IMPRINTING SALMON AND STEELHEAD TROUT FOR HOMING, 1983

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ABSTRACT

The National Marine Fisheries Service (NMFS), under contract to the Bonneville Power Administration, began conducting research on imprinting Pacific salmon and steelhead for homing in 1978. The juvenile marking phase was completed in 1980; over 4 million juvenile salmon and steelhead were marked and released in 23 experiments. The primary objectives were to determine: (1) a triggering mechanism to activate the homing imprint, (2) if a single imprint or a sequential imprint is necessary to assure homing, and (3) the relationship between the physiological condition of fish and their ability to imprint.

Research in 1983 concentrated on: (1) recovering returning adults from previous experiments and (2) analyzing completed 1979 and 1980 steelhead and chinook salmon experiments.

Ten experimental studies are discussed. Six of the studies, conducted by the NMFS, employed a variety of techniques for imprinting fish. The remaining four, conducted by the Idaho Fishery Cooperative Unit (under contract to NMFS), tested the feasiblity of imprinting fish by a short-distance voluntary migration before transport. In five experiments (three steelhead and two fall chinook salmon studies), survival was enhanced by the imprint-transportation procedures, and homing to the homing site area was partly successful. Returns from the Astoria, Oregon, release of fall chinook salmon from Big Creek Hatchery (Knappa, Oregon), for example, showed that the imprint technique used (limited short distance migration) should provide 2-3 times more fish to the various fisheries while providing adequate returns to the hatchery for egg take each year. In the remaining five experiments (four spring chinook salmon and one fall chinook salmon experiment), survival was too low for an analysis of the homing objectives.

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INTRODUCTION

The National Marine Fisheries Service (NMFS), under contract to the Bonneville Power Administration (BPA), is conducting research on imprinting Pacific salmon and steelhead for homing. For the purposes of this study, imprinting is defined as a rapid and irreversible learning experience that provides fish with the ability to return to natal streams or a preselected site. The ablility to activate the imprint mechanism at the proper time should assure a suitable homing cue that, coupled with transportation (Park et al. 1979), will result in high smolt survival and ensure adequate returns to the homing site or hatchery.

In our study, we used single and sequential imprints. Single imprinting is cueing fish to a single unique water supply prior to release. Various mechanical stimuli may be used in combination with the unique water source to achieve the single imprint. Sequential imprinting is cueing fish to two or more water sources in a step-by-step process to establish a series of signposts for the route "home."

The primary objectives of our homing research are as follows:

1. Determine a triggering mechanism to activate the homing imprint in salmonids.

2. Determine whether a single imprint or a series of stimuli (sequential imprinting) are necessary to assure homing for various stocks of salmonids.

3. Determine the relationship between the physiological condition of fish (gill Na^+-K^+ ATPase activity, etc.) and their ability to imprint.

Our study began in 1978, and the juvenile marking phase was completed in 1980. During the 3-year marking phase of the program, over 4 million juvenile salmon and steelhead were marked and released in 23 experiments (Table 1). Fish within marked groups were from randomized samples whenever possible. The 16 homing imprint sites used were spread throughout the major portion of the Columbia River System available to anadromous fish migrations (Figure 1). The first 5 years of activities and results from 13 of the 23 experiments were previously reported by Slatick et al. (1979, 1980, 1981b, 1982, 1983) and Novotny and Zaugg (1979, 1981). Adult returns in 1983 provided the necessary data to complete analysis of the remaining experiments. As shown in Table 1, six of these studies were conducted by NMFS and four by the Idaho Cooperative Fishery Research Unit under contract to NMFS. Results of the NMFS studies covering a variety of mechanisms for activating the homing imprint are presented in the body of this report. The Idaho Cooperative Fishery Research Unit studied the effects on homing of a short-distance voluntary migration prior to transportation from four hatcheries. Results of these studies are presented as Appendix A of this report.

GENERAL METHODS

The degree of success (ability to home and survival enhancement) for the various treatments of experimental fish are based on the returns of adults previously marked as juveniles with a coded wire tag (CWT). Homing of various groups is determined by the rate of return of marked adults to the homing sites. Survival of various groups is measured by the combined total recoveries of CWT at the homing site, from in-river sites (Figure 2),

Table 1.--Homing imprint experiments 1978-80--species, Location, numbers of fish marked and released, and years when adults are expected back for evaluation.

Species and hatchery of origin-homing site	Year, fish marked, and released 1978 (no.)	1979 (no)	1980 (no.)	Adult evaluation (yr)
		Snake River system		
Steelhead				
Dworshak	74,741b/	--	99,135f/	1980-83
Tucannon	36,686b/	67,573e/	--	1980-82
Tucannon-L. Goose Dam	--	--	78,091=/	1981-82
Spring chinook salmon				
Kooskia	186,597c/	--	123,600f/	1980-83
Rapid River	--	--	121,566f/	1981-83
Fall chinook salmon				
Hagerman-Lower Granite Dam	--	--	114,000f/	1981-84
		Columbia River system		
Steelhead				
Chelan-Leavenworth	137,949b/	137,817a/	--	1979-8 1
Wells-Winthrop	96,978b/	65,234a/	--	1979-81
Spring chinook salmon				
Carson-Pasco	--	113,681a/	--	1980-82
Carson	--	159,682a/	159,327e/	1980-83
Leavenworth	--	--	491,768e/	1981-83
Coho salmon				
Carson-Pasco	102,594d/	--	--	1978-79
Willard-Stavebolt Creek	414,907d/	--	--	1978-79
Wi l Lard	--	--	436,118b/	1980-81
Fall chinook salmon				
Big White Salmon-Stavebolt	--	473,027a/	--	1980-82
Big Creek-Stavebolt Creek	--	--	143,805e/	1981-84
Spring Creek	--	--	259,786e/	1981-84

Subtotals by species				Grand Totals
Spring chinook salmon	186,597	273,363	896,261	1,356,221
Fall chinook salmon	--	473,027	517,591	990,618
Coho salmon	517,501	--	436,118	953,619
Steelhead	346,354	270,663	177,226	794,213
	1,050,452	1,017,023	2,027,196	4,094,671

a/ Results in Slatick et al. 1983.
b/ Results in Slatick et al. 1982.
c/ Results in Slatick et al. 1981b.
d/ Results in Slatick et al. 1980.
e/ Results in body of this report (NMFS research).
f/ Results in Appendix A of this report (Idaho Cooperative Fishery Research Unit research).

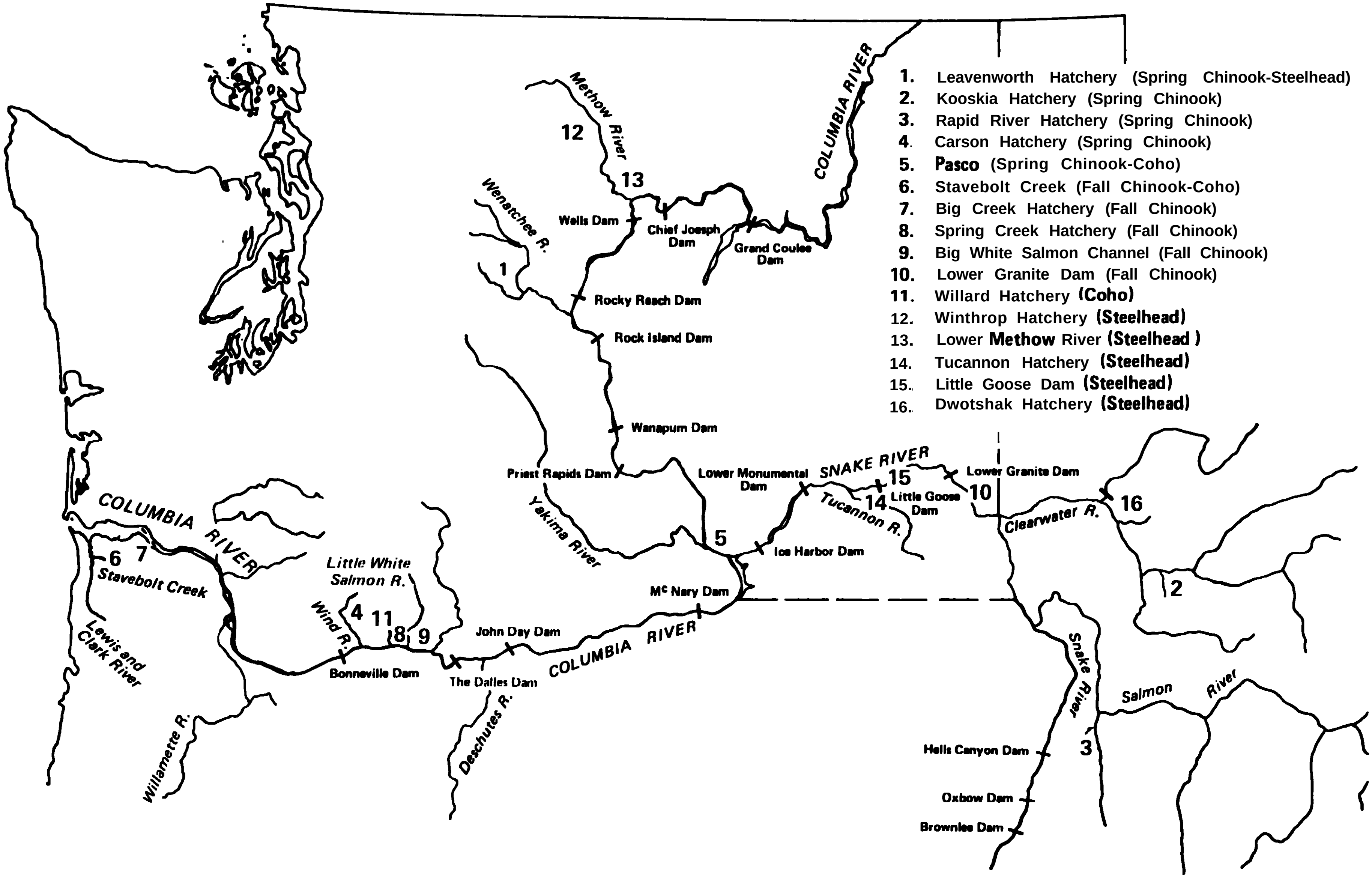


Figure 1.--Area map indicating experimental homing sites, 1978-1980.

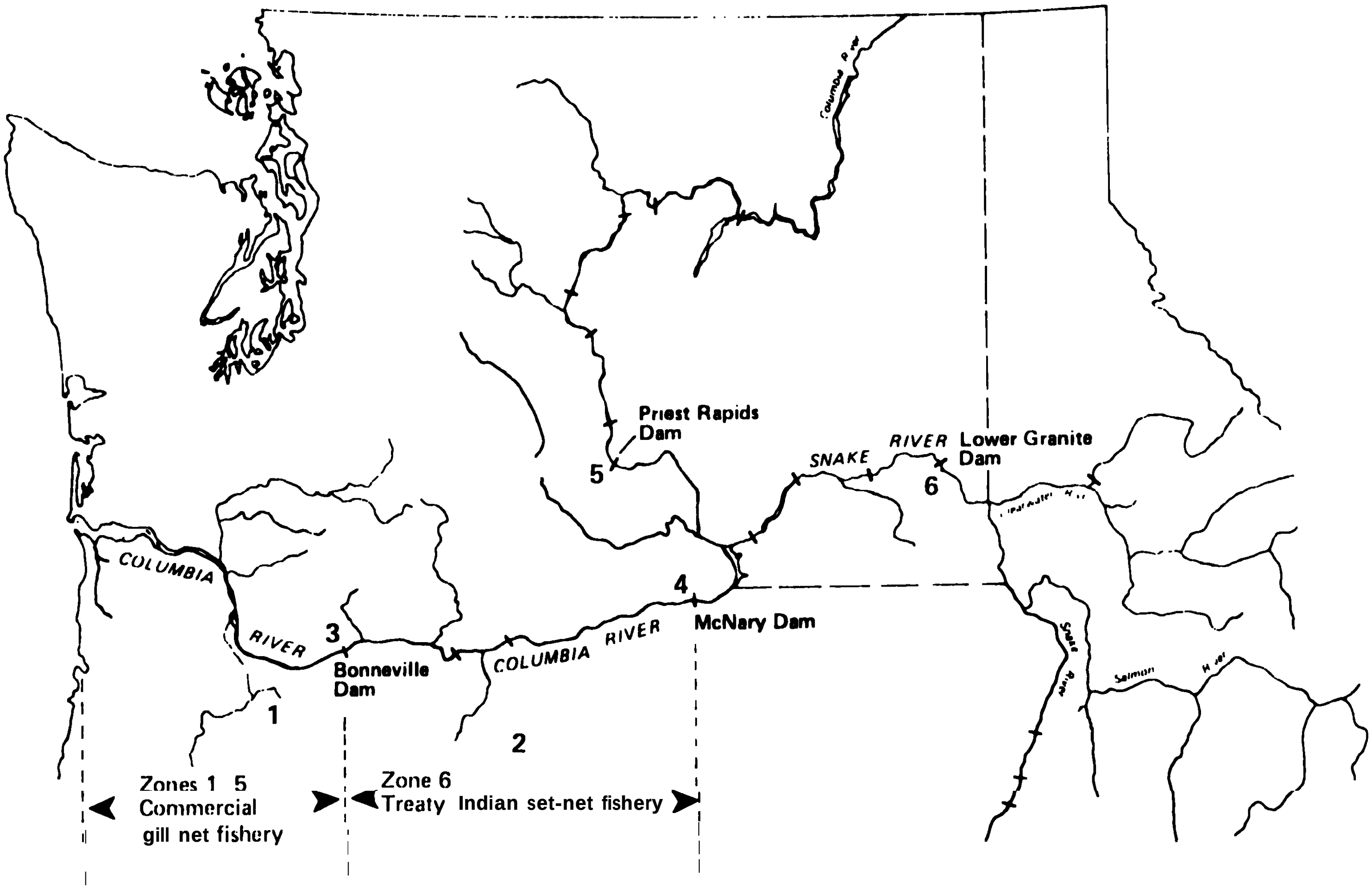


Figure 2.--Mop of Columbia River system showing location of six in-river sampling locations.

from commercial and sport fisheries, and from hatcheries and spawning grounds. ALL homing sites are Located at permanent facilities (hatcheries) except Stavebolt Creek, Oregon, and Pasco, Washington, where special facilities were constructed. A weir and trap were constructed to intercept adults in Stavebolt Creek. A fish Ladder and three raceways were constructed to recover adults returning to the homing site at Pasco. In-river traps were constructed to intercept tagged adults in the fishladders at Bonneville, McNary, and Lower Granite Dams without having to sacrifice the fish. The traps generally consisted of a denil fishladder leading adults to a tag detection system which shunted all tagged fish into a trap (Figure 3). ALL experimental fish for homing and transportation tests were marked with a CWT and a brand which was readable on adults. Those returning to in-river traps could be identified by the brand, jaw-tagged to indicate they had been previously identified, and released to continue their upstream migration (Ebel et al. 1973). Discrete multivariate analysis was used to statistically compare test and control treatments of completed experiments (Bishop et al. 1975). In this procedure, the treatments were structured by the G-statistic (Sokal and Rohlf 1981). Significance was established at $P<0.05$, $df=1$

STEELHEAD EXPERIMENTS

Analysis of the 1978 and 1979 experiments on steelhead from the upper mid-Columbia River and 1978 experiments from the Snake River areas (Table 1) were reported by Slatick et al. (1982 and 1983).

Returns of adults from the 1979 and 1980 experimental releases of smolts from the Snake River area are essentially complete. The final

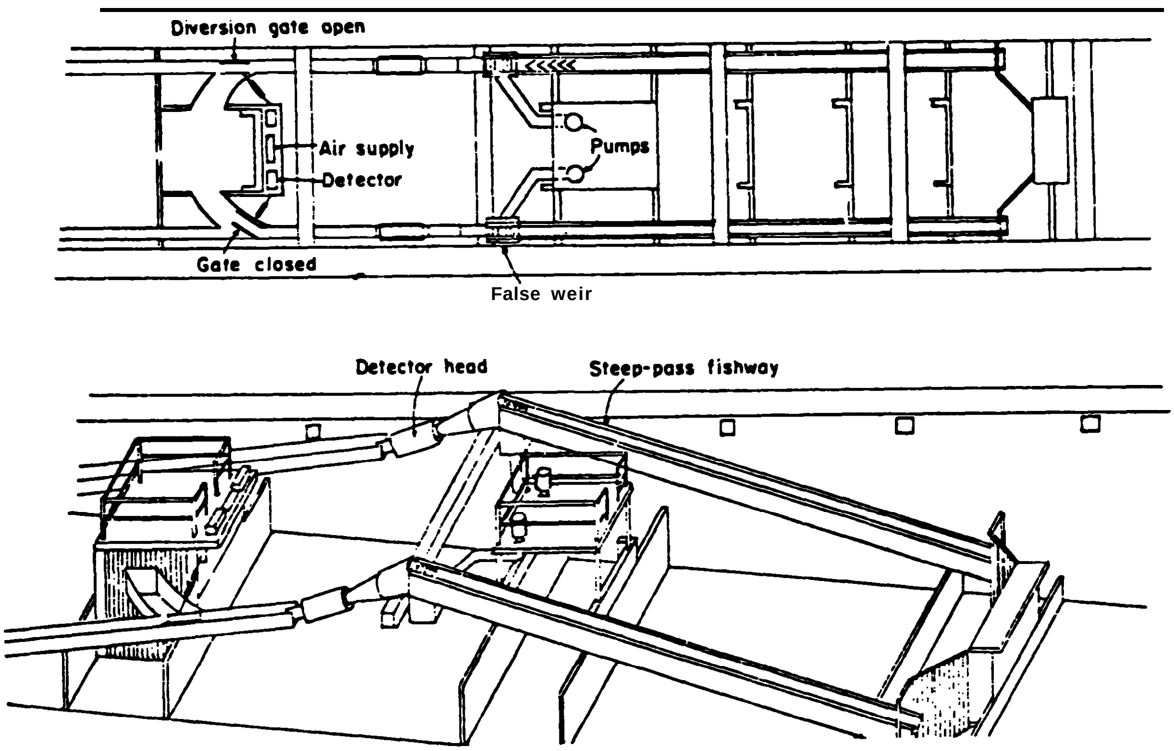


Figure 3.--Plan view and isometric diagrams of wire tag detector and fish separator systems used at Bonneville, McNary, and Lower Granite Dams,

analysis of the 1979 and 1980 Tucannon experiments, with statistical treatment, are presented here. Final analysis of the 1980 Dworshak experiment is in Appendix A.

Tucannon, 1979

Background and Experimental Design

The objective of the 1979 Tucannon Hatchery [Washington Department of Game (WDG)] homing test was to determine if sequential exposure to hatchery and migration route waters prior to release would ensure homing of returning adult steelhead.

