Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2004:

Final report for the 2001 spring/summer chinook salmon juvenile migration

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by

Douglas M. Marsh, Jerrel R. Harmon,
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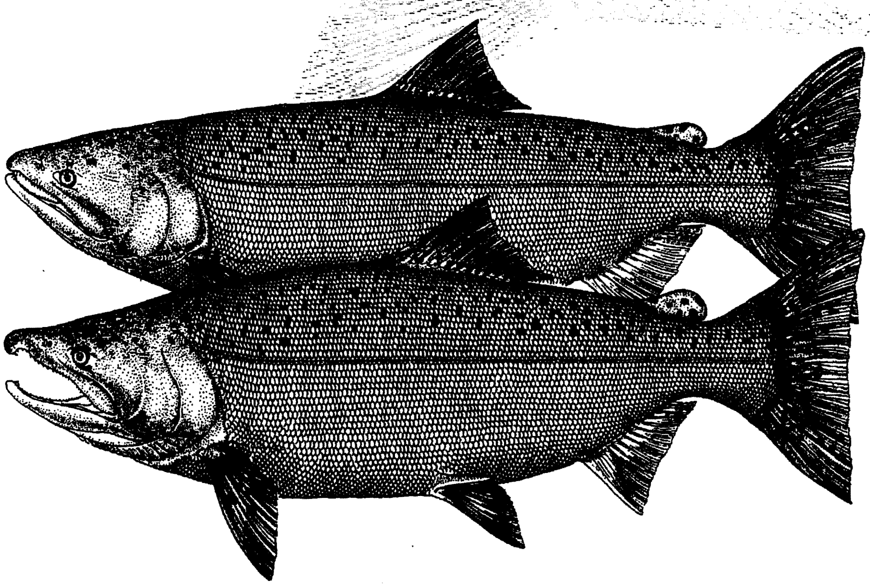
April 2005



Research Related to Transportation of Juvenile Salmonids on the Columbia and Snake Rivers, 2004: Final report for the 2001 Spring/Summer Chinook Salmon Juvenile Migration

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Report of research by

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

for

Walla Walla District
Northwestern Division
U.S. Army Corps of Engineers
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EXECUTIVE SUMMARY

Since 1995, the National Marine Fisheries Service has evaluated transportation of Snake River spring/summer chinook salmon smolts. Beginning in 2002, spring chinook salmon transportation was also evaluated from McNary Dam using fish PIT-tagged at upper Columbia River hatcheries.

From March to August 2004, we recovered age-3-ocean spring/summer chinook salmon adults from smolts tagged at Lower Granite Dam in 2001, completing adult returns from that study year. In 2001, we tagged only wild fish, and because of record low flows, all fish were placed in barges at Lower Granite Dam. No inriver group was tagged. In 2004 we detected 25 wild age-3-ocean transported fish at Lower Granite Dam. Based on combined returns from the 2001 marking (jacks through age-3-ocean fish), the smolt-to-adult return rate (SAR) of transported fish was 0.96 (95% confidence interval 0.84, 1.11). As in previous years, SARs were variable over the course of the juvenile migration.

Nearly 87% of adults from the 2001 tagging year that were detected at Bonneville Dam migrated successfully to Lower Granite Dam (not adjusted for any take in the Zone 6 fishery). Median travel time from Bonneville Dam to Lower Granite Dam was approximately 14 d for both age-2- and age-3-ocean fish.

One note of special interest, an age-4-ocean adult from our 2000 wild spring/summer Chinook salmon marking was detected passing Lower Granite Dam on 9 June 2004.

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INTRODUCTION

In 2004, we continued studies to evaluate transportation of juvenile fish as a means to mitigate for downstream losses that result from the lower Snake and Columbia River federal hydropower system. The primary objective of our studies is to compare adult returns of yearling chinook salmon PIT-tagged as smolts and transported to a release site below Bonneville Dam to those of their cohorts allowed to migrate inriver under optimal conditions for inriver survival. Detections from PIT-tagged smolts released to migrate inriver will also provide data for short-term survival estimates between the point of release and Bonneville Dam tailrace (Iwamoto et al. 1994; Smith et al. 1999).

