40/min. PIT tags were also placed in each fish during the surgical tagging procedure.

Three groups of 36 fish were tagged each day. Test fish ranged from 121 to 239 mm in length (median 145 mm). Tagged fish were placed in 19-L containers, supplied with supplemental oxygen, and observed for several minutes to ensure recovery from anesthesia. When all fish had regained equilibria, the containers were transferred to an insulated holding tank which measured 1.2 m wide by 2.1 m long by 0.4 m deep and was supplied with a continuous supply of flow-through river water. The upper half of each container was perforated with 1.3-cm holes to ensure an ample supply of fresh water. Fish were held for 24 h prior to release to monitor for mortality.

All tags were checked to verify that they were operating prior to release. One group was released at a load of 16,400 ft^3/sec into Turbine Unit 9, and the other was released at a load of 11,200 ft^3/sec into the same unit. Fish were equally divided between all three gatewell slots (A, B, C) of Turbine Unit 9 each day of release. The third group was released from a barge approximately 2 km downstream from McNary Dam. Test fish were released two-at-a-time spaced from 5 to 8 min apart. Turbine loading was alternated daily, and the order of gatewell releases was also varied daily.

† Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Control fish released downstream from McNary Dam were released in pairs at 15-min intervals to spread the time of their release over that of both test groups (Table 2). All releases were made during daylight hours, typically from 0930 to 1430.

Tagged fish from any group that died prior to release were released with the live fish from that group to validate the assumption that dead fish would not be carried by the current downstream as far as the receiver array at Irrigon, Oregon. Fish were monitored as they passed receiver arrays at Irrigon, East Crow Butte and West Crow Butte located 15, 41, and 46 km downstream from McNary Dam, respectively (Figure 1). Additional data were obtained from PIT-tag detections at John Day and Bonneville Dams.

Data files were downloaded daily from telemetry receivers during the study period. Files contained a record for each time a radio-tagged fish was detected. Records included a date/time stamp, the frequency and code of each individual transmitter, the antenna number on which the detection was made, and the relative strength of the signal. Each file was compiled to combine and count records of each individual fish by the same receiver/antenna within a 5-min interval. Compiled files were sorted by receiver location and loaded to a database.

The following exclusion criteria were used to separate valid detections from background noise (clean the data).

1) Detections records with less than 5 total signals were rejected.

2) Detections of fish that occurred prior to the date and time of release (out of sequence in time) were rejected.

3) Detections with less than 2 hits/min were rejected (tags generated 40 signals per minute).

4) Detections upstream from McNary Dam (out of sequence in space) were rejected.

Final cleaning of the data set was accomplished by four individuals independently examining each line of data to determine if it was valid or invalid based on location, travel time, number of detections, and number of detections per minute. The results of this effort were pooled, and each line of data that was not unanimously agreed upon as being either valid or invalid was examined by the group to make a final determination of its validity. The data set resulting from this process was used for all analyses of the study objective.

Table 2. Date, time, location, and number of fish released at McNary Dam 2002.

		Treatment							
		Intake A		Intake B		Intake C		Control	
Date	Load (kcfs)	Rel. time	No.	Rel. time	No.	Rel. time	No.	Rel. time	No.
5/14	11.2	1107	12	1024	11	0941	12	0945	17
5/14	16.4	1448	12	1230	12	1351	11	1230	18
5/15	11.2	1022	11	1058	12	1152	12	0945	18
5/15	16.4	1521	11	1449	12	1417	11	1230	18
5/16	11.2	1042	11	0919	11	0955	11	0945	18
5/16	16.4	1148	11	1228	11	1324	12	1200	17
5/17	11.2	1143	11	1229	12	1320	12	1130	18
5/17	16.4	1027	11	0900	12	0943	10	0900	17
5/21	11.2	1144	12	1209	12	1321	12	1115	17
5/21	16.4	1021	12	0906	12	0940	12	0900	17
5/22	11.2	1041	12	0909	11	0951	12	0915	18
5/22	16.4	1146	12	1226	12	1331	12	1145	17
5/23	11.2	1143	11	1227	12	1320	12	1130	18
5/23	16.4	0900	12	0924	12	1008	12	0900	17
5/24	11.2	0849	11	0903	11	0940	12	0900	14
5/24	16.4	1116	12	1201	11	1256	12	1115	17
5/29	11.2	1129	12	1215	10	1324	12	1115	18
5/29	16.4	1025	11	0903	12	0946	12	0900	18
5/30	11.2	1011	12	0854	10	0935	11	0900	18
5/30	16.4	1115	12	1135	12	1219	12	1115	18
5/31	11.2	1155	12	1237	11	1319	12	1145	18
5/31	16.4	0910	11	0959	10	1043	12	0915	18
6/1	11.2	0856	12	0938	12	1021	11	0900	17
6/1	16.4	1136	12	1220	12	1305	11	1115	16
6/4	11.2	0928	12	1011	11	1048	12	0915	18
6/4	16.4	1203	12	1239	12	1315	9	1145	17
6/5	11.2	1210	12	1248	12	1324	12	1200	17
6/5	16.4	1101	12	1017	12	0933	11	0930	17
6/6	11.2	1053	11	1017	12	0941	12	0930	17
6/6	16.4	1158	12	1238	12	1325	11	1200	17
6/7	11.2	1150	12	1226	12	1303	12	0930	16
6/7	16.4	1046	12	1009	12	0927	10	1145	18
6/11	11.2	1009	6	0948	6	0934	4	1030	6
6/11	16.4	1034	5	1058	6	1117	4	0945	6