The spring water portion of the hatchery water supply was used as the initial homing cue. Two groups of fish which had been maintained on 100% Tucannon River water were removed from the hatchery ponds and held in a tank truck while the composition of the water supply to the ponds was altered. The fish were then returned to the ponds, one of which contained 100% spring water and the other a 20:80% mixture of spring and Tucannon River water. Following a 48-h holding period, the fish were transported by truck around the 34 miles of Tucannon River they would have encountered during a natural outmigration and loaded into a barge moored on the Snake Kiver at the Lyons Ferry Grain Terminal (RN 386). Ensuing barge transport to the release site below Bonneville Dam (RM 140) provided sequential exposure of test fish to Snake and Columbia River waters along the barge route. A control lot was released from the hatchery into the Tucannon Kiver (Figure 4). These fish provided data on survival and behavior for naturally imprinted nonindigenous steelhead of the same stock as our test release. Steelhead used were Skamania stock (WDG), a lower river race from the Washougal River, Washington.

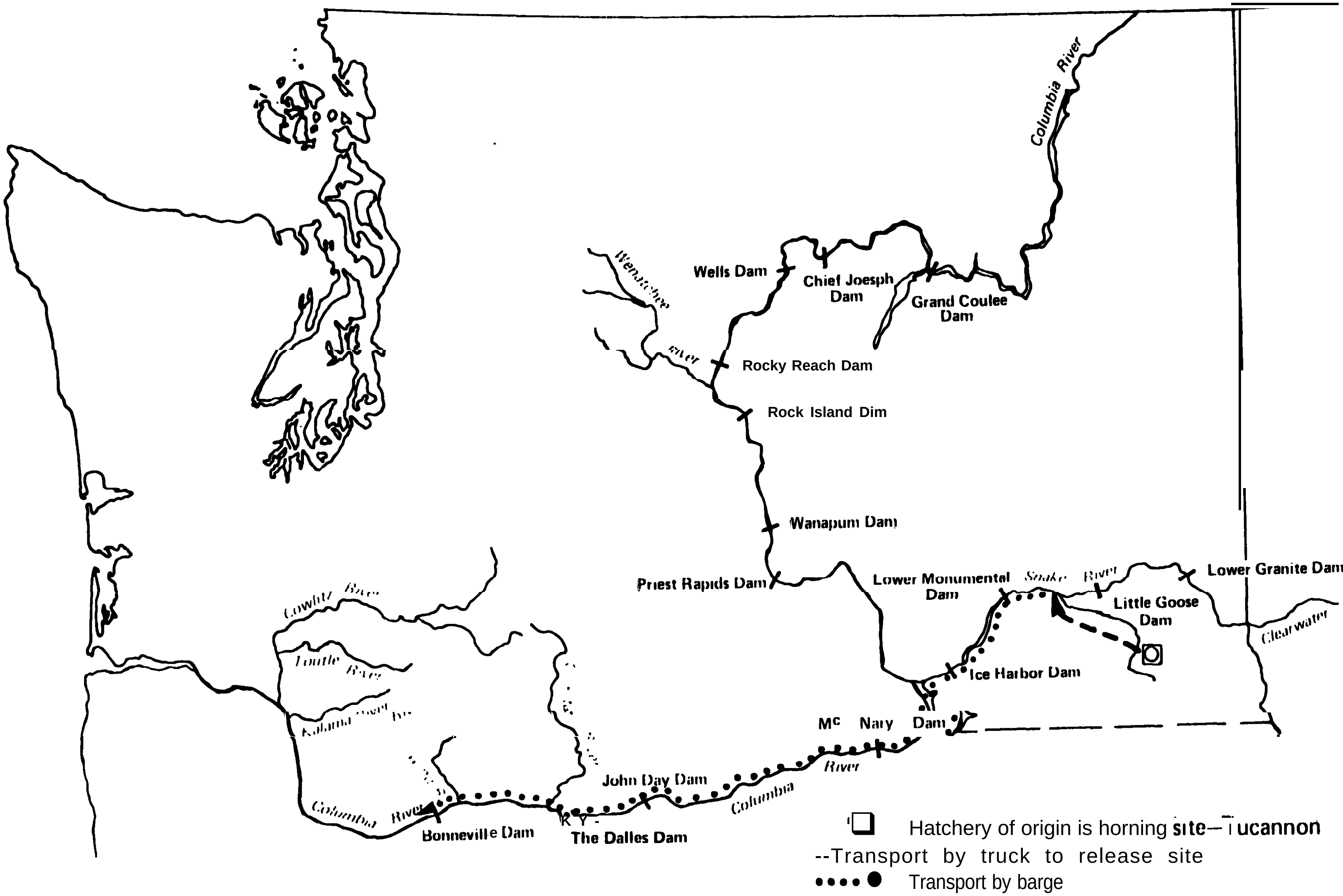


Figure 4.--Study area germane to the 1979 homing experiment with steelhead from the Tucannon Hatchery (WDG).

With slight modification (test fish held 2 h in tanker instead of 1 h, and a control release from the hatchery into the Tucannon River vs Grande Ronde River), this is a replicate of the experiment conducted in 1978. Additional details of the experimental design are given in Slatick et al. (1980).

Kesults

Adult returns to the in-river sampling sites and to the sport fisheries through 1983 complete the expected returns from this experiment. Total adult recoveries at dams and the Indian Zone 6 fishery are summarized in Table 2. Estimated recoveries in the fisheries and at Priest Rapids and Lower Granite Dams are summarized in Table 3. Miscellaneous returns in sport fisheries and hatcheries are summarized in Appendix Table B1.

Homing.--In general, the homing behavior of adult steelhead, transported as smolts in 1979, was similar to the 1978 experiment (Slatick et al. 1982). Returns of adults indicate the methods used in 1979 were unsuccessful in returning steelhead from any of the test or control groups to the Tucannon Hatchery homing site.

Recoveries of marked adults at Lower Granite Dam (45 miles upstream from the mouth of the Tucannon River) indicate that a portion of the barged test fish received a homing cue to the Snake River during the barge transport process (Table 2). Although these test fish overshot their home stream, their return to the Snake River is evidence that homing cues were acquired during barge transport.

Table 2.--Complete returns to four samplng locations of l-, 2-, and 3-ocean age steelhead from control and test releases as smolts from the Tucannon Hatchery in 1979. Recoveries were from June 1980 to November 1983.

Sampling location and experiment	Control or test	Number juveniles released	No. of adults recaptured[a/] l-ocean age	2-ocean age	3-ocean age	Total 1,2,3	Adult return % of juveniles released[b/]	Test to control ratio
Bonneville Dam								
Tucannon	control	24,787	1	1	0	2	0.008	
100% spring water	test	20,728	3	22	2	27	0.133**	16.25:1
20% spring water	test	22,058	2	4	1	7	0.031	3.88:1
Indian fishery								
Tucannon	control		0	0	0	0	0.000	
100% spring water	test		2	19	5	26	0.125	
20% spring water	test		0	13	5	18	0.081	
McNary Dam								
Tucannon	control		5	1	0	6	0.024	
100% spring water	test		0	0	0	0	0.000	
20% spring water	test		1	0	1	2	0.009	0.38:1
Lower Granite Dam								
Tucannon	control		0	1	0	1	0.004	
100% spring water	test		1	5	1	7	0.034	8.5:1
20% spring water	test		0	1	0	1	0.004	1.1:1
Total		67,573	15	67	15	97		

a/ Because of differences in sampling intensity (efficiency) at each trapping site, results are not comparable between sites.

b/ Numbers of controls recovered are too small to test for statistical significance between control and test groups.

** P < 0.01, df=l indicates significant difference between two test groups.

Whether homing to the Snake River differed between 1978 and 1979 is not known. The data indicate that a greater proportion of the 1978 test release were imprinted to the Snake River than the 1979 release (58% of the total estimated recoveries were from Lower Granite Dam for the 1978 release vs 40% for the 1979 release). However, as discussed in the next section on survival, poor river conditions for passage of adults in 1981 may have impacted their survival and reduced the opportunity for recovery of additional test fish from the 1979 release at Lower Granite Dam. If true, this would mean that we underestimated the numbers of fish that were imprinted to the Snake River in the 1979 experiment.

Adult steelhead migrating similar distances, but choosing the mainstem Columbia River, would have to pass the Priest Rapids Dam sampling station. No test fish were observed at Priest Rapids Dam or taken in the sport fisheries located upriver from the dam. By comparison, eight of the control fish released from the hatchery into the Tucannon River were recovered at Priest Rapids Dam, and four were caught in the Wenatchee River sport fishery (Appendix Table Bl). This would indicate that straying of noni ndigenous stocks of fish can be caused by reasons other than transportation and lack of imprinting.

A substantial number of test juveniles did not receive an imprint to the Snake River and remained in the Columbia River below the confluence of the Snake River. This was indicated by the following data: (a) the test/control (T/C) ratios (16.25:1 and 3.88:1) were higher at Bonneville Dam than at Lower Granite Dam [8.5:1 and 1:1 (Table 2)); (b) only test fish remained in the Bonneville area and were taken in the fall and winter Zone 6 Indian fishery (Table 3); and (c) 21 test fish were recovered at

Table 3.--Minimum estimated recovery of steelhead in Lndian fishery (Zone 6) and Priest Rapids and Lower Granite Dam sampling sites, and actual recoveries in the sport fishery and hatcheries from control and test releases of smolts imprinted to the Tucannon Hatchery in 1979.

Location and recovery[a/]	Number and % of adults recaptured					
	Control (24,787)[b/]		100% spring water (20,728)[b/]		20% spring water (22,058)[b/]	
	N	%	N	%	N	%
Indian fishery[c/] (Zone 6)						
Fall	0		28		22	
Winter	0		20		8	
Sub total	0	0.000	48	0.233	30	0.136
Sport fisheries and hatcheries[d/]						
Columbia River system below Snake River	0		11		10	
Columbia River system above Snake River	5		0		1	
Snake River system	0		1		0	
Sub total	5	0.020	12	0.058	11	0.050
TOTAL	5	0.020	60	0.289e/	41	0.186e/
Priest Rapids Dam[f/]	8		0		0	
Lower Granite Dam[g/]	3		39		4	
Sub total	11	0.044	39	0.189	4	0.018
Grand total	16	0.065	99	0.478	45	0.204

a/ Because of differences in recovery (efficiency) at each location, results are not comparable between sites.
b/ Number of juveniles released.
c/ Estimated recoveries based on sampling the Zone 6 Indian fishery.
d/ Actual recoveries.
e/ Total for barged fish $\frac{60 + 41}{20,728 + 22,058} = \frac{101}{42,786} = 0.236$
f/ Estimated recoveries based on WDG samplng at Priest Rapids Dam.
g/ Estimated recoveries are based on recoveries of jaw-tagged versus coded wire-tagged only adult steelhead at hatcheries upriver from Lower Granite Dam from control and test releases of juveniles from the transportation study.

hatcheries and in sport fisheries below the confluence of the Snake River, as compared to only the recoveries of two test fish in the fisheries above the mouth of the Snake River (Table 3).

Survival and contribution to fishery.--Transporting the fish around dams enhanced survival. Up to 16 times as many transported fish returned as adults to the Bonneville Dam sampling site as did controls. Survival of fish from the 100% spring water test group was significantly higher ($P<0.01$, $df=1$ than survival of fish from the 20% spring water test group. The 16: 1 transport benefit was over twice the 7.19: 1 benefit measured in 1978. The increased benefit may have been due to poorer survival of control releases in 1979.

The 0.065% estimated recovery rate of adults from the control release in 1979 was less than one-tenth that of the 0.841% estimated recovery of the 1978 release indicating a much lower survival of control fish released in 1979. We assumed this was mostly because juveniles from the 1979 control release incurred mortalities in passing six hydroelectric dams on their seaward migration; whereas a large number of the juveniles from the 1978 control releases (made in the Grande Ronde River) avoided these losses by being collected at upriver collector dams (Little Goose and Lower Granite Dams) and transported below Bonneville Dam. Recoveries of marks from these releases at Jones Beach in 1978 and 1979 provided credence to our assumption. Sampling of the 1979 smolt outmigration showed a significantly higher ($P<0.01$, $df=1$ survival rate of fish from the transported releases than from the control release (Dawley et al. 1980).

The 0.337% estimated recovery rate of test fish released in 1979 was less than one-third that of the 1.08% estimated recovery of the 1978 release, indicating a much lower survival of test fish also in 1979. This was partly due to lower survival back to the river and partly to adverse river conditions further impacting survival and/or homing of adults returning in 1981. Comparisons of adults recovered in the lower river fisheries indicated that survival of the 1978 release was about 2-1/2 times higher than the survival of the 1979 release. By contrast, comparisons of recoveries at Lower Granite Dam showed that returns from 1978 test fish releases were over five times that of the 1979 release; indicating an additional 50% loss of fish occurred between the lower and upper river. We suspect that adverse river conditions were to blame for much of this loss.

A majority of adults from this stock of steelhead migrated over Bonneville Dam from June to mid-July 1981, a period of high spill at mainstem dams. During this time the presence of gas bubble disease in adult steelhead was observed at the Bonneville Dam sampling site (29 June to 6 July 1981). As they migrated upriver, subsequent exposure could have resulted in mortality to some of the fish.

Adults which were imprinted and continued their migration to the Snake River were confronted with high water temperatures (ranging from 70" to 78°F) from 17 July to 15 September. Historically, such temperatures result in a thermal block to migrating steelhead. In most years, such temperatures occur for a 2-3-week period in late August and early September. Fish generally hold in the cooler Columbia River below the mouth of the Snake River until water temperatures in the Snake River begin to drop. For late migrating fish, a short delay is not a problem.

However, a delay of over 2 months as occurred in 1981 may have been sufficient to prevent as many as 50% of these fish from making it back upstream to Lower Granite Dam. Because of this, it was difficult to correctly determine degree of differences in homing and survival between the 1978 and 1979 experiments.

Conclusions

1. Adults from both test and control groups failed to return to the Tucannon Hatchery homing site.

2. During the barging processes, a portion of the test fish received a homing cue which enabled some adults to home to the Snake River.

3. Those test fish failing to imprint to the Snake River returned as adults to and remained in the Columbia River and its tributaries below the confluence of the Snake River.

4. The combination of impaired homing and enhanced survival of transported fish resulted in barged releases providing approximately 11 times as many fish to the user groups as control releases (estimated recovery in fisheries--0.236% for barged fish vs 0.020% for control fish).

5. An accurate assessment of survival and homing for this experiment was not possible because of probable adult losses in 1981 due to adverse river conditions.

Tucannon-Little Goose Dam, 1980

Background and Experimental Design

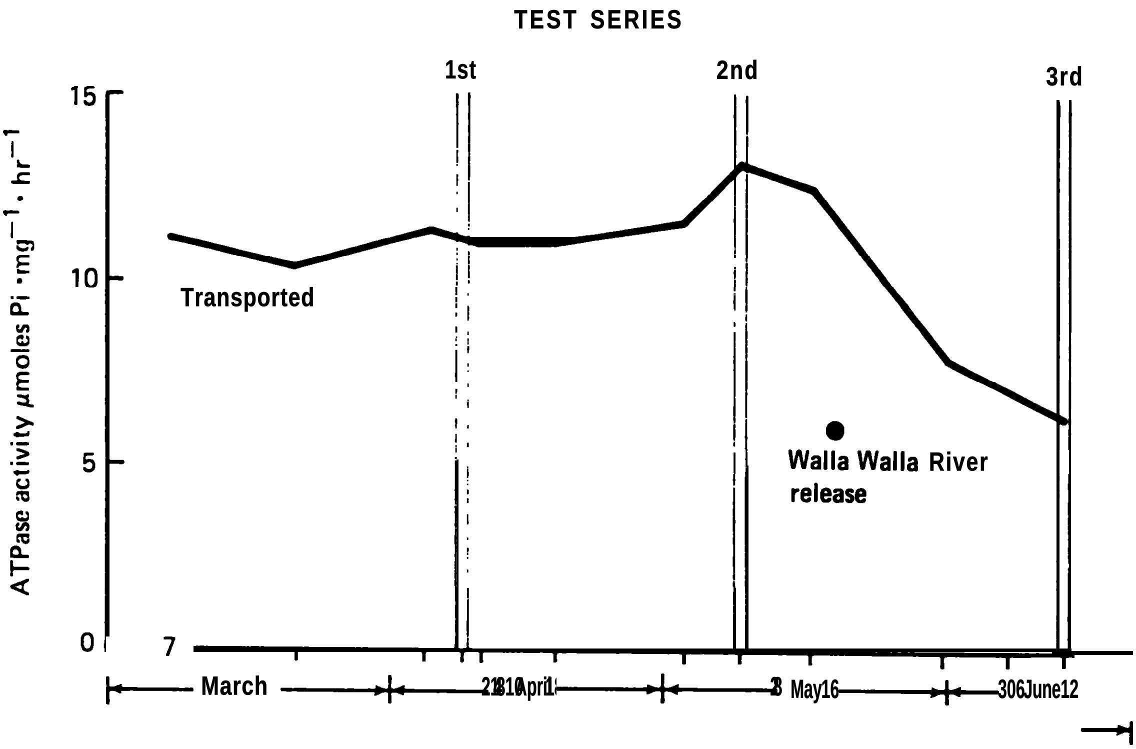
The object of this experiment was to determine if Na+-K+ ATPase enzyme activity in juvenile steelhead at the time of the imprint attempt and subsequent transport had an effect on the subsequent homing and survival of adults.

Measurements for a profile of the Na^+-K^+ ATPase enzyme activity were taken from 7 March to 12 June 1980 at the Tucannon Hatchery. Juveniles were released on the rise, peak, and decline of the Ka^+-K^+ ATPase profile on 8 April, 8 May, and 12 June, respectively (Figure 5). These three test groups of fish were imprinted to the Snake River at Little Goose Dam and transported by truck to a release site at Dalton Point in the Columbia River below Bonneville Dam (Figure 6). A control release into the Snake River was not made. A group of marked steelhead was originally scheduled to be released into the Grande Ronde River to serve as a control for this experiment; however due to management decisions, they were released into the Walla Walla River. These fish were to provide data on survival and behavior for naturally migrating nonindigenous steelhead of the same stock as our test releases. Steelhead used were Chelan stock (WDG), a mixed racial group of steelhead which migrate to the upper mid-Columbia River above Priest Rapids Dam (brood stock are taken from the fishway at Priest Rapids Dam each year). Additional details of the experimental design are given in Slatick et al. (1981b).

Results

Adult returns to in-river sampling sites and to the sport fisheries through 1983 complete the expected returns from this experiment. Total adult recoveries of transported fish in the Columbia River system are summarized in Table 4. Estimated recoveries in the fisheries and at Lower Granite Dam are summarized in Table 5.

Homing.--Recoveries of adult steelhead in the Snake River system indicated that juveniles released at or near the peak of the Na^+-K^+



Number of adults recovered	36	110	1	1
Average mm at release	168.6	173.9	135.7	172.8

Figure 5.--Composite Na^+-K^+ ATPase profile for steelhead smolts reared at the Tucannon Hatchery, indicating size at release, number of adult recoveries, and time frame for imprinting tests in 1980. Serial releases of marked transported fish were made on 8 April, 8 May, and 12 June 1980.