Here we report adult returns in 2004 and final results from the 2001 spring/summer chinook salmon tagging year at Lower Granite Dam. Information is also provided on the 2004 juvenile transportation study tagging effort (Appendix B) and previous complete returns (1995-2000) and incomplete adult returns (2002 to 2004) (Appendix C).

In 1995-96 and 1998-2000, we PIT tagged yearling chinook salmon smolts at Lower Granite Dam to compare adult returns of marked smolts transported to below Bonneville Dam versus those of smolts released to the tailrace of Lower Granite Dam to migrate in the river. Inriver-migrating smolts collected at downstream dams were returned to the river to continue their migration.

Based on adult returns from those years (and from fish PIT tagged in the same years upstream of Lower Granite Dam) we found that smolts bypassed and returned to the river at downstream dams survived to adulthood at lower, rather than higher, rates than those bypassed only at Lower Granite Dam. Further, fish not detected at dams (fish that passed via spillways, passed through turbines, or were not detected at juvenile fish facilities) returned at higher rates than fish bypassed at downstream collector dams.

Thus, in hindsight, the study designs from 1995 through 1999 did not provide sufficient information to compare the returns of non-detected and non-transported fish to those of fish that were transported. For the 2000 transportation studies, we altered the inclusion criteria to provide better comparison between these groups. The 2001 outmigration occurred during a record low-flow year. Because of this, we only marked a transport index group. All marked fish were placed in transport barges at Lower Granite Dam. Here, we report the results of analyses based on complete returns of fish marked in 2001.

METHODS

Sampling and Tagging of Juveniles

As in past years, we collected and PIT tagged wild Snake River spring/summer chinook salmon at Lower Granite Dam. Originally we had planned to continue with the transport study modified in 2000. However, because 2001 was a record low-flow year, we only marked a barge index group. All PIT-tagged fish were placed in a barge at Lower Granite Dam. No fish were released into the Lower Granite Dam tailrace.

The number of PIT-tagged fish required for a transport index group at Lower Granite Dam was expressed as

$$N = (Z_{\alpha/2})^2 \times SAR \times (1\text{-}SAR)/w^2$$

where N is the number of PIT-tagged juveniles required for a transport index group, SAR is the expected smolt-to-adult return rate, and *w* is one-half the width of a 95% confidence interval for the SAR, based on assumed binomial variation.

We set $\alpha = 0.05$, and *w* at 0.002 (0.2%), and we assumed an SAR for transported fish of 0.01 (1.0%). This produced N = 10,000; therefore, we proposed to tag a minimum of 10,000 fish for the transport index group in spring 2001. Basic collection and handling of juveniles followed the methodology described by Marsh et al. (1996, 2001). We continued using the recirculating anesthetic water system described by Marsh et al. (2001).

We recorded fork lengths of all fish during tagging. To avoid tagging spring/summer chinook salmon of hatchery origin with partial or no fin clips (identifying them as hatchery fish), we set the maximum fork length for a fish to be considered wild at 124 mm. Based on previous analyses of known wild fish collected and measured during their outmigration (Marsh et al. 2001), this limited the number of hatchery fish marked (on average, less than 6% of hatchery fish were below this fork length) while keeping to a minimum the number of wild fish inadvertently excluded (on average, less than 5% of wild fish are over this fork length).

Adult Recoveries and Data Analysis

In 2004, we completed the recovery of adults tagged as juveniles in 2001.

RESULTS

Sampling and Tagging of Juveniles

From 10 April through 8 June 2001, we tagged 17,597 wild yearling spring/summer chinook salmon (Table 1 and Appendix Table A1), or 5.6% of the wild yearling spring/summer chinook salmon collected at Lower Granite Dam. The number of fish tagged daily ranged from 49 to 1,104. Of the 17,597 wild yearling spring/summer chinook salmon tagged, 16,566 were released into barges at Lower Granite Dam.