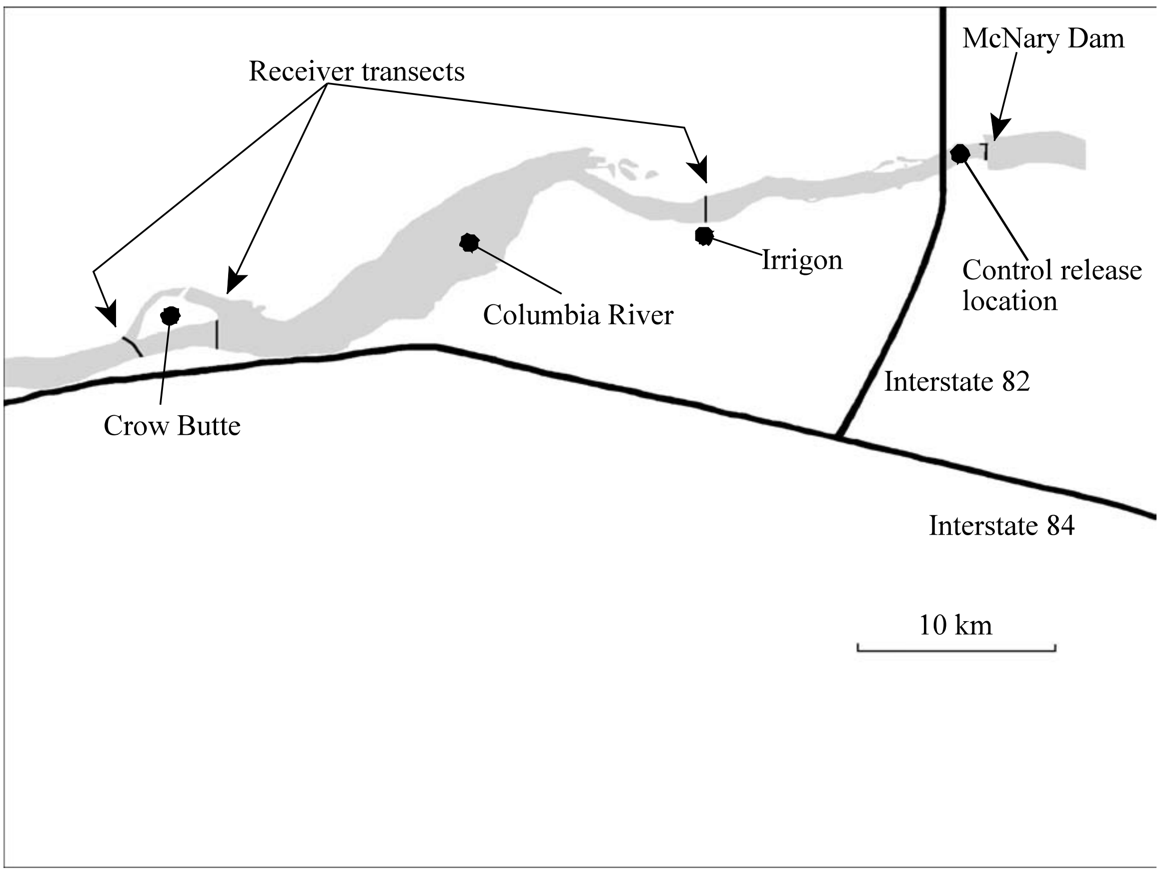

Figure 1. McNary Dam and vicinity showing the downstream release site and radiotelemetry receiver transects at Irrigon, East Crow Butte and West Crow Butte.