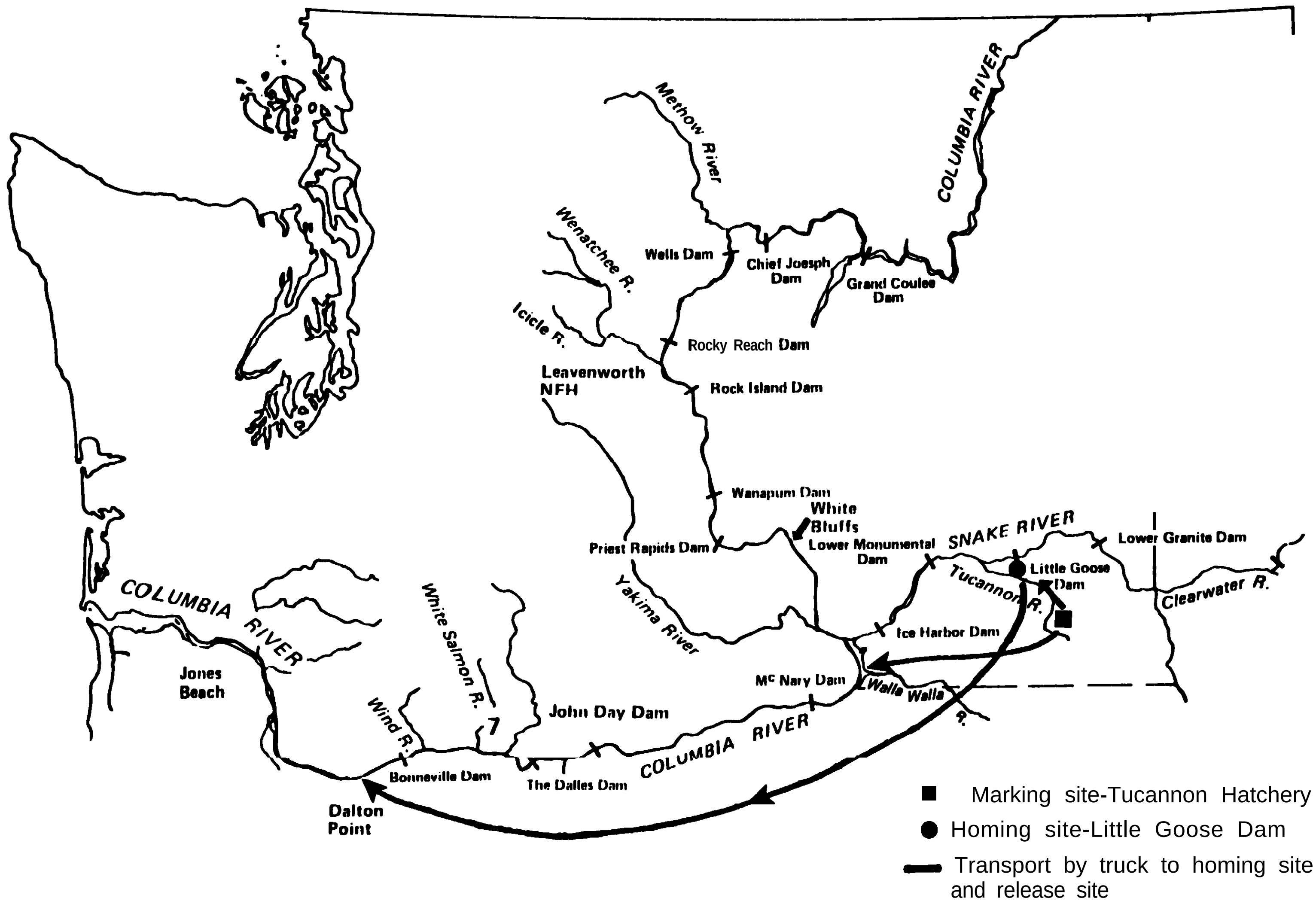


Figure 6. --Study area geermane to the 1980 homing experiment with steelhead from the Tucannon Hatchery (WDG) .

Table 4.--Complete returns to fisheries, hatcheries, and sampling sites of 1-, 2- and 3-ocean age steelhead from serial releases of juveniles based on the rise, peak, and decline of their Na+-K+ ATPase enzyme activity profile. The fish were reared at the Tucannon Hatchery, imprinted to the Snake River, then transported by truck to below Bonneville Dam and released into the Columbia River in 1980. Recoveries were from June 1981 to November 1983.

	Number and % of adults recovered[a/]					
	1st ATPase release 8 April (21,652)[b/]		2nd ATPase release 8 May (19,747)[b/]		3rd ATPase release 12 June (18,964)[b/]	
Sampling location	N	%	N	%	N	%
mid-Columbia River (below Snake R.)						
Bonneville Dam	5		5		0	
Indian fishery	23		90**		0	
McNary Dam	0		0		0	
Sport fishery	7		6		0	
Hatcheries	0		2		0	
Subtotal	35	0.162	103	0.522**	0	0.000
Upper Mid-Columbia River (above Snake R.)						
Priest Rapids Dam	0		0		0	
Hatcheries	0		0		1	
Subtotal	0	0.000	0	0.000	1	0.005
Snake River						
Lower Granite Dam	1		4		0	
Sport fishery	0		2		0	
Hatcheries	0		1		0	
Subtotal	1	0.005	7	0.035	0	0.000
Grand Total	36	0.166	110	0.557**	1	0.005

a/ Because of differences in sampling intensity (efficiency) at each recovery site, results are not comparable between sites.
b/ Number of juveniles released.

** P<0.01, d f = 1; indicates significant difference between 1st and 2nd ATPase release group.

ATPase activity profile (second release) homed back to the Snake River as adults in greater numbers than adults from juveniles released on the rise (first release) or extreme decline (third release) of the profile curve (Table 4). However, the best return was only seven fish (0.035%). This is in sharp contrast to the recovery of 279 fish (1.591%) from a similar experiment conducted in 1976, which used the same stock of fish (Slatick et al, 1981a). Release strategies used in 1980 obviously did not provide the needed cues for returning fish to the Snake River. Over 80% of the estimated return failed to imprint to the Snake River (57 in Snake River vs 274 overall recovery--Table 5).

The complete lack of recoveries of adults from the third Na+-K+ ATPase release series in the fisheries or at the sampling sites in the mid-Columbia and Snake Rivers indicated that these juveniles may have reverted to parr and may have been physiologically unable to imprint a homing cue to the Snake River. Novotny (in press 1984) states that by June 12, all size groups of fish in the third Na+-K+ ATPase release had entered a pos t-smolt condition.

Survival and contribution to fishery.--Survival of fish from the second release was significantly greater than from the first release ($P<0.01$, df=l). Recoveries from the third Na+-K+ ATPase and Walla Walla River releases were too few to test for statistical significance. Estimated recoveries indicated that the second release provided 4.1 times more fish to the Indian fishery and 1.75 times more fish to the sport fisheries and hatcheries than did fish from the first Na+-K+ ATPase release (Table 5).

Table 5 .--Minimum estimated recovery of steelhead in Indian fishery (Zone 6) and Lower Granite Dam sampling sites, and actual recoveries in the sport fishery and hatcheries from releases of juveniles imprinted to the Walla Walla and Snake Rivers in 1980. Recoveries were from June 1981 to November 1983.

Location and recovery[a]	Number and % of adults recaptured							
	Walla Walla R. Natural migration[b] 17-18 May[c] (17,923)[d]		1st ATPase release Transported[b] 8 April[c] (21,652)[d]		2nd ATPase release Transported[b] 8 May[c] (19,747)[d]		3rd ATPase release Transported[b] 12 June[c] (18,964)[d]	
	N	%	N	%	N	%	N	%
Indian fishery[e]								
Fall	0		5		25		0	
Winter	0		37		134		0	
Sub total	0	0.000	42	0.195	159	0.806	0	0.000
Sport fisheries and hatcheries[f]								
Columbia River system below Snake River	0		7		8		0	
Columbia River system above Snake River	0		0		0		1	
Snake River system	0		0		3		0	
Subtotal	0	0.000	7	0.032	11	0.056	1	0.005
TOTAL	0	0.000	49	0.226	170	0.861	1	0.005
Lower Granite Dam[g]	16	0.095	4	0.018	50	0.253	0	0.000
GRAND TOTAL	16	0.095	53	0.245	220	1.114	1	0.005

a/ Because of differences in recovery (efficiency) at each locations, results are not comparable between sites.
b/ Type of release.
c/ Release date.
d/ Number of juveniles released.
e/ Estimated recoveries based on sampling the Zone 6 fishery.
f/ Actual recoveries.
g/ Estimated recoveries are based on recoveries of jaw-tagged versus coded wire-tagged only adult steelhead at hatch- cries upriver from Lower Granite Dam from control and test releases of juveniles from the transportation study.

There appeared to be some correlation between the level of Na+-K+ ATPase enzyme activity and migratory survival. Juvenile steelhead in the second release group had the highest Na+-K+ ATPase enzyme activity level and also had the greatest number of adult recoveries (110 fish); fish in the first release group had the next highest Na+-K+ ATPase level and the next best survival (36 fish); fish in the third release group had the lowest Na+-K+ ATPase level on the profile and the poorest survival (1 fish – Figure 5).

Conclusions

1. The level of Na+-K+ ATPase apparently influenced homing and survival; within the Na+-K+ ATPase levels tested, the best adult returns were from the group released when the levels of Na+-K+ ATPase were highest.

2. Migratory survival of steelhead juveniles that have not smolted or have reverted to parr (as indicated by Na+-K+ ATPase enzyme activity) is very poor.

3. When compared to an earlier study in 1976, the optimum release strategy for imprinting a homing cue to the Snake Kiver in juveniles was not achieved in the 1980 experiment. A total of 279 adults from the 1976 study versus 7 adults from the 1980 study were recovered in the Snake Kiver.

SALMON EXPERIMENTS

Analysis of the 1578 and 1979 experiments on spring chinook salmon from Kooskia and Carson National Fish Hatcheries (NFH), the 1978 and 1980 experiments on coho salmon from Carson and Willard NFH, and the 1979 experiment on fall chinook salmon from Spring Creek NFH (Table 1) were reported by Slatick et al. (1980, 1981b, 1982, 1983). Returns of adult spring and fall chinook salmon from the six 1980 experiments are now complete. The final analysis of results with statistical treatment are presented in this report and in Appendix A.

Spring Chinook Salmon, Carson NFH, 1980

Background and Experimental Design

The objective was to imprint spring chinook salmon to return to Carson NFH by a simulated release at the hatchery combined with single or sequential exposure to early outmigration route waters (Tyee Springs and Wind River). The experiment was a replicate, with minor modifications of the 1979 homing test conducted at Carson NFH (Slatick et al. 1980).

Experimental design consisted of a control group released from Carson NFH and three test groups which were given variations of the simulated release imprint technique. Test groups following simulated release were transported by truck and released at Dalton Point (RM 142), or Hammond, Oregon, (RM 8) (Figure 7). All fish were premarked several months prior to release. Further details on experimental background and design are given in Appendix Table B5 and in Slatick et al. (1981b).

To evaluate the experiment, we examined returns to Carson NFH and sampled upstream migrant spring chinook salmon at the Bonneville Dam trapping facility. In addition, we checked tag recovery data from ocean and Columbia River spawning ground surveys and hatcheries.

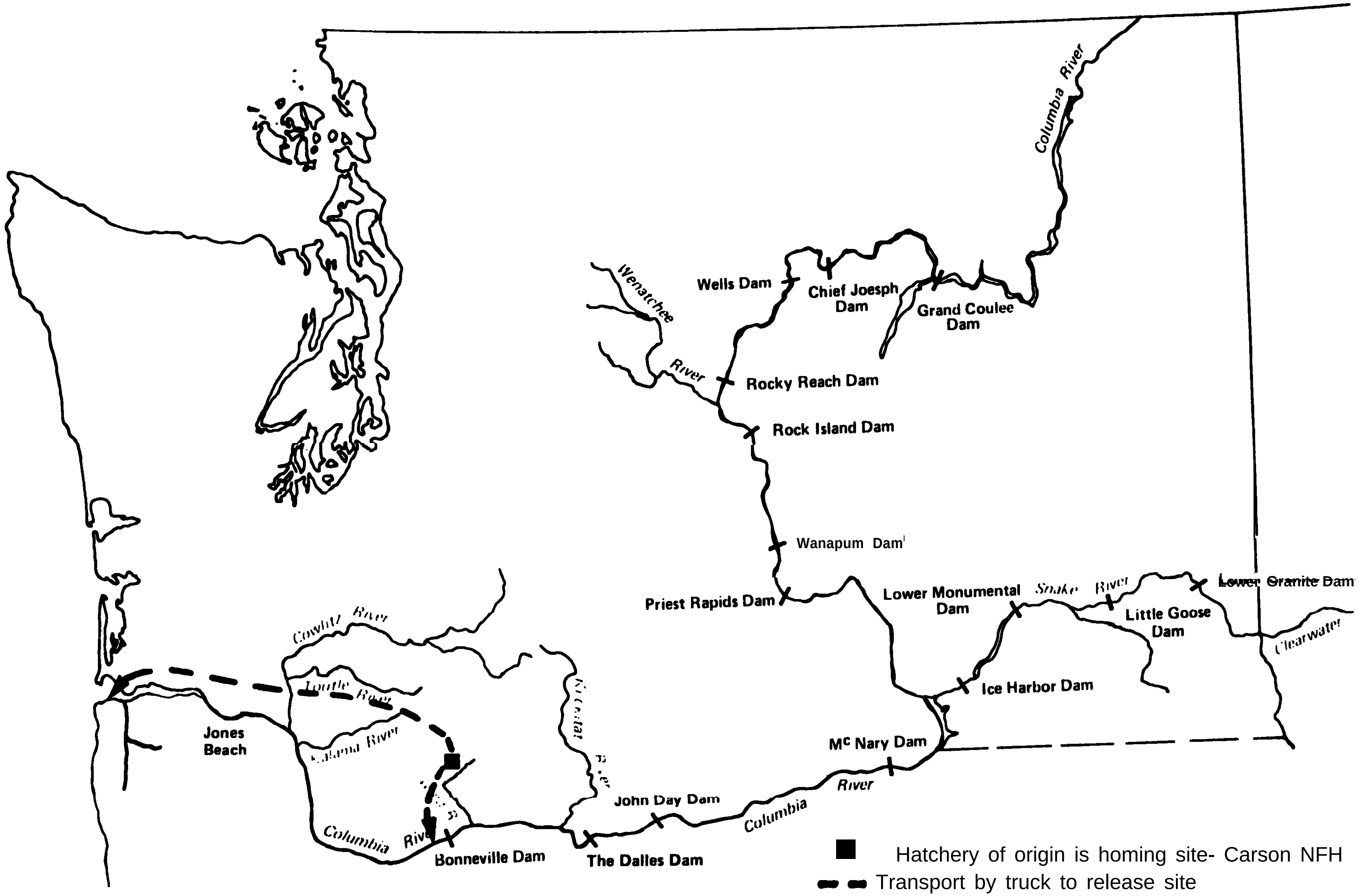


Figure 7.--Study area germance to the 1980 homing experiment with spring chinook salmon from the Carson NFH.

Kesults

Adult returns were negligible: two recoveries were from the control group (one at Carson NFH and in the Canadian ocean fisheries) and one recovery from Test Group 2 (sequential imprint – Dalton Point release). The Test Group 2 recovery was made during spawning ground surveys of the Wind River in 1983.

Juvenile sampling data and delayed mortality in 14-d holding tests did not indicate any problems with these fish releases. Juvenile spring chinook salmon from control and experimental groups were recaptured during MNFS sampling of the 1980 outmigration at Jones Beach (Dawley et al. 1981). Recapture data are presented in Table 6. Recapture rates were higher for test groups released at Dalton Point than for the control group released at Carson NFH. Rate of recapture was also comparable to other marked groups of fish passing Jones Beach. Holding of samples from the Dalton Point release groups for observations of delayed mortality resulted in 14-d survival rates averaging 92%.[1/]

The lack of adult returns was apparently not due to hatchery problems. The U.S. Fish and Wildlife Service (USFWS) estimated 2,524 adults (0.11%) returned from the 1980 production release of 2.3 million fish.[2/] At that rate, 37 fish rather than one from the control release should have returned to the hatchery. Therefore , the most logical explanation is delayed mortality from handling and marking. Since it mostly occurred below Jones Beach, it is probable that the additional stress from marking induced

1/ Personal communication. Dr. Tim Newcomb, Natl. Mar. Fish. Serv., 2725 Montlake Blvd. East, Seattle, Washington 98112.

2/ Personal communication. Craig JUGS, FAO, USFWS, Vancouver, Washington.

Table 6.--Jones Beach outmigrant recaptures of juvenile spring chinook salmon marked for the 1980 Carson NFH homing experiment.

Experimental group	Number released	Recaptures[a]	
		No.	%
Control Hatchery release	37,499	19	0.051
Test #1 Single imprint Dalton Point release	36,262	36	0.099
Test #2 Sequential imprint Dalton Point release	41,537	23	0.055
Test #3 Sequential imprint Hammond, Oregon,release	43,180	--	--

a/ Number and percent of release adjusted for sampling effort.

delayed mortality after entry into seawater. Previous studies by NMFS and other agencies have shown that stressed fish survive at a lower rate in seawater than unstressed fish[3/], and some diseases such as bacterial kidney disease (BKD) manifest themselves after entry into seawater (Slatick et al. 1983).

Conclusions

1. Negligible adult recoveries from test and control releases precluded an analysis of homing objectives.

2. Survival rates (average 92%) of marked juvenile spring chinook salmon from 14-d delayed mortality holding tests and sampling of outmigrants at Jones Beach indicated no serious short-term mortality due to stress of handling or transportation.

3. Survival of the marked juvenile spring chinook salmon until their return as adults was severely affected by an unknown factor(s).

Spring Chinook Salmon, Leavenworth NFH, 1980

Background and Experimental Design

The principal experimental objective was to imprint spring chinook salmon for return to Leavenworth NFH. The imprint technique consisted of short-distance (1 mile) volitional migration followed by recapture and truck transport. Leavenworth NFH was chosen as the test site due to availability of fish for research purposes, existence of adult return facilities, and suitability of the nearby Icicle River bypass channel for recapture of volitional migrants. Preparation of the Icicle River channel

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3/ Personal communication. Gene Matthews, Natl. Mar. Fish. Serv., 2725 Montlake Blvd. East., Seattle, Washington 98112.

for the test included installation of an inclined plane trap and enclosure of an area for fish holding.

Five marked groups of approximately 100,000 fish per group were used in the study (Appendix Table B6). With the exception of a control group marked in November 1979, experimental handling and marking took place during the spring of 1980, coincident with timing of the natural outmigration. During this time, we believed the fish were most Likely to accept imprinting and to exhibit true volitional migration. Handling of most marked groups was extensive. Experimental groups which required volitional migration were released at the head of the Icicle River bypass channel, recaptured at the trap, and then returned to hatchery raceways for marking and subsequent transport.