	Number tagged	Number released	Mean fork length (mm)
Spring/summer chinook salmon	17,597	16,512	111.7

Because all tagged fish were returned to transport raceways, we were unable to determine post-tagging delayed mortality. The number of juveniles actually released was 17,597; however, two groups had to be discarded: on 18 May 2001, the barge carrying fish marked on 17 May (898 wild spring/summer chinook salmon) was forced to release fish above Ice Harbor Dam when all the internal screens became clogged with juvenile lamprey and on 24 May, a hydraulic oil spill in one of the gatewells caused a layer of oil to cover all the raceways. Tagging was stopped immediately, and all fish that had been tagged (133 wild spring/summer chinook salmon) were removed from the study.

Adult Recoveries and Data Analysis

At Lower Granite Dam, we began recovering jacks in 2002 and finished with age-3-ocean adults in August 2004. Returns by study group and age-class are shown below.

	Juvenile numbers	Returns by Age-class Jack	2-ocean	3-ocean	SAR	95% C.I.
Transport	16,512	21	113	25	0.96	(0.81, 1.11)

The percentage of wild age-3-ocean adults in 2004 (from our tagging) was the second lowest we have observed since we started transport studies in 1995 (Table 1).

As in previous years, temporal differences were seen in the SARs (Figure 1). The pattern observed was similar to those seen in past studies: a decrease in the transport SAR just before its sharpest rise, which, for 2001, began around 26 April. Also, as in past years, smaller sample sizes in the first and last two weeks of the season may account for much of the variability observed during these periods.

The number of returning adults observed at Bonneville Dam and subsequently observed at Lower Granite Dam (conversion rate; Table 2) was slightly higher for age-2-ocean adults and all adults combined than in past years; however, jacks and age-3-ocean adults had lower conversion rates. We did not adjust the values for the estimated annual Zone-6 harvest rate. As we have observed in previous years, more fish were lost in the Bonneville Dam to McNary Dam reach of the river than in the McNary Dam to Lower Granite Dam reach. During each return year from the 2001 juvenile migration, more dams were being equipped with PIT tag detection systems for adults. When the jacks from 2001 returned in 2002, only Bonneville, McNary, and Lower Granite Dams were equipped with adult detection systems. By 2003, Ice Harbor, Priest Rapids, Rock Island, and Wells Dams had each been equipped with adult detection systems.

Travel times from Bonneville Dam to Lower Granite Dam ranged from 11 to 14.5 d (Table 3), increasing with each age class. In 2003, with the addition of detection capabilities at dams on the Columbia River above the confluence with the Snake River, we could have observed any mainstem straying that might have occurred; however, none was observed. For jacks, age-2- and age-3-ocean adults, median travel time between Bonneville and McNary Dams was 1.0, 1.0, and 0.5 days longer, respectively, than the median travel time between McNary and Lower Granite Dams.

Table 1. Age-class percentages for current transportation studies (1995-2001).

Study year	Jack (%)	2-ocean (%)	3-ocean (%)	Total adults
1995	0.0194	0.6323	0.3484	55
1996	0.0625	0.6250	0.3125	16
1998	0.0690	0.7011	0.2299	87
1999	0.0427	0.8110	0.1463	328
2000	0.0383	0.4037	0.5580	832
2001	0.1321	0.7107	0.1572	159