Results and Discussion

A total of 1,708 radio-tagged yearling chinook salmon were released between 14 May and 11 June. Of these, 573 were released into the turbine operating at 11,200 ft^3/sec, 570 were released into the turbine operating at 16,400 ft^3/sec, and 565 were released 2 km downstream from McNary Dam.

We detected 1,143 (82.5%) of the fish released into the turbines and 97.7% of those released into the tailrace. Detections of turbine-released fish were almost equally divided between those released at 16,400 ft^3/sec (82.1%) and those released at 11,200 ft^3/sec (82.9%). Detection probabilities at Irrigon, East Crow Butte, and West Crow Butte were all high, ranging from a low of 83.1% at Irrigon for test fish released at 11,200 ft^3/sec to a high of 96.6% at East Crow Butte, also for test fish released at 11,200 ft^3/sec. There was little chance that a radio-tagged fish passed the combined receiver arrays without detection (Table 3). PIT-tag detections at John Day and Bonneville Dam provided additional information. This data was typically used during the data cleaning process to confirm radio-tag detection data. The high detection probabilities at the Irrigon and Crow Butte receiver arrays minimized the need for additional information from PIT-tag data.

Tagged fish that died prior to release were released with their respective groups. This was done to assure that mortalities were not traveling downstream as far as our receiver arrays at Irrigon and Crow Butte which would result in false positive detections. A total of five tagged dead fish were released with the tailrace releases, four with the turbine releases at 11,200 ft^3/sec, and seven with the turbine releases at 16,400 ft^3/sec. None of these fish were detected on receivers at Irrigon or Crow Butte, so we were confident that all fish detected at downriver telemetry sites were alive.

Relative survivals for test fish released at 11,200 and 16,400 ft^3/sec were 87.3 and 85.5%, respectively (Table 4). Balloon-tag studies conducted concurrently with this study to estimate immediate turbine survival resulted in survival estimates of 93.0% (90% CI, 90-97%) at 11,200 ft^3/sec and 94.6% (90% CI, 91.5 - 98.1%) at 16,400 ft^3/sec (Normandeau Associates et al. 2003). While keeping in mind that two different methodologies were employed, the difference between radio- and balloon-tag survival estimates indicated that much of the mortality associated with passage through the powerhouse may have been due to conditions experienced by fish in the tailrace after turbine passage. It is unknown what portion of the indicated tailrace mortality was due to turbine passage and what portion was due directly to the tailrace conditions experienced by all fish passing through this area.

Table 3. Geometric means and standard deviations of detection probabilities by site for all three release groups of radio-tagged yearling chinook salmon.

	Turbine Unit 9 operating at 11,200 ft^3/sec		
	Irrigon	East Crow Butte	West Crow Butte
Geometric mean	0.831	0.966	0.864
Standard deviation	0.123	0.036	0.142
	Turbine Unit 9 operating at 16,400 ft^3/sec		
	Irrigon	East Crow Butte	West Crow Butte
Geometric mean	0.852	0.941	0.904
Standard deviation	0.104	0.042	0.101
	Tailrace		
	Irrigon	East Crow Butte	West Crow Butte
Geometric mean	0.865	0.937	0.925
Standard deviation	0.109	0.058	0.086

Table 4. Relative survival estimates, 95% confidence intervals (CI), and standard errors for radio-tagged yearling chinook salmon released into Turbine Unit 9 at 11,200 and 16,400 ft^3/sec operating loads.

	11,200 ft^3/sec	16,400 ft^3/sec
Relative survival (%)	87.3	85.5
standard error	0.013	0.011
Low 95% CI	84.6	83.2
High 95% CI	90.1	87.8

Survival estimates were somewhat intermediate to those of previous survival studies. Survival was estimated at 81% through turbines at The Dalles Dam in 2000 (Absolon et al. 2002). Relative survival rates of 93, 92, and 87% were estimated at Lower Granite, Little Goose, and Lower Monumental Dams from 1993 to 1995, respectively (Muir et al. 2001).