Groups to be released at either White Bluffs or Dalton Point (Figure 8) were transported in 5,000-gallon tank trucks. For each group, releases were made on three dates: 24 and 27 April and 1 May. For groups other than the fall-marked control, fish released on different dates had unique cold brands and wire tag codes. This procedure was followed to allow evaluation of returns in the event of significant mortality in an individual transport load.

Specific experimental objectives and the relationship of marked groups to objectives were as follows:

1. Effects of handling fish at or near smoltification. Two groups were marked and released as controls from Leavenworth NFH. Control Group 1 was marked in November 1979. Control Group 2 was composed of volitional migrants recaptured and marked in April 1980, Comparison of returns to the hatchery would indicate to what extent survival was reduced by spring handling.

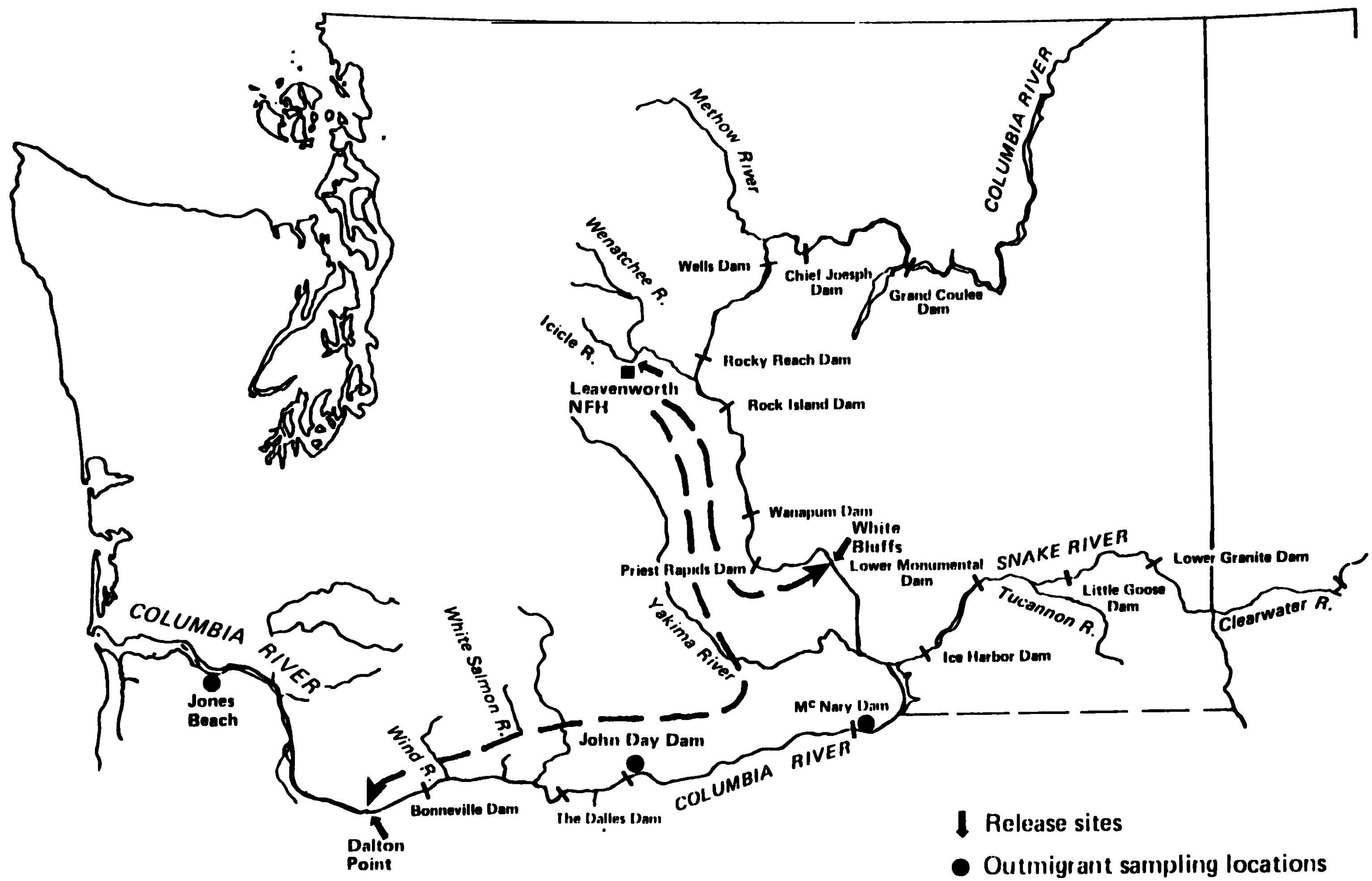


Figure 8.--Study area for the 1980 homing experiment with spring chinook salmon from the Leavenworth NFH.

2. Homing of fish allowed 1 mile of volitional migration, followed by transport to White Bluffs. Comparison of ret urns from the White Bluffs release (Test Group 1) and the spring-marked control would be made. Return ratios observed at the hatchery and at lower river locations would determine if imprinting occurred in the White Bluffs release, and if so, in what proportion of the release group.

3. Homing of fish allowed 1 mile of volitional migration, followed by transport to Dalton Point. Comparison of ret urns from the Dalton Point release (Test Group 2) and the spring-marked control would be made. As in Objective 2, results would indicate whether or not imprinting occurred and in what proportion of the group. Additional comparison of returns would be made between this Dalton Point release and the White Bluffs release. Results would determine if imprinting was disrupted by transportation to the more distant Dalton Point release site.

4. Homing of fish held in an enclosed section of the Icicle River bypass channel then transported to Dalton Point. Returns from this group (Test Group 3) would be compared with returns from volitional migrants released at Dalton Point. Results would indicate if simple exposure to Icicle River water was as effective as volitional migration in imprinting spring chinook salmon to return to Leavenworth NFH.

5. Reduced or enhanced survival due to transportation. Returns from transported groups would be compared with returns from Control Group 2. If transport groups failed to home, evaluation would be based on Lower river recoveries.

To evaluate the experiment, we examined returns to Leavenworth NFH, sampled upstream migrant spring chinook salmon at river system Live traps

(Figure 8) and participated in spawning ground surveys in the Wenatchee River drainage. In addition, we checked tag recovery data from fisheries and Columbia River hatcheries.

Results

Spring chinook salmon marked for the experiment returned as 4- and S-year-old fish during 1982 and 1983, respectively. Recovery location and number of recoveries by marked group are given in Table 7.

Homing.--Statistical analysis of homing objectives was not possible due to low returns for the spring-marked control and truck transport groups. Although returns were low, it is noteworthy that fish transported to White Bluffs (RM 362) returned to Leavenworth NFH about as well as fish from the spring-marked control groups. Similar behavior was not seen for fish transported to Dalton Point (RM 142) from either the volitional-migrant or pen-held groups, None of these fish returned to Leavenworth NFH, and of five observed returns, three were indicative of straying (recoveries in the Drano Lake and Sherears Falls sport fisheries and at Klickitat Hatchery).

Homing behavior shown by fish from the White Bluffs release may have resulted from cues acquired during migration down the Icicle River bypass channel. Lack of homing for the corresponding Dalton Point releases indicates that regardless of source, the imprint was insufficient to guide the return of fish which had been transported farther downstream.

Survival.--Spring chinook salmon from experimental releases were recaptured during NMFS sampling of the 1980 outmigration. Recaptures were observed at McNary Dam, John Day Dam, and/or Jones Beach, depending on

Table 7.--Adult returns of spring chinook salmon marked for the 1980 Leavenworth NFH homing experiment.

Recovery area	Experimental group and number released				
	Control 1 98,638 Marked fall 1979	Control 2 98,789 Marked spring 1980	Test 1 100,105 Volitional migr. White Bluffs release	Test 2 98,448 Volitional migr. Dalton Pt. release	Test 3 96,633 Pen held Dalton Pt. release
River system live traps					
Bonneville trap	1	2	1	1	0
McNary trap	5	0	0	0	0
Sport fishery					
Drano Lake	0	0	0	1	0
Deschutes River	0	0	0	1	0
Indian ceremonial fishery	0	0	0	1	0
Hatcheries					
Klickitat Hatchery	0	0	0	0	1
Leavenworth NFH	48[a]	4	6	0	0
Total	52	6	7	4	1

a/ Includes two fish observed previously at the McNary trap.

where the fish were released (Figure 8). Relevant data from outmigrant sampling programs (Sims et al. 1981; Dawley et al. 1981) are presented in Table 8. Sample data indicate higher in-river survival for fish transported to White Bluffs or Dalton Point than for control releases from Leavenworth NFH. Survival of spring and fall marked control groups to sampling locations was nearly equal.

To provide data regarding the effect of transport stress on survival, NMFS personnel met each of the six Dalton Point transport loads, removed samples of approximately 200 fish, and held the samples for observation of delayed mortality as described by Park et al. (1981). After 14 days, survival in the samples averaged 94% (range 90-99%).4/

Adult returns from experimental groups were not consistent with the relative outmigrant survival indicated by juvenile sampling. Equal outmigrant survival for spring and fall-marked control releases were not reflected in adult returns. Instead, 48 fish from the fall marked release returned to Leavenworth NFH, but only four fish returned from the spring marked control. Similarly, very low adult returns were observed for White Bluffs and Dalton Point transport groups (Table 7).

Drastically reduced survival was common to all groups handled in the spring. Although ultimate survival was affected, it was not due to short-term mortality from stress of handling or transportation as indicated by a high rate of recovery of juveniles at dams and at Jones Beach. Instead, spring handling apparently predisposed these fish to extreme mortality following ocean entry. One explanation (discussed previously) the would be the inability of stressed fish to survive in seawater. A

4/ Personal communication. Dr. Tim Newcomb, Natl. Mar. Fish. Serv., 2725 Montlake Blvd. East, Seattle, Washington 98112.

Table 8.--Outmigrant recaptures of spring chinook salmon marked for the 1980 Leavenworth NFH homing experiment.

Experimental group	McNary Dam recaptures[a]		John Day Dam recaptures[a]		Jones Beach recaptures[a]	
	No.	%	No.	%	No.	%
Control 1 Marked fall 1979	9,241	9.562	241	0.249	31	0.032
Control 2 Marked spring 1980	11,326	11.465	344	0.348	31	0.031
Test 1 Volitional migration White Bluffs release	16,289	16.272	876	0.875	85	0.085
Test 2 Volitional migration Dalton Point release					134	0.136
Test 3 Pen-held in Icicle River Dalton Point release					91	0.093

a/ Number and percent of release adjusted for sampling effort.

second explanation could be related to disease. Disease surveys conducted during the spring of 1980 [Novotny and Zaugg 1984 (in press)] confirmed the presence of BKD organisms in 80 and 66% of the spring chinook salmon sampled on 31 March and 28 April, respectively. In a previous experiment reported in Slatick et al. (1983), spring chinook salmon held in seawater sustained severe losses due to BKD.

Decreased adult returns were also evident for the fall marked control group, although not to the extent seen for experimental groups handled in the spring. Both the 1982 and 1983 brood stocks at Leavenworth NFH were subject to biological sampling according to procedures established by USFWS. Results of the sampling indicate a return of approximately 2,900 fish (0.203%) from 1,423,000 unmarked spring chinook salmon released in 1980. Percentage return from the fall-marked control (0.050%) was significantly less ($P<0.01$, $df=1$). Handling and marking may have also influenced survival of this group, even through the fish were marked in November and not subjected to further manipulation.

Conclusions

1. Homing of adults from the volitional migration test group released at White Bluffs was comparable to the spring marked control release. However, numbers of fish recovered were too low to be of statistical significance.

2. Negligible adult recoveries from all experimental groups other than the fall marked control group and precluded an analysis. of the homing objectives.

3. The outmigrant survival indicated by juvenile sampling was not indicative of adult returns from experimental groups.

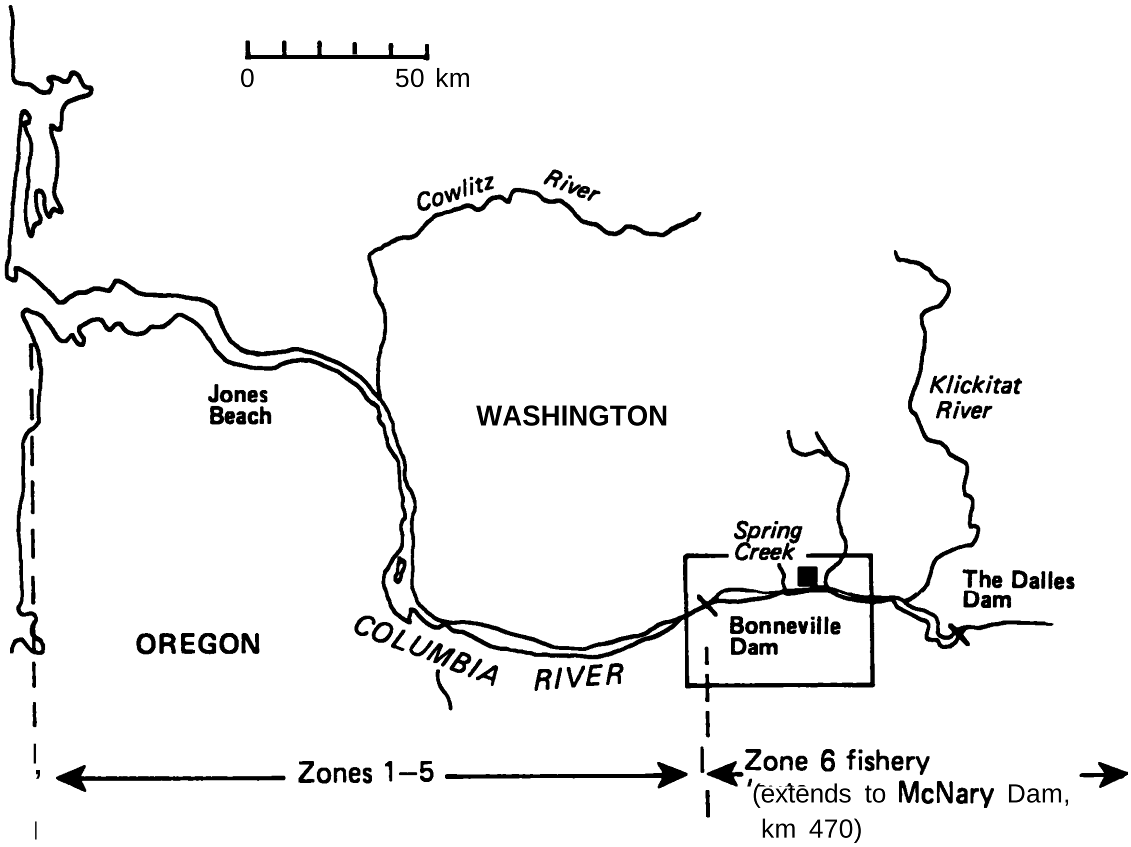
4. Handling and marking in the spring had more of an adverse impact on survival than marking in the fall.

Fall Chinook Salmon, Spring Creek NFH, 1980

Background and Experimental Design

The objective was to imprint juvenile fall chinook salmon which were transported by barge from Spring Creek NFH and released below Bonneville Dam to return as adults to the hatchery. The experimental design consisted of a control group and two test groups utilizing 259,786 marked fall chinook salmon from Spring Creek NFH. One experimental group was pumped directly from the raceways into a barge; the second group was crowded through a 350-ft transport channel before being pumped into the barge. Both groups were given sequential homing cues by being transported to a release site below Bonneville Dam by a barge initially containing Spring Creek water and then Columbia River water (Figure 9). The control group was marked by USFWS personnel as part of the fall chinook salmon hatchery evaluation study. Additional details of the experimental design are given in Slatick et al. (1981b).

This experiment may have been impacted by the eruption of Mount St. Helens on 18 May 1980. Juveniles in the control group were released from Spring Creek NFH on 6 May and migrated seaward under normal river conditions. Median passage of this group at the Jones Beach sampling site was 12-14 May (Dawley et al. 1981). Fish for the two test groups were loaded into the barge and released below Bonneville Dam on 19 May, one day



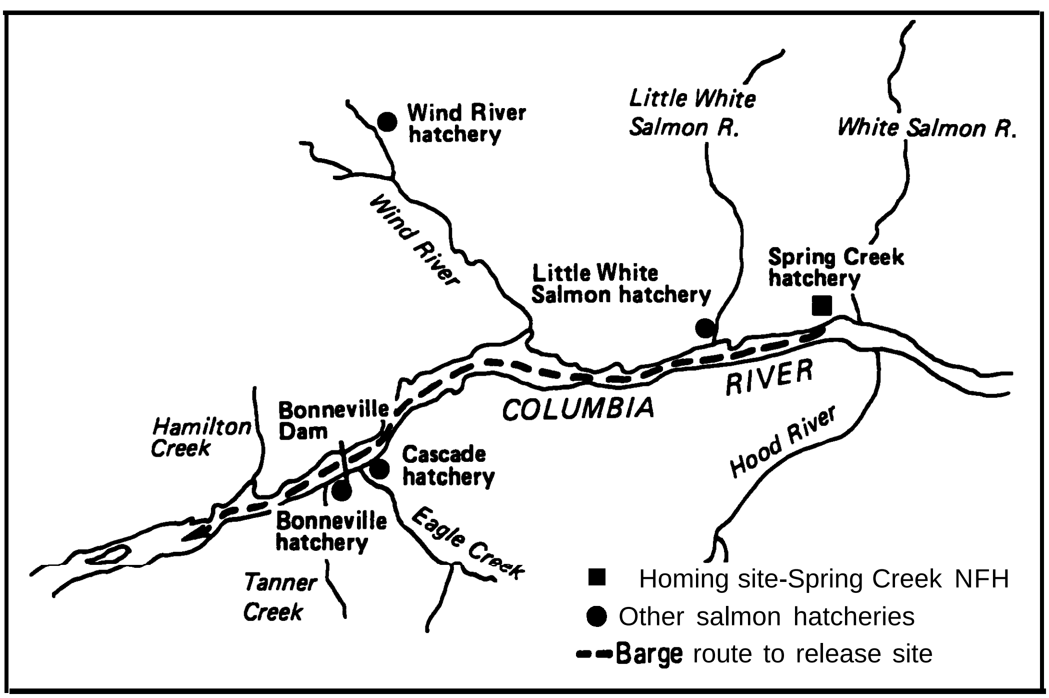


Figure 9.--Location map of release sites and recovery areas for the 1980 Spring Creek homing study.

after the volcanic eruption. During their seaward migration, the test fish had to contend with the plume of volcanic debris emitting from the Cowlitz Kiver. Median passage of the test fish at Jones Beach was 25 May. There is evidence from Dawley et al. (1981) that survival of subyearling chinook salmon was adversely impacted by the eruption.

Results

Preliminary results were discussed in Slatick et al. (1982, 1983). Additional recoveries at hatcheries and from ocean and Columbia River fisheries in 1983 completed the expected adult returns for this experiment.

Homing.--Adult recoveries at the Spring Creek NFH homing site indicated that the techniques used to implant a homing imprint in the juvenile fall chinook salmon were not completely successful. Recoveries indicated a T/C ratio of 0.67:l for fish from Test 1 and 0.52:1 for fish from Test 2 (Table 9). These lower recovery rates of fish from the test lots than from the control Lot were statistically significant ($P<0.01$, df=l).