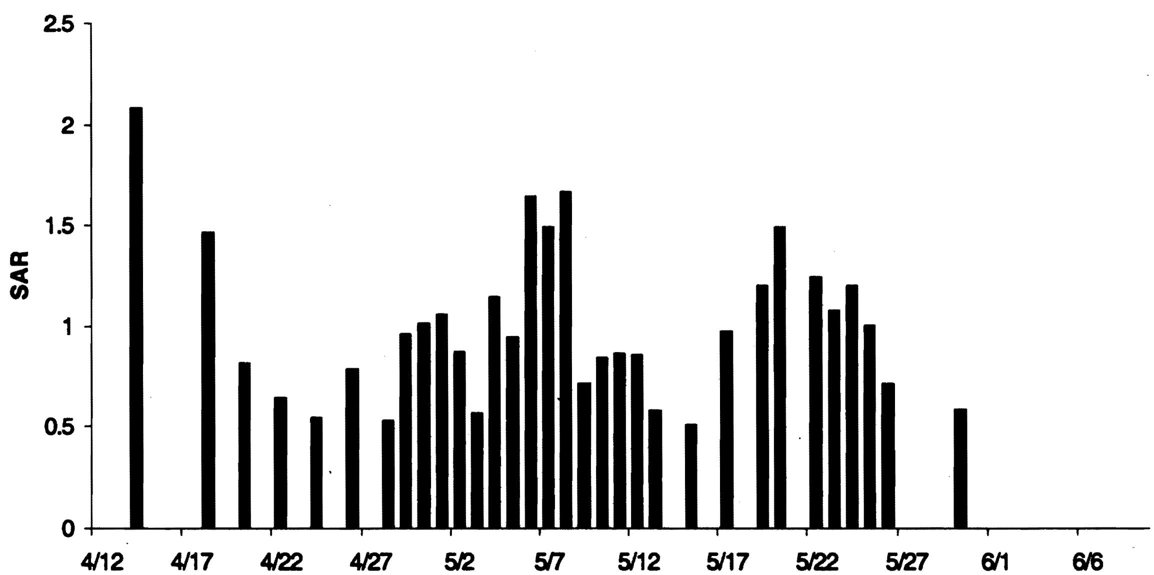

Figure 1. Smolt-to-adult return rates by release date for transported spring/summer chinook salmon smolts tagged at Lower Granite Dam in 2001. Data presented as 3-day running averages of daily releases and juvenile release numbers adjusted proportionally to daily collection numbers. Overall SAR was 0.95.

Table 2. Percentage of adult spring/summer chinook salmon PIT tagged in 2001 that were observed at Bonneville Dam and subsequently detected at Lower Granite Dam (the conversion rate).

Age class		Seen at Bonneville Dam	Seen at Lower Granite Dam	Conversion rate
Jacks	Transport	17	16	94.12
Age-2-ocean	Transport	122	108	88.52
Age-3-ocean	Transport	31	24	77.42
Totals	Transport	170	148	87.06

Table 3. Median travel times from Bonneville Dam to Lower Granite Dam for adult spring/summer chinook salmon PIT tagged as juveniles in 2001.

Age class		Median travel time from Bonneville Dam to Lower Granite Dam (days)
Jacks	Transport	11.0
Age-2-ocean	Transport	14.0
Age-3-ocean	Transport	14.5

DISCUSSION

We have not observed any temporal differences in migrational behavior, physiology, disease, or transport methodologies that might explain the abrupt and sustained seasonal changes in SARs of transported fish. We believe the pattern relates to arrival timing of smolts in the estuary and near-ocean environments in recent years. Conditions that might vary annually in these areas include predator abundance and dynamics (birds, fish, and marine mammals), alternative prey availability for those predators (anchovies, herring, and sand lance), and abundance of prey for juvenile salmon (enhanced survival of fast-growing, robust smolts).

The proportion of adults in each age class changed again, with a sharp drop in the percentage of fish returning as age-3-ocean adults (16% vs. 56% from the 2000 study year). This level of age-3-ocean returns was just slightly higher than the 1999 study year, which had the lowest percentage since 1995.

REFERENCES

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R. Skalski. 1994. Survival estimates for the passage of juvenile chinook salmon through Snake River dams and reservoirs. Report of the National Marine Fisheries Service to the Bonneville Power Administration, Portland, Oregon.

Marsh, D. M., J. R. Harmon, K. W. McIntyre, K. L. Thomas, N. N. Paasch, B. P. Sandford, D. J. Kamikawa, and G. M. Matthews. 1996. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1995. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2001. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 2000. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 2000. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1998. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., J. R. Harmon, N. N. Paasch, K. L. Thomas, K. W. McIntyre, B. P. Sandford, and G. M. Matthews. 1997. Research related to transportation of juvenile salmonids on the Columbia and Snake Rivers, 1996. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Matthews, G. M. and R.S. Waples. 1991. Status review for Snake River Spring and Summer Chinook Salmon. NOAA Technical Memorandum NMFS F/NWC-200.