Median travel time from each release location was calculated from time of release to time of first detection at Irrigon and East Crow and West Crow Buttes. As expected, travel time for fish released downstream from the dam was shorter than for fish released into the turbines because the distance traveled was 2-km shorter and because fish did not have to pass through the turbine and near-tailrace environment. Turbine-released fish took about 30 min longer to reach Irrigon than tailrace-released fish, and continued to lose time to East Crow Butte where they were about 1 h, 30 min slower. They did not lose any more time in the relatively short distance from East to West Crow Butte.

It would appear that the effects of turbine passage may have affected travel time of these fish at least until they reached the East Crow Butte detection array. Median time to first detection for tailrace-released fish was 3 h, 21 min; 19 h, 37 min; and 21 h, 2 min at Irrigon, East Crow Butte, and West Crow Butte respectively. Median time to first detection combined turbine-released fish was 3 h, 57 min; 21 h, 4 min; and 22 h, 29 min at Irrigon, East Crow Butte, and West Crow Butte, respectively (Table 5).

We also detected a number of turbine-released fish on radiotelemetry antennas placed on the wing wall at the north side of the spillway adjacent to the navigation lock. Most of these fish likely traveled to this area across the north end of the powerhouse and across the entire spillway. A total of 25 fish were detected in the eddy at one or more of the three antennas along the north spillbay wing wall. Of these, two were detected by the tailrace exit antennas before detection in the eddy, indicating they may have traveled downstream some distance before moving back upstream into the eddy. The other 23 fish most likely traveled directly north in front of turbine units 10-14 and across the entire spillway.

Of the 25 fish detected in the eddy, 17 were released at a flow of 11,200 ft^3/sec and 8 were released at 16,400 ft^3/sec. Thirteen of the 25 fish (8 released at 11,200 ft^3/sec and 5 at 16,400 ft^3/sec) were not detected downstream from the eddy. Eleven of the 25 fish were detected at Irrigon, and one was first detected at East Crow Butte after

Table 5. Median travel time from time of release to time of first detection at the Irrigon and Crow Butte telemetry transects for yearling chinook salmon released at McNary Dam in spring 2002. Releases were made 2 km downstream from the dam and into Turbine Unit 9 at operating loads of 16,400 or 11,200 ft^3/sec.

Detection Site	Tailrace releases (hh:mm)	Turbine releases (hh:mm)		
		Combined	11,200 ft^3/sec	16,400 ft^3/sec
Irrigon	3:21	3:57	4:00	3:53
East Crow Butte	19:37	21:04	21:29	20:45
West Crow Butte	21:02	22:29	22:35	22:16

leaving the McNary Dam area. Median travel time for these 11 fish was 6 h, 18 min, which was much longer than the 3 h, 57 min for all turbine fish combined. Travel time for the one fish first detected at East Crow Butte was 3 h, 18 min longer than the median for all turbine fish combined to that point.

Fish released at 11,200 ft^3/sec that were detected in the eddy were almost equally distributed across all three slots of Turbine Unit 9, with 6, 5, and 6, being released into Gatewell Slots A, B, and C, respectively. At 16,400 ft^3/sec, there was a shift in the distribution, with 0, 3, and 5 being released into Gatewell Slots A, B, and C, respectively. Median time the 25 fish remained in the eddy was 2 h, 25 min, with a range between 3 min and 69 h, 56 min.

CONCLUSIONS

1. We found no significant difference in the condition of hatchery yearling chinook salmon released into a gatewell at an operating load of 16,400 ft^3/sec compared to those released in an adjacent gatewell operating at a lesser load near 11,200 ft^3/sec (within 1% of peak efficiency). The number of fish that were descaled, had minor levels of descaling, were mortalities, or had other injuries were very similar for both operating conditions.

2. We found no significant difference in relative survival between groups of run-of-river hatchery yearling chinook salmon released into Turbine Unit 9 at operating loads of 11,200 and 16,400 ft^3/sec.

ACKNOWLEDGMENTS

We wish to express our appreciation to those who assisted with this research. We thank the Walla Walla District U.S. Army Corps of Engineers personnel including Tim Wik and Brad Eby. Rosanna Tudor and the staff of the Washington Department of Fish and Wildlife at McNary Dam provided valuable assistance collecting the study fish. We also greatly appreciate the assistance of National Marine Fisheries Service personnel including Thomas Ruehle, Lynn McComas, Darren Ogden, Jeffrey Moser, Scott Davidson, Ronald Marr, Byron Iverson, and Mark Kaminski, who were involved throughout the study period. Without the efforts of all of the above people and the personnel hired for the project, the study would not have been successful.

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