A large number of adults strayed to other hatcheries in the Bonneville Pool area. Straying was more prevalent for fish from the test groups than from the control group. Of the total hatchery recoveries, up to 74% of the test fish and 14% of the control fish were recovered as strays to other hatcheries, primarily the Bonneville Hatchery (Table 10). The straying rate (14%) of control fish indicated that a 100% imprinting rate may not be feasible with this stock of fish. The 74 and 72% straying rates infer that only 26 and 28% of the juveniles (from Test Lots 1 and 2, respectively)

Table 9.--Recoveries of fall chinook salmon (1-, 2-, and 3-ocean age) at hatcheries and from the ocean and Columbia River fisheries that were released as control or test groups of smolts following imprinting to the Spring Creek NFH in 1980. Recoveries are through December 1983.

Experimental groups	Number released a/	Hatcheries: Spring Creek homing site N	Hatcheries: Spring Creek homing site %	Hatcheries: Bonneville area hatcheries N	Hatcheries: Totals hatchery recovery N	Hatcheries: Totals hatchery recovery %	River fisheries: Zone 1-5 N	River fisheries: Zone 6 N	River fisheries: Other b/ N	Combined Columbia River N	Ocean N	Total recovery N	Total recovery %	T/C ratio
Control (Spring Creek release)	60,500	121	0.200	20	141	0.232	57	121	2	321	235	556	0.919	
Test #1 (Loaded raceway and barged)	99,583	133	0.133**	388**	521	0.523**	101^{NS}	76**	1	698**	409^{NS}	1,107	1.112	1.21:1**
Test #2 (Loaded channel and barged)	99,703	104	0.104**	265**	369	0.370**	93^{NS}	81**	1	544NS	346^{NS}	890	0.893	0.97: 1^{NS}
Total	259,786	358		673	1,031		251	278	4	1,564	989	2,553		

a/ Adjusted for initial tag loss.
b/ Include sport fishery and spawning ground survey.

NS Nonsignificant
** $P<0.01$, d f = 1; indicates significant difference between test and control group.

Table 10.--A comparison of hatchery recoveries at the homing site and as strays to other hatcheries of fall chinook and coho salmon from the 1980 Spring Creek and Willard NFH homing experiments.

Experimental groups	Adult recoveries at hatcheries			
	Homing site		Other hatcheries	
	%	(N)	%	(N)
1980 Spring Creek fall chinook salmon				
Control	86.0	(121)	14.0	(20)
Barge Test 1	26.0	(133)	74.0	(388)
Barge Test 2	28.0	(104)	72.0	(265)
1980 Willard coho salmon				
Control	98.0	(252)	2.0	(4)
Conbined barge test	89.0	(201)	11.0	(25)

received a homing imprint when they were loaded into the barge containing Spring Creek NFH water. We believe that the short period (20 min and 1 h 55 min for Test Lots 1 and 2, respectively) these juveniles were in Spring Creek NFH water in the barge was insufficient for the majority of the fish to receive a positive homing imprint.

It is very possible that a longer imprint time (approximately 24 h) in a barge containing Spring Creek NFH water would give a more positive homing cue to fall chinook salmon smolts to return as adults to the Spring Creek NFH homing site. Slatick et al. (1982) reported that coho salmon juveniles, which had been held in a barge containing Little White Salmon River water for 19 to 21 h, exhibited a strong positive homing imprint. Of the total hatchery recoveries of adult coho salmon, 89% of the fish from the barged test groups and 98% of the fish from the control group returned to the Little White Salmon NFH homing site (Table 10).

Survival and contribution to fishery.--The data indicate that even though outmigrants from the barged test lots had to migrate through potentially adverse conditions caused by the volcanic plume, their survival equalled or surpassed the survival of the control release that migrated downriver prior to the eruption. Fish from Test Group 1 had a significantly ($P<0.01$, df=1) higher overall survival rate (ratio 1.21:1) than did fish from the control release (Table 9). Although there was no significant difference in the ocean recovery of fish between Test Lot 1 and the control release, fish from Test Lot 1 returned to the Columbia River in significantly ($P<0.01$, df=1) greater numbers than control fish (ratio 1.32:1). Survival of fish from Test Lot 2 was similar to survival of fish from the control release and significantly lower, ($P<0.01$, df=1) than survival of Test Group 1. The extra handling that juveniles in Test Lot 2 received when they were crowded through the transport channel before being pumped into the barge may have been responsible for their lower survival rate.

There were some significant differences in recoveries of fish from the test and control lots by various user groups in the Columbia River system. Up to twice as many barged as control fish were recovered at hatcheries in the Bonneville area (ratios: 2.25:l for Test 1 and 1.59:1 for Test 2). Because of lack of imprinting, significantly (P<O.Ol, df=l) more fish from barged groups than from the control group were recovered in hatcheries other than the Spring Creek NFH homing site. Conversely, significantly (P<O.Ol, df=l) more fish from the control group than from the barged groups were recovered at the Spring Creek NFH and also in the Zone 6 fishery (Table 9). Recoveries in the Zone l-5 fishery area showed no significant difference in the numbers of fish taken from either the barged or control lots.

Treatments used in this experiment significantly enhanced survival and provided some homing of test fish (up to 67% of rate of return of control fish to Spring Creek NFH). We would expect a significant improvement in numbers of test fish harvested in the Zone 6 fishery and returning to Spring Creek NFH if this study were repeated in a year without a volcanic eruption to impact survival of test fish. A longer imprint period in the barge might also increase the numbers of fish homing to their hatchery of origin.

Conclusions

1. Methods used to implant a homing cue in test groups of juvenile fall chinook salmon barged below Bonneville Dam were only partially successful.

2. Based on the straying rate of control fish (14%), a 100% imprinting rate may not be possible with this stock of fish.

3. The extra handling that juveniles in Test Group 2 received may have caused a decrease in survival compared to Test Group 1.

4. Improved returns of test fish to areas above Bonneville Dam would be expected if this study were repeated in a year without a volcanic eruption to impact survival of test fish.

5. A longer imprint period in the barge would increase numbers of fish homing to Spring Creek NFH.

Fall Chinook Salmon, Big Creek-
Stavebolt Creek, 1980

Background and Experimental Design

The object of this experiment was to determine if juvenile fall chinook salmon exposed to a limited short distance migration would imprint for return as adults to a lower river homing site. The study was designed to assess the effectiveness of a short distance migration down Stavebolt Creek in implanting a homing cue in fish.

The experimental design consisted of a control group and two test groups utilizing juvenile fall chinook salmon from the Oregon Department of Fish and Wildlife (ODFW) Big Creek Hatchery at Knappa, Oregon. Groups of 12,000 to 15,000 unmarked juveniles were hauled 30 miles by truck daily from Big Creek Hatchery to the homing site on Stavebolt Creek over an 8-d period (12 to 19 May 1980). After a short migration of 600 feet, the fish were recaptured, marked, and released. Fish in Test Group 1 (49,528 fish) received 4 to 6 h of exposure to Stavebolt Creek water. They were then transported to the West Mooring Basin at Astoria, Oregon, and released into the Columbia River immediately above the confluence with Youngs Bay--single imprint (Figure 10). Fish in Test Group 2 (50,414 fish) received 6 to 9 h exposure to Stavebolt Creek water before being released back into Stavebolt Creek immediately above its confluence with the Lewis and Clark River--natural imprint. The control group of 43,863 fish was marked 22 May and released 23 May at Big Creek Hatchery.

A group of 142,400 juveniles was also marked from a random sample of the entire hatchery production as part of the fall chinook salmon hatchery evaluation study. These fish were premarked by ODFW personnel and released 13 May 1980. This marked production release enabled us to compare the behavior of the subpopulation of fish used in our experiment to the behavior of the total salmon population reared and released at the Big Creek Hatchery.

Results

Releases at Big Creek Hatchery.--A comparison of adult recoveries from our experimental control release and the hatchery evaluation release showed a close similarity in their migratory behavior. These data are based on a sample of the population which returned to the Columbia River. There were no significant differences between the proportions of these two groups of adults recovered in the Zone 1 gill-net fishery, returning to the Big Creek

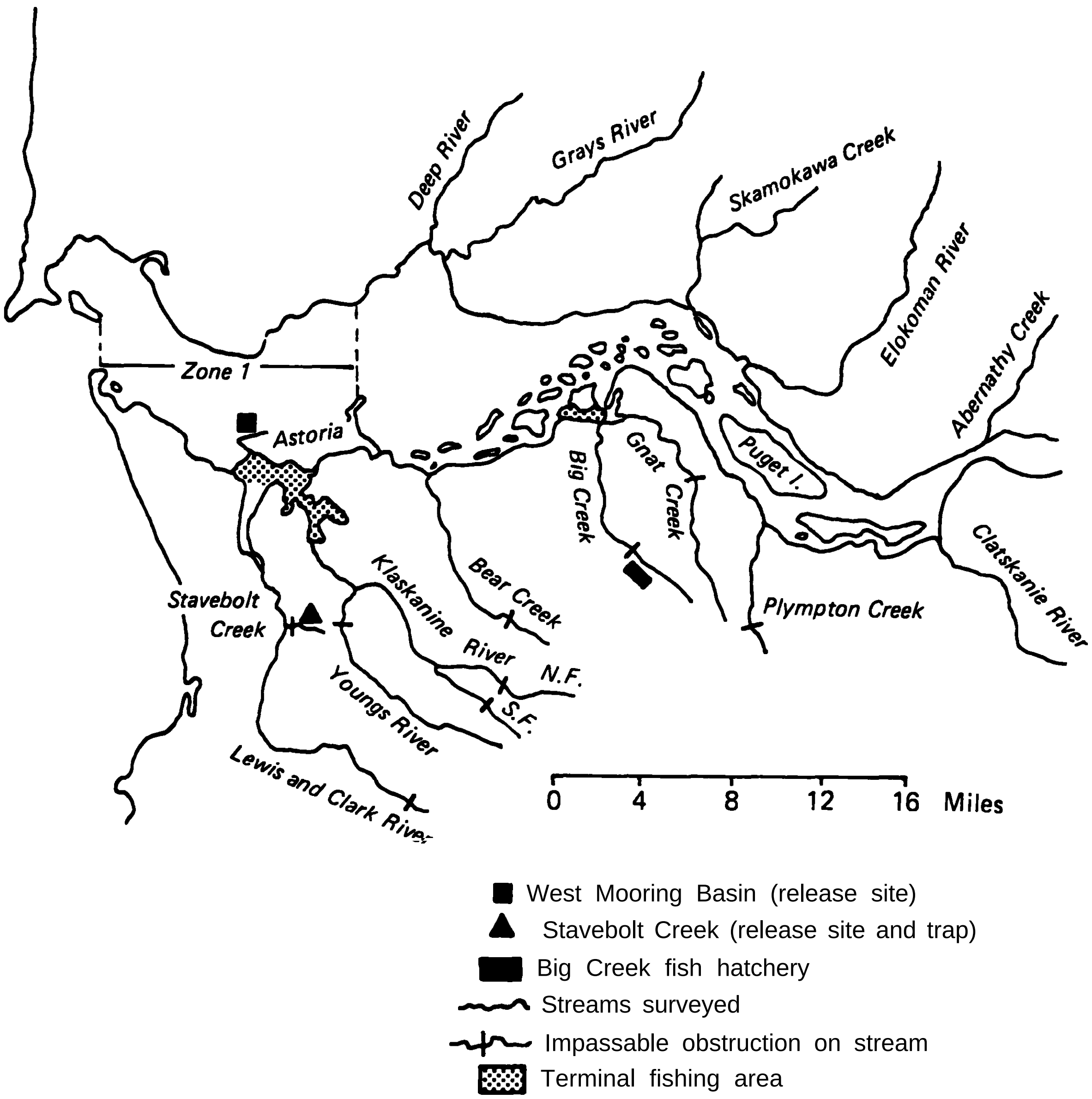


Figure 10.--Location map of release site and recovery areas for the 1980 Big Creek-Stavebolt Creek homing study.

environs, or straying to other tributary systems in the lower Columbia River (Figure 11). These data demonstrate that the behavior of fish from the subpopulation used in our experiment was representative of the Big Creek Hatchery fall chinook salmon population, and that differences in behavior by fish in the test groups would be the result of behavior modification induced by the experimental treatments.

Homing.--Recoveries of adult fall chinook salmon that returned to the Columbia River system demonstrated that the experimental treatments influenced their migratory behavior pattern. There were significant differences in homing between fish from the control release and fish from and between the two experimental treatments.

As expected, the majority of adults from the control release homed to Big Creek. A total of 62% of the recoveries were in the Big Creek homing area; this included the Big Creek terminal fishery, spawning fish in Big Creek, and the Big Creek Hatchery (Table 11). Twenty-one percent of the fish strayed to other tributaries within a radius of 24 miles, one fish (2%) was recovered from the gill net fishery in Youngs Bay, and six fish (14%) were recovered in the Zone 1 fishery.

Adults from the Stavebolt Creek release demonstrated a strong positive homing response to Youngs Bay. A total of 29 recoveries (64%) were in the Youngs Bay area and only 2 recoveries in the Big Creek area (Table 11). The remaining 14 recoveries (31%) were from the Zone 1 fishery adjacent to Youngs Bay. There appeared to be a positive response for the Stavebolt Creek area. Although no fish were actually recovered in the Stavebolt Creek trap, four marked fish (9%) were recovered in the Lewis and Clark

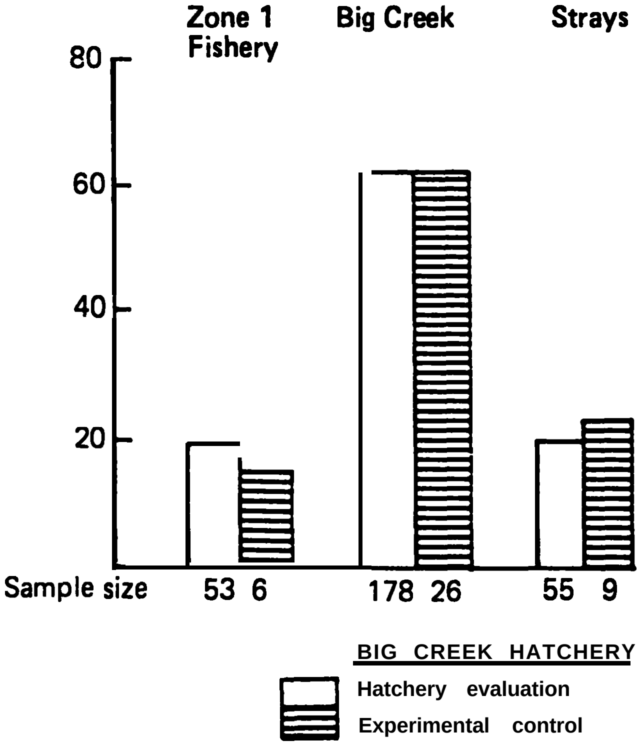


Figure 11.--Comparison of tag recovery locations of adult fall chinook salmon in the Columbia River system from two marked groups of juveniles released at the Big Creek Hatchery in 1980. Recoveries are through December 1983.

Table 11.—A comparison between recoveries in various fisheries and spawning escapement Locations in the Columbia River of adult fall chinook salmon from the 1980 Big Creek-Stavebolt Creek experiment. Recoveries are through December 1983.

Recovery area	Percentages of adults recovered at varous locations in Columbia River[a/]					
	Control Big Creek release		Test 1 Astoria release		Test 2 Stavebolt Creek release	
	%	(n)	%	(n)	%	(n)
Commercial fisheries						
Zone 1	14.0	(6)	28.0	(17)	31.0	(14)
Youngs Bay	2.0	(1)	36.0	(22)	56.0	(25)
Big Creek	2.0	(1)	2.0	(1)	0.0	(0)
Sub total	18.0	(8)	66.0	(40)**	87.0	(39)**
Spawning escapement						
Lewis and Clark River	0.0	(0)	2.0	(1)	9.0	(4)
Big Creek Hatchery	52.0	(22)	23.0	(14)	2.0	(1)
Big Creek	7.0	(3)	2.0	(1)	0.0	(0)
Other tributaries[b/]	21.0	(9)	8.0	(5)	2.0	(1)
Sub total	80.0	(34)	35.0	(21)**	13.0	(6)**
Total adults recovered in Columbia River		(42)		(61)[NS]		(45)[NS]

a/ Numbers rounded off to nearest percent.

b/ Recovery locations include Bear Creek, Gnat Creek, and Plympton Creek in Oregon, and Grays River, Skamokawa Creek, Elokoman River, and Abernathy Creek in Washington.

** $P<0.01$, df=1; indicates significant difference between test and control group.

NS Nonsignificant

River within 4 miles of the creek, and no marked fish were recovered in the other two river systems that drained into Youngs Bay and contained spawning f al L chinook salmon.

This stock of fall chinook salmon returns on its spawning migration in September before the fall rains begin, and small tributaries such as Stavebolt Creek have insufficient water to maintain Large salmon. Thus the rejection of Stavebolt Creek by adult salmon was very possibly due to the extremely low flows in the creek at the time of the spawning migration. A similar situation with a different early run stock of fall chinook salmon was reported in Slatick et al. (1983).

Adults from the Astoria test release did not show as positive a homing response to the Youngs Bay area as fish from the Stavebolt Creek release. Only 38% of the Astoria released fish homed to Youngs Bay--significantly ($P<0.05$, $df=1$) less than the 64% return from the Stavebolt Creek release (Table 11). One fish (2%) was recovered in the Lewis and Clark River and none in the Stavebolt Creek trap. No marked fish were recovered in the other two river systems that drained into Youngs Bay and contained spawning fall chinook salmon. Numbers of recoveries in the Zone 1 fishery were comparable to those from the Stavebolt Creek release.

Fish from the Astoria release which did not home to the Youngs Bay area or were not captured in the Lower river fisheries continued their migration up the Columbia River to the Big Creek area (hatchery of origin). The overall percentage return of these fish to the Big Creek Hatchery was 64% of the return of the control releases made at the hatchery (Table 11).

Survival and contribution to fishery.-- Total tag recoveries from both the ocean and Columbia River indicate that fish from the Astoria test release had a significantly ($P<0.10$, $df=1$) enhanced survival over those released as controls at the hatchery (T/C ratio of 1.41:1). Recoveries from the Stavebolt Creek test release showed a 1.19: 1 T/C ratio; however, the increase was not statistically significant. Both test releases contributed significantly ($P<0.10$, $df=1$) more fish than the control release did to the ocean fishery (Table 12). There was no significant overall difference between test and control recoveries back to the Columbia River; but there were significant differences between test and control releases with respect to the riverine commercial fisheries and spawning escapement. Both test groups contributed significantly ($P<0.01$, $df=1$) more fish to the fishery; whereas significantly ($P<0.01$, $df=1$) more control than test fish were from the spawning escapement (Figure 12).