Muir, W. D., S. G. Smith, J. G. Williams, E. E. Hockersmith, and J. R. Skalski. 2001. Survival estimates for migrant yearling chinook salmon and steelhead tagged with passive integrated transponders in the lower Snake and lower Columbia Rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

Smith, S. J., W. Muir, G. Axel, R. Zabel, J. G. Williams, and J. R. Skalski. 1999. Survival estimates for the passage of juvenile salmonids through Snake and Columbia River dams and reservoirs, 1999. Report of the National Marine Fisheries Service to the Bonneville Power Administration, Portland, Oregon.

Raymond, H. L. 1988. Effects of hydropower development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8:1-24.

APPENDIX A

Juvenile Data from the 2001 Spring/Summer Chinook Salmon Tagging Year

Appendix Table A. Total wild spring/summer chinook salmon tagged at Lower Granite Dam in spring 2001.

Tag date	Tagged	Transported	Tag date	Tagged	Transported
10-Apr	14	14	8-May	276	276
11-Apr	68	68	9-May	795	795
12-Apr	77	77	10-May	945	945
13-Apr	43	43	11-May	905	905
16-Apr	38	38	12-May	467	467
17-Apr	75	75	14-May	349	349
18-Apr	30	30	15-May	958	958
19-Apr	115	115	17-May[a]	898	898
20-Apr	67	67	18-May	636	636
21-Apr	68	68	19-May	488	488
22-Apr	114	114	21-May	218	218
23-Apr	83	83	22-May	268	268
24-Apr	80	80	23-May	354	354
25-Apr	145	145	24-May[b]	133	133
26-Apr	223	223	25-May	209	209
27-Apr	506	506	29-May	75	75
28-Apr	562	562	30-May	57	57
29-Apr	1,108	1,108	31-May	49	49
30-Apr	1,004	1,004	1-Jun	61	61
1-May	448	448	4-Jun	56	56
2-May	498	497	5-Jun	128	128
3-May	477	477	6-Jun	203	203
4-May	436	430	7-Jun	573	573
5-May	1,003	1,001	8-Jun	32	32
6-May	830	830			
7-May	464	464	Totals	17,709	17,700

a These fish had to be released above Ice Harbor Dam when all internal barge screens became clogged with juvenile lamprey.

b These fish were removed from the study because a hydraulic oil leak in one of the gatewells caused a layer of oil to form on all raceways.

APPENDIX B

2004 Juvenile Transportation Study Tagging

Snake River Spring/Summer Chinook Salmon and Steelhead

From 9 April through 10 June 2004, we PIT tagged a total of 11,208 wild yearling Chinook and 8,103 wild steelhead smolts and loaded them into barges at Lower Granite Dam. The region decided not to tag an inriver group, so no fish were released to the river.

Because it was not possible to remove all mortalities from the raceways, we were unable to estimate post-marking delayed mortality (24-hour).

Snake River Fall Chinook Salmon

From 2 June through 30 July 2004, we PIT tagged a total of 49,287 subyearling chinook salmon at Lower Granite Dam, releasing 3,617 of these fish into barges and 45,296 into the Lower Granite Dam tailrace. We also marked 2,544 subyearling chinook salmon at Lower Granite Dam in September and October for a transport index group.

Based on mortality counts, post-marking delayed mortality (24-hour) averaged 0.6% over the entire tagging season (including the fall marking).

Other transport groups were created at downstream dams by setting the separation-by-code system to transport 80% of the fish collected. The remaining fish were diverted back to the river to aid in making reach survival estimates.