These data demonstrate that treatments used in this experiment enhanced survival and modified the riverine migratory behavior of these adult fall chinook salmon. The modified (altered) migratory behavior in turn affected the numbers of fish which entered the various fisheries and spawning escapement locations in the 1981-83 seasons. An ability to increase the harvest or spawning escapement by modifying migratory behavior can be a useful tool for future management of this stock of fish. A more detailed examination of the data illustrates some of the management options available with the homing imprint treatments used in this study.

Adults which returned from the control release provided the lowest proportion of fish to the ocean and Columbia River fisheries and the greatest proportion of fish to the spawning escapement (Figure 12). In the

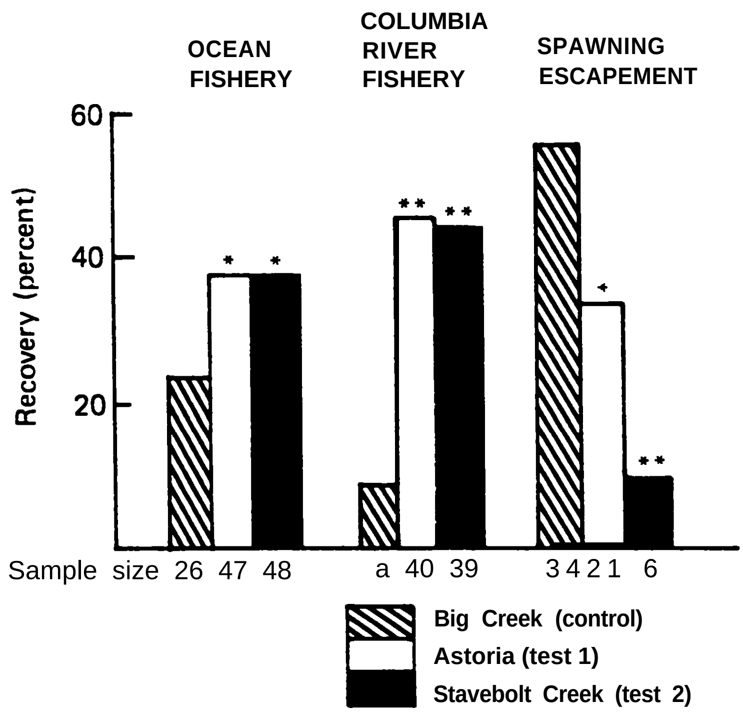
Table 12.--Recoveries of tags from control and test groups of l-, 2-, and 3-ocean age fall chinook salmon taken in the ocean and Columbia River fisheries, hatcheries, and on the spawning grounds. As juvenile test fish were imprinted to Stavebolt Creek and released in two location; control fish were released at Big Creek Hatchery in 1980. Recoveries are through December 1983.

Experimental groups	Number released	No. recovered by area: Ocean	No. recovered by area: Columbia River	Total recovery: No.	Total recovery: %	T/C[a/] ratio
Control (Big Creek Hatchery)	43,863	26	42	68	0.155	
Test 1 Single impring (Astoria release)	49,528	$47^{\dagger}$	61^{NS}	108	$0.218^{\dagger}$	1.41:1
Test 2 Natural imprint (Stavebolt release)	50,414	$48^{\dagger}$	45^{NS}	93	0.184^{NS}	1.19:1

a/ Test/control ratio is based on total recoveries.

† P<O.lO, df=l; indicates significant difference between test and control group.

NS Nonsignificant



* $P < 0.10$, df=l	Indicates significant difference between
** $P < 0.01$, df=l	test and control group

Figure 12.--A comparison of the distribution of adult recoveries from control and test releases of juveniles in the 1980 Big Creek-Stavebolt Creek experiments. Recoveries are through December 1983.

spawning escapement, 73% of the fish returned to Big Creek and an additional 27% strayed and were located on spawning grounds of other Columbia River tributaries (excluding the Youngs Bay drainage systems) within a 24-mile radius of Big Creek.

Recoveries of the Stavebolt Creek release were about 1.6 times that of controls in the ocean fishery and 5 times that of controls in the river fisheries (Figure 12). The majority of the test fish recoveries in the river were in Young Bay (a potential selective fishery). Spawning escapement was only six fish--four to the Lewis and Clark River, one to Skamokawa Creek, and one to Big Creek Hatchery (hatchery of origin). This was about 30% of the escapement for the Astoria release and 18% of the escapement for the control release (Figure 12). If this treatment were implemented, recoveries would probably be insufficient for brood stock but would provide a selective (Youngs Bay) fishery, contribute harvest to the ocean and Zone 1 fishery, and would help supplement a depleted spawning population of fall chinook salmon in the Lewis and Clark River.

Adults returning from the Astoria release had an equally high rate of harvest as the Stavebolt Creek release in all areas and an escapement that approached 60% of the control release. The rate of return to Big Creek Hatchery was 56% of the control release. With this treatment, we would provide significantly more fish to the various fisheries than if fish were released directly from the hatchery. We would also provide sufficient returns to the hatchery for egg take each year (assuming comparable rates of return to those measured on the 1980 releases). The rate of return to Big Creek Hatchery from the 1980 release was 0.1%; more than sufficient for egg take (Appendix Table B7). With this treatment, the rate of return would be reduced to 0.056%--approximately the rate of return needed for sustaining brood stock.

Conclusions

1. The behavior of fish from the subpopulation used in our experiment was representative of the Big Creek Hatchery fall chinook salmon population, and differences in behavior by fish from the test groups were the result of behavior modification induced by the experimental treatments.

2. Adult; from the Stavebolt Creek release demonstrated a positive homing response to Youngs Bay.

3. Adults from the Astoria test release did not show as positive a homing response to Youngs Bay as did fish from the Stavebolt Creek release. Most of those that did not home to the Bay homed back to Big Creek. Numbers returning to the hatchery were 64% of the control release made at the hatchery.

4. Overall survival (fishery and escapement) of the Astoria release was significantly higher than the control release.

5. The modified (altered) migratory behavior of adults induced by the experimental treatments affected the numbers of fish entering the spawning escapement or harvested in the fishery. Test releases contributed significantly more fish to the fisheries; whereas control fish contributed significantly more fish to the spawning escapement.

6. Adults returning from the Astoria release had an equally high rate of harvest as the Stavebolt Creek release (2-1/2 times greater than the control release) and an escapement that approached 60% that of the control release.

7. Imprint techniques like those used in the Astoria release would provide significantly more fish to the fishery than fish released directly from the hatchery while providing adequate returns to the hatchery for egg take each year (assuming comparable rates of return to those measured on the 1980 releases).

SUMMARY

Efforts in the sixth year of research on imprinting salmon and steelhead for homing concentrated on: (1) recovery of returning adults from 10 individual experiments in the fisheries, at dams, and at hatcheries and (2) final analysis on the completed 1979 and 1980 steelhead and 1980 salmon experiments--six by NMFS and four by the Idaho Cooperative Fishery Unit. Discrete multivariate analyses were used to statistically compare test and control treatments of completed experiments. Results of the experiments by NMFS are presented in the body of this report; those by Idaho, studying the effects on homing of a short-distance volunteer migration prior to transport, are presented as Appendix A. A summary of major findings for both the NMFS and the Idaho experiments follow:

Steelhead, Tucannon, 1979

1. Adults from both the test and control groups failed to return to the Tucannon hatchery homing site.

2. During the barging processes a portion of the test fish received a homing cue which enabled some adults to home to the Snake River.

3. More adults from the 100% spring water test group than from the control group were recovered in the Snake River.

4. Adults from the test groups which had failed to imprint the Snake River remained in the Columbia river and its tributaries below the confluence of the Snake River and contributed to the lower river sport and Indian fisheries.

5. The combination of impaired homing and enhanced survival of transported fish resulted in barged releases providing approximately 11 times as many fish to the user groups as control releases--estimated 0.236% for barged fish vs 0.020% for control fish.

6. Survival of fish from the 100% spring water test release was over twice as high as survival of fish from the 20% spring water test release.

7. An accurate assessment of survival and homing for this experiment was not possible because of adult losses in 1981 due to adverse river conditions.

Steelhead, Tucannon-Little Goose Dam, 1980

1. At the Na^+-K^+ ATPase parameters examined, the best adult homing and survival was from the release group (second) which had the highest levels of Na^+-K^+ ATPase enzyme activity when they were released as juveniles.

2. Migratory survival of steelhead juveniles which had not smolted or had reverted to parr (as indicated by low Na^+-K^+ ATPase enzyme activity) was very poor.

3. When compared to a homing study conducted in 1976, it appears that the optimum release strategy for imprinting a homing cue to the Snake River in juveniles was not achieved in the 1980 experiment. A total of 279 adults from the 1976 study were recovered in the Snake River compared to only 7 adults from the 1980 study.

Spring Chinook Salmon, Carson NFH, 1980

1. Adult recoveries from test and control releases were negligible and precluded an analysis of homing objectives.

2. Survival rates (average 92%) of marked juvenile spring chinook salmon from 14-d delayed mortality holding tests and sampling of outmigrants at Jones Beach did not indicate serious short-term mortality due to stress of handling or transportation. Survival to return as adults, however, was severely affected.

Spring Chinook Salmon, Leavenworth NFH, 1980

1. Homing of adults from the volitional migration test group released in the Columbia River at White Bluffs was comparable to the spring marked control release. However, numbers of fish recovered were too low to be of statistical significance.

2. Adult recoveries from all experimental groups, other than the fall marked control group, were negligible and precluded an analysis of the homing objectives.

3. Adult recoveries from all experimental groups were contrary to the relative outmigrant survival indicated by juvenile sampling. As an example, juveniles from the Dalton Point release held for the 14-d delayed mortality tests had an average survival rate of 94%.

4. Survival was extremely low in experimental groups handled and marked in the spring.

5. Juvenile sampling did not indicate serious short-term mortality due to stress of handling or transportation. Apparently mortality took place following ocean entry, possibly due to disease, e.g., BKD.

6. Survival of the fall marked control group was significantly less than survival of unmarked fish from the 1980 hatchery production release.

Fall Chinook Salmon, Spring Creek NFH, 1980

1. Methods used to imprint a homing cue in marked groups of juvenile fall chinook salmon were only partially successful--a longer imprint period may have been more successful.

2. Of the total hatchery recoveries, up to 74% of the test fish and 14% of the control fish were recovered as strays to other hatcheries, primarily the Bonneville Hatchery.

3. The straying rate of control fish indicated that a 100% imprinting rate may not be possible with this stock of fish.

4. Even though outmigrants from the barge test release migrated through the plume of volcanic debris in the Columbia River, the survival rate of fish from Barge Test Group 1 was significantly greater than for fish from the control group which had migrated under normal river conditions.

5. Survival of fish from Test Group 2 was significantly lower than fish from Test Group 1. The extra handling that juveniles in Test Group 2 received may have been the cause.

6. Improved returns of test fish to areas above Bonneville Dam would be expected if this study were repeated in a year without a volcanic eruption to impact survival of test fish.

Fall Chinook Salmon, Big Creek and Stavebolt Creek, 1980

1. Data demonstrated that the behavior of fish from the subpopulation used in our experiment was representative of the Big Creek

Hatchery fall chinook salmon population, and that differences in behavior by fish from the test groups was the result of behavior modification induced by the experimental treatments.

2. As expected, the majority of adults from the control release homed to Big Creek.

3. Adults from the Stavebolt Creek release demonstrated a positive homing response to Youngs Bay.

4. Adults from the Astoria test release did not show as positive a homing response to Youngs Bay as fish from the Stavebolt Creek release. Most of those that did not home to Youngs Bay homed back to Big Creek. Numbers returning to the hatchery were 64% of the control releases made at the hatchery.

5. Overall survival (fishery and escapement) of the Astoria release was significantly higher than the control release.

6. The modified (altered) migratory behavior of adults induced by the experimental treatments affected the numbers of fish entering the spawning escapement or harvested in the fishery. Test releases contributed significantly more fish to the fisheries; whereas control fish contributed significantly more fish to the spawning escapement.

7. Adults returning from the Astoria release had an equally high rate of harvest as the Stavebolt Creek release (2-1/2 times greater than the control release) and an escapement that approached 60% that of the control release.

8. Imprint techniques used in the Astoria release would provide significantly more fish to the fishery than fish released directly from the hatchery while providing adequate returns to the hatchery for egg take each

year (assuming comparable rates of return to those measured on the 1980 releases).

Cooperative Fishery Unit of Idaho Studies

In 1980, the Cooperative Fishery Unit at the University of Idaho conducted four experiments to determine if hatchery-reared fish exposed to a short distance migration prior to transportation would receive sufficient homing cues for successful return to the homing site (Appendix A). Tests included spring chinook salmon from Rapid River and Kooskia Hatcheries, fall chinook salmon from Hagerman NFH, and steelhead from Dworshak NFH. The hatchery was considered the homing site except for the Hagerman NFH group which was expected to return to Lower Granite Dam. The limited, short migrations tested ranged from a few meters (the length of a hatchery raceway) to 4 km.

Major findings include:

1. Initial survival was increased by the short migration/transport technique. tip to two to three times as many migration/transport fish were recovered as smolts in the Columbia Kiver estuary as were the comparable normal migration fish.

2. Homing among the salmon migration/transport groups was poor. Four to thirty times more normal/migration fish returned to homing sites than did the migration/transport groups. Steelhead homed somewhat better--about twice as many normal migration fish returned to the hatchery as migration/transport fish.

3. Observed straying was prevalent among test fish. Both spring chinook salmon and steelhead were recovered in the Deschutes River--far

downstream from the expected homing sites. Also, a disproportionately high number of steelhead were taken during early spring in the Columbia River Indian net fishery indicating the fish were lost or milling during their adult migration.

4. Similar studies with steelhead and fall chinook salmon conducted in previous years had successful homing of transported fish. Therefore, the authors believe that the right combination of voluntary migration, sequential imprinting, and mode of transportation can result in successful homing of these fish.

5. Homing and survival of all spring chinook salmon test groups on the other hand was relatively poor. As in the NMFS studies, the authors feel this was probably because of other problems such as fish health, stress from marking, and disease transmission during transportation.

CONTRACT EXPENDITURES

Contract expenditures for Bonneville Power Administration's Project 78-l for FY83 came to a total of $137.7K. See Appendix Table B8 for a summary of expenditures. No major property was purchased during the fiscal year.

ACKNOWLEDGMENTS

The extensive scope of our marking and recovery program was made possible by the interest and cooperative effort of NMFS, the U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Washington's Departments of Game and Fisheries, and the Idaho Department of Fish and Game in providing both fish and facilities for our experiments and adult recovery efforts in both the ocean and river fisheries. Additional ocean recoveries have been provided by California Department of Fish and Game, Alaska Department of Fish and Game, and the Canadian Fisheries Service. The U.S. Army Corps of Engineers provided the fish barge and facilities at dams on the Columbia and Snake River. Financial support for this research came from the region's electrical ratepayers through the Bonneville Power Administration.

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APPENDIX A

HOMING OF HATCHERY SALMON AND STEELHEAD ALLOWED A SHORT-DISTANCE VOLUNTARY MIGRATION BEFORE TRANSPORT TO THE LOWER COLUMBIA RIVER

HOMING OF HATCHERY SALMON AND STEELHEAD ALLOWED A SHORT-DISTANCE VOLUNTARY MIGRATION BEFORE TRANSPORT TO THE LOWER COLUMBIA RIVER

A final report

submitted to

National Marine Fisheries Service

Contract 80-ABC-00115

by

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ABSTRACT

Eight groups of salmon and steelhead smolts were marked and released in 1980 to evaluate the effect of a short distance seaward migration on homing. Four of the groups migrated normally from their respective hatcheries or usual release sites, and the other four were allowed to voluntarily migrate a short distance from the hatchery ponds before being collected, marked (if not already) and transported to the lower Columbia River. Voluntary migration distances ranged from merely migrating out of a raceway, migrating across the hatcheries in discharge flumes, or moving down a river abcct 4 km.

More of the fish that migrated only a short distance and were then transported were recaptured by purse and beach seining as they passed through the estuary th a nthose that migrated downstream normally. Adult returns to hatcheries in Idaho or Snake River dams, conversely, were higher from normal-migration groups than from short migration-transport groups. Spring chinook salmon that migrated normally returned at four to six times higher rates to Rapid River and Kooskia hatcheries than fish that were transported after migrating a short distance. Fall chinook salmon transported to Lower Granite Dam from Hagerman hatcher: and then transported downstream returned at one-thirtieth the rate offish released. in the Snake River at Asotin.

Steelhead trout from the migration-transport group had better success than chinook salmon in finding their way back to Idaho. Normal-migration steelhead trout were recaptured in Idaho at only twice the rate of fish that migrated a short distance before being transported. The overall return of migration-transport fish was nearly twice that of normal-migration fish, but many of the fish appeared lost and were recaptured in the Columbia River Indian net fishery in early spring.

INTRODUCTION

Studies to evaluate the role of seaward migration on the acquisition of homing cues by hatchery chinook salmon and steelhead trout were conducted in 1980. Our objective was to determine if smolts pick up sufficient cues for satisfactory homing if their initial voluntary seaward migration is only a short distance. Three groups of chinook salmon and one group of steelhead were allowed to migrate a short distance voluntarily before they were collected and transported to the lower Columbia River. Control groups for each of the short distance migration-transport groups were allowed to migrate seaward normally.

Two general observations led us to believe that salmon and steelhead smolts can pick up the cues they need fcr homing in a short time period once they start their seaward migration. The first observation was that salmon and steelhead usually return to the point of release. Fish released at the hatchery normally return to the hatchery, but fish taker! from the hatchery and released at other locations usually return to the point of release. Smolts transplanted to a drainage different from that of the hatchery may spend only a fraction of a day in the stream of release before migrating into the ocean or larger streams. Despite the short time they spend in the stream of release, the transplanted fish are able tc acquire the cues they need to lead them back to the release point.

The second observation was that collecting salmon and steelhead smolts from the Snake River at Lower Granite and Little Goose Dams on the Snake River and transporting them 460 km downstream to Fonnevilie Dam apparently has not impaired their homing (Park et al. 1980). Even though transported smolts do not migrate through the Lower Snake River, the Snake-Columbia rivers confluence area, or the Columbia River upstream from Bonneville Dam, they successfully return as adults to their **natal** areas or release points. Some smolts have migrated less than 85 km and as few as four days when collected at Lower Granite Dam and transported to the lower river. These Snake River fish have **apparently** already acquired the cues they need for successful homing by the time they reach Lower Granite Pam.

Another instance that led us tc believe that, smolts acquire homing cues rapidly at the onset of seaward migration seemed to be contradictory at first glance. Steelhead trout smolts collected in the outlet trap of the Barnaby Slough rearing facility adjacent to the Skagit River in Washington were transported by truck to a release point upstream from the slough. When the adults returned to the slough rather than the upstream reiease point, (James Gearheard, correspondence, Washington Department of Game), we wondered why this case was an exception to the general observation that fish return to the site of release. Did the fish return to Barnaby Slough because **it** was downstream from the release site? In the Clearwater

River of Idaho, fish transported to an upstream release point bypassed the hatchery where they were reared and returned to an upstream release point. In the Barnaby Slough case, the smolte had to migrate voluntarily out of the slough into the trap before they could be collected and transported to the upstream release site. We suspect that the smolts acquired their primary homing cues when they migrated out of the slough, and that is the reason they returned to the slough. In the Clearwater River case, the fish were pumped into trucks from the rearing pond and did not initiate any voluntary seaward migration until released upstream from the hatchery.

Whatever cues fish use for homing, they can be obtained in the hatchery (Lake Michigan morpholine experiments, Hasler and Sholtz, 1983) and with the onset **Of** voluntary migration. Return of fish to the site of release leads us to believe that cues obtained in a hatchery are disregarded if the fish have an opportunity to migrate seaward voluntarily.

SPRING CHINOOK--RAPID RIVER SFH

Fish Marked and Released

A group of fish marked in November 1979 by Idaho Department of Fish and Game (IDFG) personnel for a contribution to fisheries study was used as the normal migration group from Rapid River State Fish Hatchery (SFH). Fish were taken from a rearing pond, tagged with a coded wire, fin clipped, branded, and then released into an effluent channel. The channel was not screened so the fish could leave and migrate downstream during the winter or early spring if they chose to do so. Voiuntary migration out of the rearing ponds during the fall and winter is normally allowed at Rapid River SFH. The normal-migration group consisted of 82,360 fish tagged with coded wires with binary codes 10/21/13 and 10/21/14 (Table 1). Sixty-one thousand of the fish with coded wire tags (CWT) were also branded (left anterior IU 1st position).

Because some of the November-marked fish could migrate downstream before the usual spring seaward migration when the short-distance migration group was released, we also branded (right anterior IL 1st position) 10,300 fish and released them for normal migration in Aprii, 1980 (Table 1). We wanted to compare the relative survivals to Lower Granite Dam and the estuary of normal-migration fish, some of which left the

Table 1. Spring chinook salmon smolts released in 1979-80 and adults recaptured at Rapid River SFH for the migration-haning study.

	Normal-migration groups			Migration-transport group
	Fall-spring release		Spring release	
	CWT[a] 10/21/13 Brand LAIU(1)	CWT 10/21/14 Brand LAIU(1)	Brand RAIU(1)	CWT 10/21/15 Brand LAIU(3)
Number of fish marked and released				
CWT	39,204	43,156		39,206
Brand	39,204	21,804	10,304	39,206
Date fish released	11/5/79[b]	11/5/79[b]	4/15/80	4/15/80
Mean total length at release (mm)	130 (n = 383)	130	149 (n = 366)	144 (n = 369)
Smolts recaptured				
At Lower Granite Dam	2[c] 815[d]	132[c]	116	4[c]
Estuary	19[d]	2[c]	16	29[d]
Estimated number of smolts collected at Lower Granite Dam	6396		1702	
Adults recaptured				
Columbia River	6			4
Rapid River Hatchery	25			2
Adults recaptured (%)				
In Idaho	0.030			0.005
Total	0.038			0.015

[a] CWT--binary wire tag code.

[b] Marked fish placed in effluent channel at hatchery after marking. Fish could leave the channel and some did during the fall and winter. The remainder left in the spring.

[c] Sacrificed fish with ad clips and CWT.

[d] Branded fish that were not sacrificed.

[e] Based on brand recoveries.

hatchery in the winter, versus those released in April, same as the short-distance migration group.

Spring chinook in the short-distance migration-transport group migrated voluntarily from the hatchery ponds in April, were collected from Rapid River after they had migrated downstream 4 km and were then marked and transported by truck to Lower Granite Dam where they were loaded on a barge or truck and transported to Bonneville Dam. Migration-transport fish were tagged with CWT (code 10/21/15) and branded (left anterior IU 3rd position) (Table 1). About 13,000 of the migration-tranport fish had to be released in Blalock Slough (RK375), an arm of the John Day Pool, when a tank truck malfunctioned. Some mortality was observed, and the fish may have had some difficulty finding the culvert leading to John Day Reservoir. Fish released in Blalock Slough were transported 140 fewer km than fish transported all the way from Lower Granite to Bonneville Dam (458 km).

Normally migrating fish might also be thought of as migration-transport fish because some are transported tc the lower Columbia River if collected at one of the dams. Normally migrating fish differ from our migration-transport test fish in that the normal-migration fish must migrate to the dam(s) before **some** are collected and transported. Short-distance migration-transport fish migrated only a short distance (less than 4 km) before all were collected and transported to the lower Columbia River.

Normal-migration fish averaged 130 mm total length when tagged in November 1979, and those sampled in April 1980 averaged 151 mm. Migration-transport fish averaged 144 mm when tagged in April 1980.

Smolts Recaptured at Dams and Estuary

Normal migration spring chinook released from Rapid River SFH were recaptured in relatively large numbers at Lower Granite Dam in the spring of l980. Fish marked in the fall of 1979 (LA IU (1) brand) that could have left the hatchery during the fall, winter or spring began showing up at the Dam in early April as soon as collection began. **Fifty** percent of the fish collected had been taken by April 23 and 90 percent by April 30. Fifty percent of the fish marked and released in mid-April 1980 (RA IU (1) brand) had been collected by April 29 and 90 percent by May 6. Fish that may have left the hatchery in fall or winter apparently stayed in the rivers upstream from Lower Granite Dam during the winter and then resumed their downstream migration in the spring.

Based on estimated numbers of marked smolts collected at Lower Granite Dam (Sims et al. 1981), a smaller proportion of the fall-marked fish arrived at the dam in the spring than the fish marked and released in mid-April. An estimated 10.5 percent of the 61,600 fish branded in the fall were collected at Lower Granite Dam versus 16.5 percent of the 10,300 fish branded and released in April.

Because of the differential recapture rates between the fish marked in the fall versus those marked in the spring, the value of the normal-migration group as a control for the migration-transport group is somewhat impaired. Assuming brand retention and readability was equal for the two groups and that the fall-marked fish migrated past Lower Granite Dam only in the spring of 1980, survival of the fall-marked fish from time of marking to recapture at the Dam was not as high as the fish marked in April. The estimated collection rate of fall-marked fish with coded wire tags (10/21/14) but without brands was 11.4 percent: a collection rate similar to the 10.5 percent for branded fish, indicating that brand retention was high. Additional evidence of good brand retention was obtained on April 9, 1980, when we collected 563 adipose-clipped migrants from Rapid River that had been tagged and branded the prior fall. Seventy-four percent of the Fish taggec in the fall were branded, so we expected to find 26 percent of the fish sampled without brands. Only 20 percent of those adipose-clipped fish didn't have a brand.

Ideally, equal numbers of normal-mirgation fish and migration-transport fish would start seaward in the spring. Fewer numbers cf the fall-marked fish were apparently alive to migrate in the spring than were marked in the fall. Since it is normal practice at Rapid River SFH to allow fish to leave when they wish, the comparison between the fall-marked fish and the migration-transport fish marked in the spring may be appropriate for that station.

Four of the migration-transport fish (code 10/21/15) were collected at Lower Granite Dam in 1980. A few marked fish escaped into Rapid River during marking when a holding screen collapsed at the marking site.

Since the migration-transport fish were transported from Rapid River to Bonneville Dam, the estuary sampling by NMFS personnel (Dawley et al. 1981) provides the only comparison between groups of success in migration to the ocean. Twenty-one of the 82,360 normal-migration fish marked in the fall, 16 of the 10,300 marked in the spring, and 29 of the 39,210 migration-transport fish were recaptured in the estuary sampling program (Table 1). If all groups had been recaptured at the same rate as the normal-migration group, there would have been 21, 3, and 10 fish recaptured, respectively, rather than the 21, 16, and 29. A larger proportion of both groups marked in April made it to the estuary than those marked in the fall. Normal-migration fish released in April were recaptured at five times the rate of Call-released fish. Migration-transport fish were recaptured at three times the rate of fall-released fish that migrated normally. Migration-transport fish were recaptured in the estuary at a lesser rate than normal-migration fish released in the spring, perhaps because some of the transported fish had to be released in Blalock Slough.

Timing of recaptures in the estuary differed between the three groups of fish (Figure 1). The normal-migration group marked in the fall passed through the estuary earlier (April 29 median capture date) than the normal-migration fish released in the spring (May 8 median capture date), but with similar timing to that of the migration-transport group.

Adult Returns

Adults returned to Rapid River SFH from the migration-transport group at only one-sixth the rate (0.005%) of fish from the normal-migration group (0.030%) (Table 1). Most (25 of 31) of the adults recaptured from the normal-migration group were collected at the hatchery. The other six were taken in lower river net fisheries. Four of the six adults recaptured from the migration-transport group had strayed and were taken at lower river hatcheries (Little White Salmon NFH) or rivers (Deschutes and Umatilla). The other two made it back to Rapid River SFH.

Adult returns from the two groups were reversed from smolts collected in the estuary. Migraiton-transport smolts were collected at a three-times higher rate in the estuary than normal-migration fish, but adults from the latter group were recaptured at six times the rate of the migration-transport

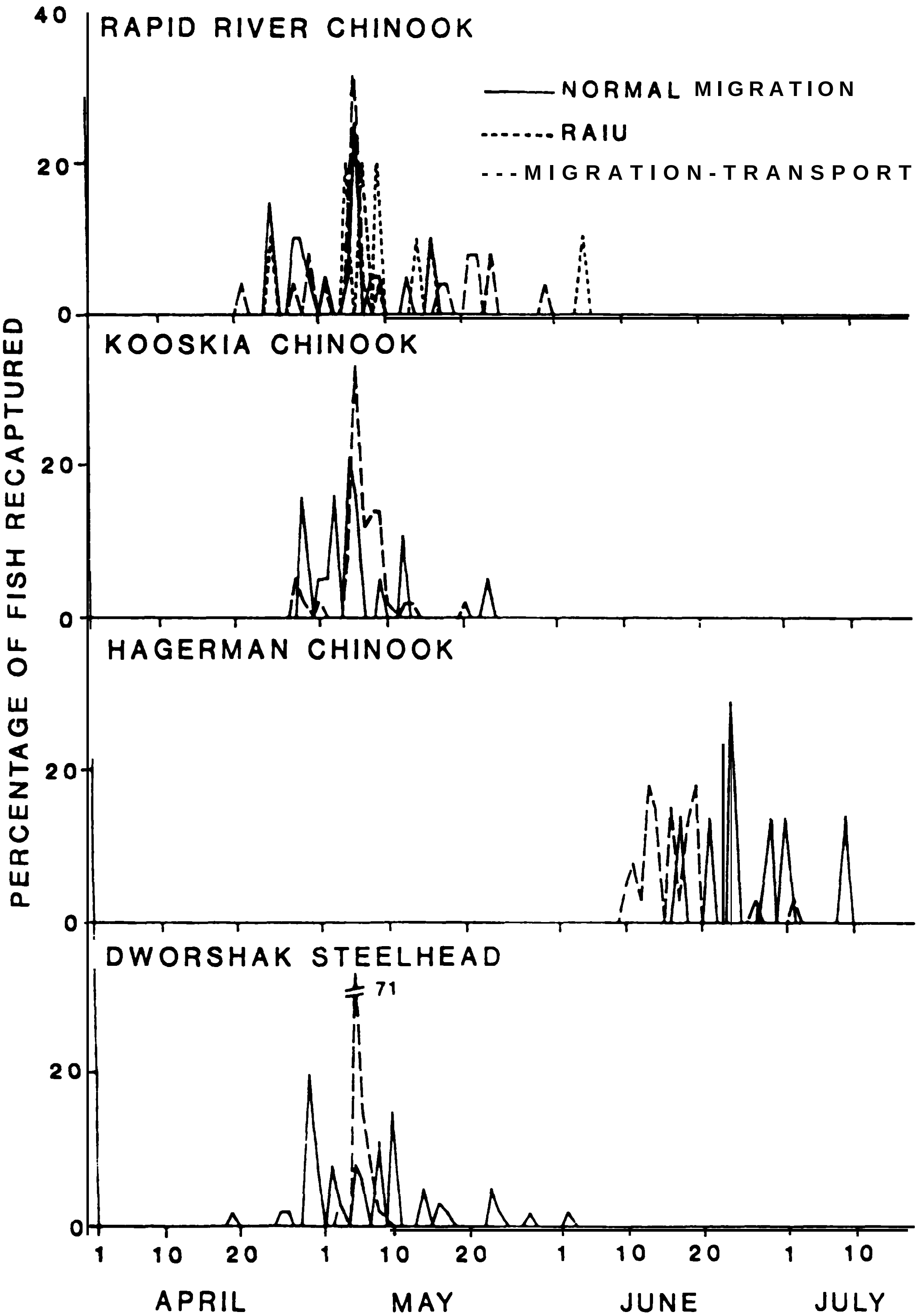

Figure i. Timing of recaptiie of normal-migration and migration-transport fish by NMFS personnel in the Columbia River estuary, 1980.

fish (Table 1). More of the migration-transport fish may have survived than is apparent from the recaptures, but strayed into streams where adults were not sampled for tags.

SPRING CHINOOK-KOOSKIA NFH

Fish Marked and Released

Both the normal-migration group and the migration-transport group of spring chinook released from Kooskia National Fish Hatchery (NFH) in 1980 were tagged (CWT) and fin clipped beforeany migration was allowed. The normal-migraticn group (CWT code 5/5/32) was flushed from the raceways and out of the hatcher:* on April 16, 1980 (Table 2). The migration-transport group (CWT code 5/5/29) was then allowed to migrate voluntarily cut of the raceways and across the hatchery in the effluent flume (approximiately 100 m) before they were trapped, placed in a truck, and transported to Lower Granite Dam and then tc the lower Columbia River. Voluntary migration of the migration-transpcrt group took place over a X-day period (April 23 to May 5). Fish used in the 1980 releases were yearling smolts that averaged 131 mm total length when released.

Table 2. Spring chinook salmon smolts released in 1980 and adults recaptured at Kooskia NFH for the migration-haning study.

	Normal-migration group	Migration-Transport group
Number of fish marked and released with coded wire tags	61,300	62,300
Wire tag code	5/5/32	5/5/29
Date fish released	16 April 80	23 April to 5 May 80
Mean total length at release (mm)	131	131 (n=505)
Smolts recaptured in estuary[a]	27	44
Estimated number of smolts collected at Lower Granite Dam	10,536	364
Adults recaptured		
Deschutes River	1	1
Kooskia NFH	8	2
Adults recaptured (%)		
In Idaho	0.013	0.003
Total	0.015	0.005

[a] Based on recovery of fish with coded wire tags.

Smolts Recaptured at Dams and Estuary

At Lower Granite Dam, an estimated 10,536 of the normal-migration fish and 364 of the migration-transport fish were collected (Table 2). About 2100 **Of** the migration-transport fish must have still been in the underground flume at the hatchery when we stopped trapping and hauling that group downstream. They subsequently left the hatchery and migrated downstream.

in the estuary sampling by NMFS personnel at Zones Beach (Columbia River km 75), 27 of the normal-migration fish were collected and 44 of the migration-transport fish (Table 2). Nearly twice as many of the migration-transport fish made it to the estuary as the normal-migraticn fish.

Median date of migration through the estuary was similar for both the normal-migration and migration-homing groups (Figure 1). Voluntary migration from the raceways of the migration-transport group was not allowed tc start until April 23 to insure that the normal-migration fish released April 16 had left the hatchery. Had both groups left the hatchery on the same date, the migration-transport group probably would have reached the estuary first.

Adult Returns

Migration-transport fish returned to Kooskia NFH as adults at one-fourth the rate of normal-migration fish (Table 2). Total returns were small (eight and three fish), with most of the fish recaptured at the hatchery.

Adult returns did not reflect the number of smolts collected as they passed through the estuary. More of the migration-transport smolts were collected in the estuary, but more of the normal1-migration fish returned as adults.

FALL CHINOOK--HAGERMAN NFH

Fish Marked and Released

Fall chinook salmon released in 1980 were fish reared at Hagerman NFH as part of the Snake River fall chinook egg bank program. Adults were collected in September 1979 at Ice Harbor Dam and transported to Tucannon SFH. Eyed eggs were then shipped to Hagerman NFH where the fish were reared until they appeared to be smolts. The fish were tagged (CWT) in May 1980 and then transported from the hatchery in early June.

The normal-migration group (CWT code 5/5/27) was released in the Snake River near Asotin on June 3, 1980 (Table 3). Fish averaged 93 mm when released. After release these fish had to migrate down the Snake River at least to Lower Granite Dam. If

Table 3. Fall chinook salmon smolts released in the Snake River in 1980 and adults recaptured for the migration-haning study.

	Normal-migration group	Migration-transport group
Number of fish marked and released with coded wire tags	60,750	57,713
Wire tag code	5/5/27	5/5/28
Date released	3 June 80	6-23 June 80
Mean total length at release (mm)	93 (n=326)	91 (n=399)
Smolts recaptured in the estuary[a]	13	46
Adults recaptured (through July 83)		
Ocean fisheries	57	20
Columbia River	5	3
Snake River dams	170	5
Adults recaptured (%)		
At Snake River dams	0.280	0.009
Total	0.382	0.049

[a]Fish with coded wire tags.

collected at the dams, they were transported to the lower Columbia River.

The migration-transport group (CWT code 5/5/28) was transported to Lower Granite Dam on June 5, 1980, and placed in the upper end of a raceway at the collection facility. Three plywood baffles were placed in the raceway at mid point, lower quarter, and tail end so that fish would have to move over them to leave the raceway. When fish moved over the last baffle at the lower end of the raceway, they went through a pipe into a waiting truck and were then transported to the lower Columbia River. Migration from the upper to the lower end of the raceway occurred over a period of 17 days. Most of the fish migrated voluntarily from the raceway at night in the first five days. Fish placed in the raceway averaged 91 mm in length, fed actively and appeared healthy.

Smolts Recaptured at Dams and Estuarv

Nose-tagged fish were not sacrificed at Lower Granite Dam when the fall chinook were moving downstream in 1980. However, most, if not all, the fish with adipose clips that entered the collection facility during June and early July were probably fall chinook released at Asotin. NMFS personnel estimated, on the basis of adipose-clipped fish collected during June, that 3,425 of the 60,750 fall chinook released at Asotin were collected at Lower Granite Dam.

Fall chinook that migrated out of the raceway at Lower Granite Dam and then transported to the lower Columbia River were recaptured in larger numbers in the estuary sampling than those released at Asotin. Only 13 of the Asotin-released fish were collected in the estuary samples versus 46 of the migration-transport fish Table 3).

Migration-transport fish passed through the estuary earlier than fish released at Asotin in 1980 (Figure 1). Median date of collection for the Asotin fish was June 24 versus June 18 for fish hauled from the raceway at Lower Granite Dam. No fish of either group were collected after July 2. In 1979 also, fall chinook released at Asotin passed through the estuary later than fish transported directly to Bonneville Dam. Fish placed on the barge May 21 and transported to below Bonneville Dam in 1979 had a median recapture date of May 27, while for those released at Asotin on May 20 the median date was July 3 (Dawley et al. 1980),

Adult Returns

Adult fall chinook from the group released at Asotin (normal migration) returned to the Snake River at 32 times the rate of adults from the group released in the raceway at Lower Granite Dam and transported to the lower Columbia River (Table 3). Reported recaptures of the normal-migration group through December 1983 were relatively high (0.385 overall) with

57 fish recaptured in ocean fisheries, 5 in Columbia River fisheries, and 170 at Ice Harbor and Lower Granite Dams. Fewer adults were recaptured from smolts released in the raceway and transported downstream, and most of those were recaptured in ocean and river fisheries rather than at the Snake River dams (Table 3).