Columbia River Hatchery Spring Chinook Salmon and Steelhead

In 2004, we continued transportation studies from McNary Dam using upper Columbia River hatchery yearling spring chinook salmon and upper Columbia River hatchery steelhead. As in 2003, three study groups were formed at McNary Dam: fish that were either transported, not collected, or bypassed through the primary bypass directly to the McNary Dam tailrace.

Beginning in late August 2003, the U.S. Fish and Wildlife Service and Biomark, Inc. began PIT-tagging hatchery yearling spring chinook salmon and steelhead. A total of 347,309 yearling spring chinook salmon were tagged at Winthrop (19,900 fish), Methow (34,945), Entiat (59,707 fish), and Leavenworth Fish Hatcheries (232,757 fish). A total of 478,854 steelhead were tagged at Winthrop (50,350), Wells (238,697), Eastbank (83,729), Chelan (9,584), and Ringold Fish Hatcheries (96,494).

Fish that were guided into the collection channel in McNary Dam were bypassed directly to the river or sent into the juvenile collection facility on alternate days. The SAR of fish transported from McNary Dam will be compared to the SAR of fish bypassed directly to the river (without entering the juvenile collection facility) and to the SAR of fish that were never detected at McNary Dam.

APPENDIX C

Adult Returns from Previous Transportation Studies and Studies In Progress

Appendix Table C1. Snake River wild spring/summer chinook salmon studies.

Tagging year	Juvenile fish numbers		Returns by Age-class			SAR					Annual report containing final results
	Transport	Inriver	Jack	2-ocean	3-ocean	Transport	Inriver	T/I	95% C.I.	Status	
2003	7,118	43,108	1	–	–	–	–	–	–	In-progress	Fall 2006
2002	4,970	34,059	28	234	–	–	–	–	–	In-progress	Fall 2005
2001	**16,512**	**–**	**21**	**113**	**25**	**0.95**	**–**	**–**	**(0.84, 1.11)**	**Completed**	**Current**
2000*	17,367	26,329	16	263	355	1.47	1.44	1	(0.9, 1.1)	Completed	2003
1999	8,384	1,920	11	164	27	2.1	1.35	1.6	(1.0, 2.4)	Completed	2001
1998	5,689	2,932	6	42	14	0.6	0.95	0.6	(0.4, 1.0)	Completed	2001
1996	7,949	3,915	1	8	3	0.11	0.08	1.5	(0.5, 7.5)	Completed	1999
1995	24,066	6,794	1	70	36	0.38	0.22	1.7	(1.1, 2.6)	Completed	1998

* Transport group formed of fish collected and transported from Little Goose Dam, adjusted with Sandford and Smith (2002).

Appendix Table C2. Snake River hatchery spring/summer chinook salmon studies.

Tagging year	Juvenile fish numbers		Returns by age-class			SAR		T/I	95% C.I.	Status	Annual report containing final results
	Transport	Inriver	Jack	2-ocean	3-ocean	Transport	Inriver				
1999	42,273	16,664	99	935	41	1.97	1.45	1.4	(1.2, 1.6)	Completed	2001
1998	39,596	23,552	48	297	34	0.62	0.57	1.1	(0.9, 1.4)	Completed	2001
1996	35,632	20,186	7	43	22	0.13	0.1	1.2	(0.8, 2.0)	Completed	1999
1995	83,064	25,757	34	444	70	0.54	0.32	1.7	(1.4, 2.1)	Completed	1998

Appendix Table C3. Upper Columbia River hatchery spring/summer chinook salmon studies.

Tagging year	Juvenile fish numbers: Transport	Bypass[a]	Inriver	Returns by Age-class: Jack	2-ocean	3-ocean	SAR: Transport	Inriver	T/I	95% C.I.	Status	Annual report containing final results
2003	31,323	37,469	–[b]	109	–	–	–	–	–	–	In progress	Fall 2006
2002	50,381	–	–[b]	36	607	–	–	–	–	–	In progress	Fall 2005

a "Bypass" fish were fish guided, then bypassed back to the river through the full-flow outfall pipe; they did not enter the collection facility. This passage route was not used in 2002.

b The"Inriver" number has not been determined at this time.