Three times more smolts from the migration-transport group were recaptured in the estuary than normal-migration fish, but adult returns to the Snake River were 33:l in favor of normal-migration fish released at Asotin.

STEELHEAD TROUT--DWORSHAK NFH

Fish Marked and Released

Steelhead trout used in the 1980 migration-homing studies were age-1 fish produced in system II at Dworshak NFH. Fish released in 1980 were in good health and should provide reliable results.

The ncrmal-migration group was tagged by IDFG personnel for their hatchery contribution studies. The 59,100 fish with wire tags (code 5/4/55) were released on April 17, 1980, by flushing the ponds into the main stem Clearwater River. The fish averaged 185 mm total length when released.

The migration-transport group was tagged (code 10/21/19) after the fish had voluntary migrated out of three ponds in system II, down an effluent sluiceway and into a trap. We started trapping and marking migrants on April 28 and finished on April 30. During the 3 days, 40,010 migrants were trapped and tagged, with 8,490 of the tagged fish also branded (left dorsal 4 4th position) (Table 4). Marked fish were hauled to Lower Granite Dam April 29 through May 2 and transferred to barges or trucks for transport to the lower Columbia River.

The migration-transport group is not strictly comparable with the normal-migration group. The migration-transport group was made up of voluntary migrants that were probably smolts, whereas the normal-migration group were flushed from the ponds and probably included some fish that didn't become smolts. The migration-transport fish were larger (159 mm average total length) when released than the normal-migration group (185 mm), probably because fish that were smolts and voluntarily migrated from the ponds tended to be the larger fish in the ponds.

Smotls Recaptured at Dams and Estuary

At the estuary, NMFS personnel collected 106 marked steeihead from the normal-migration group and 160 from the migraticn-transport group (Table 4). Yore of the migration-transport fish reached the estuary than normal-migration fish because they were all transported and the likelyhood that few, if any, of the fish in the migration-transport group were non-snclts. Migration-transport

Table 4. Steelhead trout smotls released from Dworshak NFH in 1980 and adults recaptured for the migration-haning study.

	Normal-migration group	Migraiton-transport group
Number of fish marked and released		
coded wire tags	59,125	40,010
brands		8,490
Wire tag code	5/4/55	10/21/19
Brand used		ID 4(4)
Date released	17 April 80	29 April to 2 May 80
Mean totallengthatrelease (mm)	185	199
Smolts recaptured in the estuary[a]	106	160
Adultsrecaptured		
Ocean fisheries	0	1
Deschutes River	0	4
Columbia River sport & net fisheries	44	198
Idaho fishery	34	6
Dworshak NFH	139	63
Adults recaputred (%)		
In Idaho	0.293	0.173
Total	0.367	0.680

[a]Based on recovery of CWT fish.

fish were all voluntary migrants from the hatchery ponds, and thus most were probably smolts. The normai-migration group included all fish in the ponds and likeiy included some fish that didn't become smots in 1980. Losses of fish between the hatchery and dams would account for the remainder of the difference in estuary catches of the two groups.

Timing of migration through the estuary was spread through five weeks for normal-migration fish and one week for migraticn-transport fish (Figure 1). Normal-migration fish were released from Dworshak NFH on April 17, the first fish was collected in the estuary on April 24 and the last fish on June 2. All of the migration-transport fish were collected between May 3 to 9. Migration-transport fish were hauled from Dworshak NFH to trucks or barges at Lower Granite Dam April 29 through May 2 .

Adult Returns

Steelhead trout from the normal-migration group returned to the Clearwater River at nearly double the rate of fish that migrated out of the hatchery ponds, down the sluiceway, and were then transported to the lower Columbia River (Table 4). Adults from the migration-transport group were recovered at nearly twice the rate (0.68%) of the normal-migration group (0.37%) when all areas of recovery are considered, but many of those recoveries were in the lower Columbia River fisheries in early spring, an indication they were lost and milling in the Bonneville pool.

Adult return rates to Idaho of the two groups did not reflect the number of smolts captured as they migrated through the estuary. Migration-transport group smolts were recovered in the estuary at twice the rate of the normal-migration group, but adult returns were 1.7:1 in favor of the normal-migration fish (Table 4).

DISCUSSION

Chinook salmon or steelhead trout smolts allowed to migrate short distances voluntarily (up to 4 km) before being transported to the lower Columbia River in 1980 did not acquire sufficient cues for satisfactory homing back to hatcheries or release sites. Steelhead trout returned to natal areas better than either spring or fall chinook; however, the return rate for migration-transport fish would be too low unless extremely low river flows were anticipated during the smolt migration season that would cause high mortality to fish that migrated normally.

Fish that migrated a short distance before being transported downstream apparently had better homing success than fish transported from the hatchery without any voluntary migration. Steelhead trout transported directly from Dworshak FH to the lower Coiumbia River in 1977 without any voluntary migraiton returned at one-fourth the rate of normal-migraiton fish (unpublished date, Idaho Cooperative Fishery Research Unit). The ratio might have been even more in favor of normally-migrating fish, but low flows in 1977 created poor conditions for normal migration. Steelhead smotls allowed to migrate a short distance before being transported to the lower Columbia River in 1979 (unpublished data, Idaho Cooperative Fishery Research Unit) and in 1980 (this report) returned at about half the rate of normal-migration fish. Allowing steelhead to migrate a short distance voluntarily prior to transport downstream apparently more than doubled their ability to find their way back to their natal area.

Slatick et al. (1982) in tests conducted with Dworshak NFH steelhead released in 1978, found that sequential imprinting of smolts on various waters prior to and during transportation resulted in return rates of trucked or barged fish that equalied or exceeded the normal-migration fish. In other 1978 tests with steelhead smolts reared at Wells and Chelan SFHs, Slatik found that transported groups with sequential imprints did not home successfully to the upper Columbia River imprint sites (0.05: 1 ratio of transport tc normai-migration groups).

Although the fall chinook salmon transported from Hagerman NFH to Lower Granite Dam and then to the lower Columbia River in 1980 returned at only one-thirtieth the rate of fish that migrated from Asotin, that result is contrary to results of similar studies conducted in 1979 and 1981. In 1979, a group of fall chinook from Hagerman MFH was released at Asotin and a second one hauled directly to a barge at Lower Granite Dam for transport to the lower Columbia River. The group hauled to the barge returned to the Snake River at nine times the rate of those that migrated normally from Asotin (unpublished data, Idaho Cooperative Fishery Research Unit). In 1481, a group of Hagerman NFH fall chinook was released in Lower Granite Reservoir 6 km upstream from the dam and another group was placed in a raceway at the dam, where they migrated tc a waiting truck or barge for transport to the lower Columbia River. Return rates of jacks (one year in ocean) to the Snake River in 1982 were about equal for both groups.

A short-distance-migration test with spring chinook salmon released from Kooskia NFH in 1979 had similar results to the test conducted in 1980, but adult returns were small in both years.

Tests conducted to date of short-distance voluntary migration before transportation of smotls to the lower Columbia River have demonstrated that the distances or time periods of migration have not been adequate to facilitate a high degree of homing. Since smolts that migrate to the dams and are then transported apparently acquire sufficient cues (Park et al. 1980) the question "how much migration is necessary?" stili remains. Tests with steelhead trout and fall chinook (1979 and 1981) are encouraging, and we believe the right combination of voluntary migration, sequential imprinting and mode of transportation that will alloq successful homing cf these fish can be determined with additional testing. Homing of spring chinook, on the other hand, was relatively poor in the short-distance migration tests and may reflect other problems that must be overcome, such as fish health, stress from handling and marking, and disease transmission during transportation.

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APPENDIX B

TABLES B-1 THROUGH B-8

Appendix Table B1.--Recoveries of adult steelhead from miscellaneous locations in sport fisheries and hatcheries from control and test releases of smolts imprinted to the Tucannon Hatchery in 1979. Recoveries were from June 1980 to December 1982.

Sampling location	Number of adults recaptured[a/]					
	Control Tucannon Hatchery		Test #1 100% spring water		Test #2 20% spring water	
	N	% of release	N	% of release	N	% of release
Columbia River						
Lower River below Bonneville Dam	0	0.000	3	0.014	4	0.018
Cascade Hatchery	0	0.000	1	0.005	0	0.000
Wind River	0	0.000	0	0.000	1	0.005
Big White Salmon River	0	0.000	1	0.005	0	0.000
Deschutes River	0	0.000	6	0.029	3	0.014
Deschutes River Hatcheries	0	0.000	0	0.000	2	0.009
Sub-Total	0	0.000	11	0.053	10	0.045
Upper Mid-Columbia River						
Ringold area	0	0.000	0	0.000	1	0.005
Wenatchee River	4	0.016	0	0.000	0	0.000
Wells Hatchery	1	0.004	0	0.000	0	0.000
	5	0.020	0	0.000	1	0.005
Snake River						
Snake River	0	0.000	1	0.005	0	0.000
Miscellaneous						
Ocean - Oregon	0	0.000	0	0.000	1	0.005
Total	5	0.020	12	0.058	12	0.054

a/ Because of differences in sampling intensity (efficiency) at each site, results are not comparable between sites.

Appendix Table B2.--Number and percent recovery of 1-, 2-, and 3-ocean age steelhead in Zone 6 Indian fishery from control and test releases of smolts imprinted to the Tucannon Hatchery in 1979. Recoveries were from August 1980 to March 1983.

Control or test	Numbers juveniles released	No. of adults recaptured															
		1-ocean age				2-ocean age				3-ocean age				1-, 2-, & 3- ocean age			
		Fall		Winter		Fall		Winter		Fall		Winter		Total			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	Est	%[a/]
Tucannon (control)	24,787	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000		0.000
100% spring water (test)	20,728	0	0.000	2	0.010	12	0.05×	7	0.034	4	0.019	0	0.000	25	0.121		0.233
20% spring water (test)	22,058	0	0.000	0	0.000	11	0.050	2	0.009	1	0.005	2	0.009	16	0.073		0.131

a/ Estimated recoveries based on sampling efficiency of the Zone 6 Indian fishery.

Appendix TahleB3.--Recoveries of adult steelhead from miscellaneous locations in sport fisheries and hatcheries from juveniles reared at the Tucannon Hatchery (WDG) and imprinted to the Walla Walla and Snake Rivers in 1980. Recoveries were from June 1981 to November 1983.

Sampling location	Number of adults recaptured[a/]							
	Walla Walla River release		1st ATPase release		2nd ATPase release		3rd ATPasc release	
	N	%	N	%	N	%	N	%
Columbia River								
Lower River below Bonneville Dam	0	0.000	2	0.009	0	0.000	0	0.000
Deschutes River	0	0.000	5	0.023	6	0.030	0	0.000
Deschutcs River Hatcheries	0	0.000	0	0.000	2	0.010	0	0.000
Subtotal	0	0.000	7	0.032	8	0.041	0	0.000
Upper Mid-Columbia River								
Priest Rapids Hatchery	0	0.000	0	0.000	0	0.000	1	0.005
Snake River								
Clcarwatcr River	0	0.000	0	0.000	2	0.010	0	0.000
Dworshak Hatchery	0	0.000	0	0.000	1	0.005	0	0.000
Subtotal	0	0.000	0	0.000	3	0.015	0	0.000
TOTAL	0	0.000	7	0.032	11	0.056	1	0.005

a/ Because of differences in sampling intensity (efficiency) at each site, results arc not comparable between sites.

Appendix Table B4.--Number and percent recovery of 1-, 2-, and 3-ocean age steelhead in the Zone 6 Indian fishery from experimental releases of smolts imprinted to the Walla Walla and Snake Rivers in 1980. Recoveries were from September 1981 to October 1983.

Experimental releases	Numbers of juvenile released	Number of adults recovered												
		1-ocean age				2-ocean age				3-ocean age		1-,2-,& 3-ocean age		
		Fall		Winter		Fall		Winter		Fall		Total		
		N	%	N	%	N	%	N	%	N	%	N	%	Est. %[a/]
Walla Walla River (natural migration)	16,923	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0.000
1st ATPase release (transported)	21,652	0	0.000	10	0.046	2	0.009	10	0.046	1	0.005	23	0.106	0.195
2nd ATPase release (transported)	19,747	1	0.005	9	0.046	11	0.056	65	0.329	3	0.015	89	0.451	0.806
3rd ATPase release (transported)	18,964	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0.000

a/ Estimated recoveries based on sampling efficiency of the Zone 6 Indian fishery.

Appendix Table B5 --Spring chinook salmon marked at Carson Hatchery for release in 1980. Test number, mark used, number released, date released, type of imprint, and treatment for various groups are indicated.

Test control	CWT code	Brand	Number[a] released	Date released	Homing imprint	Treatment
Control	03-57-02	LA-m	37,499	12 May	Natural migration	Released from Carson NFH into hatchery outlet creek leading into the Wind River.
Test 1	03-58-02	RA-L	36,262	12 May	Single	Loaded into tanker for 2 h, then released into raceway containing Tyee Springs water for 48 h minimum, and then trucked in Tyee Springs water to release site at Dalton Point on the Columbia River.
Test 2	03-59-02	RA-⌐	41,537	14 May	Sequential	Loaded into tanker (Tyee Springs water) for 2 h, released into raceway (Tyee Springs water) for 48 h minimum, loaded into tanker containing Tyee Springs water for 2 h, released into raceway (Wind River water) for 48 h minimum, then loaded into tanker (Wind River water), and hauled to release site at Dalton Point on the Columbia River.
Test 3	03-60-02	RA-7	43,180	15 May	Sequential	Treatment same as in Test 2 except fish were released near Hammond, Oregon, on the Columbia River.

a/ Adjusted for inital tag loss.

Appendix Table B6.--Spring chinook salmon marked at Leavenworth Hatchery for release in 1980. Test number, mark used, number released, type of imprint, and treatment for various groups are indicated.

Test control	CWT code	Brand	Number[a] released	Date released	Homing imprint	Treatment
Marked in fall, 1979						
Control 1	03-61-02	LA-≍	32,126	24 April	Natural migration	Released from hatchery into Icicle River
	03-61-02	LA-≍	32,238	27 April		
	03-61-02	LA-≍	32,274	1 May		
			96,638			
Marked in spring, 1980						
Control 2	03-46-02	LA-⁀II	32,795	24 April	Natural migration	Allowed unmarked fish to migrate naturally for 1 mile in Icicle River bypass channel. Recaptured, marked, and released from hatchery into Icicle River.
	03-47-02	LA-=)	32,929	27 April[b]		
	03-51-01	LA-(=	31,565	1 May		
	03-51-02	RA-(=	1,500[c]	1 May		
			98,789			
Test 1	03-49-02	LA-)(	32,649	24 April	Single	Allowed unmarked fish to migrate naturally for 1 mile in Icicle River bypass channel. Recaptured, marked, and transported by truck in Icicle River water to a release site at White Bluffs on the Columbia River (RM 362).
	03-50-02	LA-S	35,439	27 April		
	03-48-02	LA- U	32,017	1 May		
			100,105			
Test 2	03-52-02	RA-IK	32,960	24 April	Single	Allowed unmarked fish to migrate naturally for 1 mile in Icicle River bypass channel. Recaptured, marked, and transported by truck in Icicle River water to a release site at Dalton Point on the Columbia River (RM 142).
	03-53-02	RA-I/K	32,847	27 April		
	03-54-02	RA-ꓘI	32,641	1 May		
			98,448			
Test 3	03-43-02	RA- 9	32,441[d]	24 April	Single	Held in live pen in Icicle River bypass channel for 48 h, then transported by truck in Icicle River water to a release site at Dalton Point on the Columbia River (RM 142).
	03-44-02	RA-ɷ	32,728	27 April		
	03-45-02	RA- 6	32,464	1 May		
			97,633			

a/ Adjusted for initial tag loss.

b/ The second release date for Control 2 was reported incorrectly in Table 3, Slatick et al. (1982). Also the total number of each marked group was omitted.

c/ These 1,500 fish were incorrectly branded RA-(=.

d/ An estimated 400 of these fish escaped into the Icicle River.

Appendix Table B7.--Summary of fall chinook salmon recoveries from the 1980 Big Creek Hatchery-Stavebolt Creek homing experiment. Recoveries through December 1983.

	Control or test, imprint, release site, wire tag code, and number released			
	Control a/	Control	Test 1	Test 2
	natural	natural	single	natural
	Big Creek	Big Creek	Astoria	Stavebolt
	07-2 l-60	03-42-02	03-40-02	03-41-02
May 13 May 23	May 13-23	May 13-23		
Recovery locations (River Miles)	143,400 b/	43,863	49,528	50,414
Ocean fisheries				
California	2	1	0	1
Oregon	25	1	4	6
Washington	123	15	30	22
British Columbia	126	8	12	18
Alaska	0	1	1	1
Foreign high seas	1	0	0	0
Ocean fisheries totals	277	26	47	48
Columbia River fisheries				
Zone 1	53	6	17	14
Youngs Bay (12)	1	1	22	25
Big Creek c/ (30.4)	5	1	1	0
Columbia River fisheries totals	59	8	40	39
Hatcheries				
Grays River (20.5)	0	1	0	0
Big Creek (30.4)	144	22	14	1
Elokoman River (39.1)	0	4	0	0
Bonneville (144.5)	1	0	0	0
Hatcheries totals	145	27	14	1
Stream Surveys				
Lewis and Clark (12.0)	0	0	1	4
Grays River (20.5)	0	0	1	0
Bear Creek d/ (22.5)	5	1	0	0
Big Creek (30.4)	29	3	1	0
Gnat Creek (31.0)	0	0	1	0
Skamokawa Creek (34.0)	7	2	1	1
Elokoman River (39.1)	2	1	0	0
Plympton Creek (43.0)	30	0	1	0
Abernathy Creek (54.5)	8	0	1	0
Lewis River (87.5)	1	0	0	0
Stream surveys total	82	7	7	5
Others				
Willamette Falls trap (102.0)	1	0	0	0
TOTAL KECOVERLES	564	68	108	93

a/ Hatchery Evaluation Group, a random sample of the entire production at Big Creek Hatchery, tagged by ODFW. This group was used to illustrate normal migratory behavior of Big Creek fall chinook salmon.
b/ Total for this group was adjusted for tag loss and tagging mortality.
c/ Big Creek terminal fishery was fished in 1983 only.
d/ Bear Creek stream survey was conducted in 1983 only.

Appendix Table B8 --Summary of FY83 expenditures for BPA Project 78-1, "Imprinting of Hatchery Reared Salmon and Steelhead Trout for Homing of Transported Fish."

Item	Total spent
Salary and overhead	76.6
Travel	9.2
Vehicles	10.0
Rent	1.6
Printing	0.1
Contractual Services	3.5
Supplies	4.2
Support	29.3
Total	134.5
Returned	3.2
Grand total	137.7