Imprinting Salmon and Steelhead Trout for Homing, 1981

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COASTAL ZONE AND ESTUARINE STUDIES

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ABSTRACT

The National Marine Fisheries Service, 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 1981 concentrated on: (1) recovering returning adults from previous experiments, (2) analyzing completed 1978 steelhead and 1980 coho salmon experiments, and (3) preliminary analyzing 1979 and 1980 fall chinook salmon experiments.

Seven experimental groups are discussed: four steelhead, two fall chinook salmon, and one coho salmon. In four groups, survival was enhanced by the imprinting-transportation procedures. Homing back to the hatchery area was successful in two groups, and generally, unless there were extenuating circumstances (eruption of Mount St. Helens, disease problem, etc.), greater returns to user groups were evident.

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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. 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 ability 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 use single imprints 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, a total of 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 3 years of juvenile marking activities and preliminary analyses of adult returns were reported by Slatick et al. (1979, 1980, 1981) and Novotny and Zaugg (1979, 1981). This report summarizes adult returns through 1981 with statistical treatment of completed experiments.

ADULT RETURNS FROM IMPRINT TESTS

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 with a coded wire tag (CWT). Homing of various groups is determined by the rate of return of marked adults to the homing sites. All homing sites are located at permanent facilities (hatcheries) except the ones at Stavebolt Creek, Oregon, and Pasco, Washington, where adequate facilities were constructed. Survival of various groups was measured by the combined total recoveries of CWTs at the homing site, from in-river sampling sites (Figure 2), from commercial and sport fisheries, and from hatcheries and spawning grounds. 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.

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	74,741	--	99,135	1980-83
Tucannon	36,686	67,573	--	1980-82
Tucannon-L. Goose Dam	--	--	78,091	1981-82
Spring chinook salmon				
Kooskia	186,597 a/	--	123,600	1980-83
Rapid River	--	--	121,566	1981-83
Fall chinook salmon				
Hagerman-Lower Granite Dam	--	--	114,000	1981-84
	Columbia River System			
Steelhead				
Chelan-Leavenworth	137,949	137,817	--	1979-81
Wells-Winthrop	96,978	65,243	--	1979-81
Spring chinook salmon				
Carson-Pasco	--	113,681	--	1980-82
Carson	--	159,682	159,327	1980-83
Leavenworth	--	--	491,768	1981-83
Coho salmon				
Carson-Pasco	102,594 b/	--	--	1978-79
Willard-Stavebolt Creek	414,907 b/	--	--	1978-79
Willard	--	--	436,118	1980-81
Fall chinook salmon				
Big White Salmon-Stavebolt	--	473,027	--	1980-82
Big Creek-Stavebolt Creek	--	--	143,805	1981-84
Spring Creek	--	--	259,786	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	270,633	177,226	794,213
	1,050,452	1,017,023	2,027,196	4,094,671

a/ Results in Slatick et al. 1981.

b/ Results in Slatick et al. 1980.

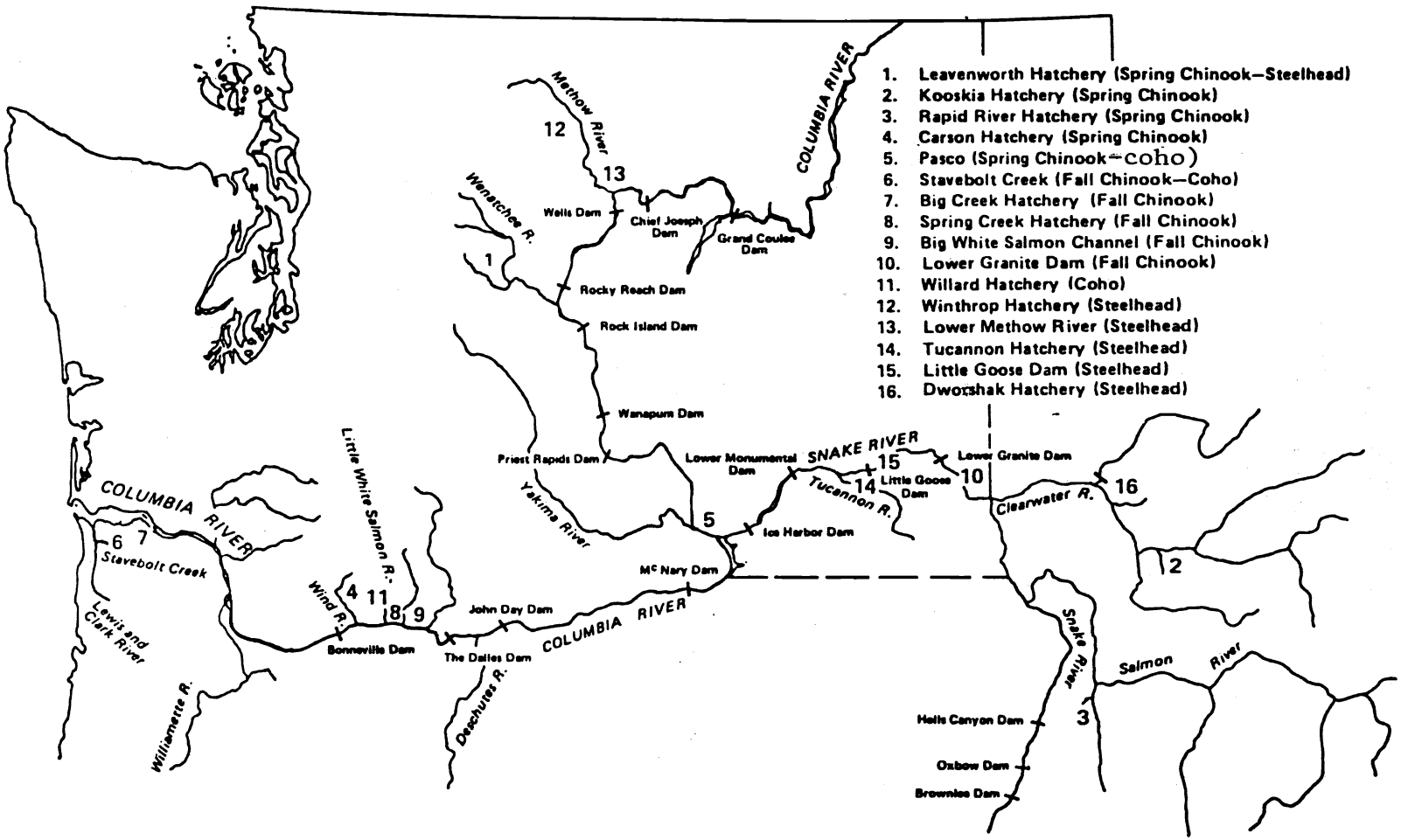

Figure 1.--Area map indicating experimental homing sites, 1978-1980.

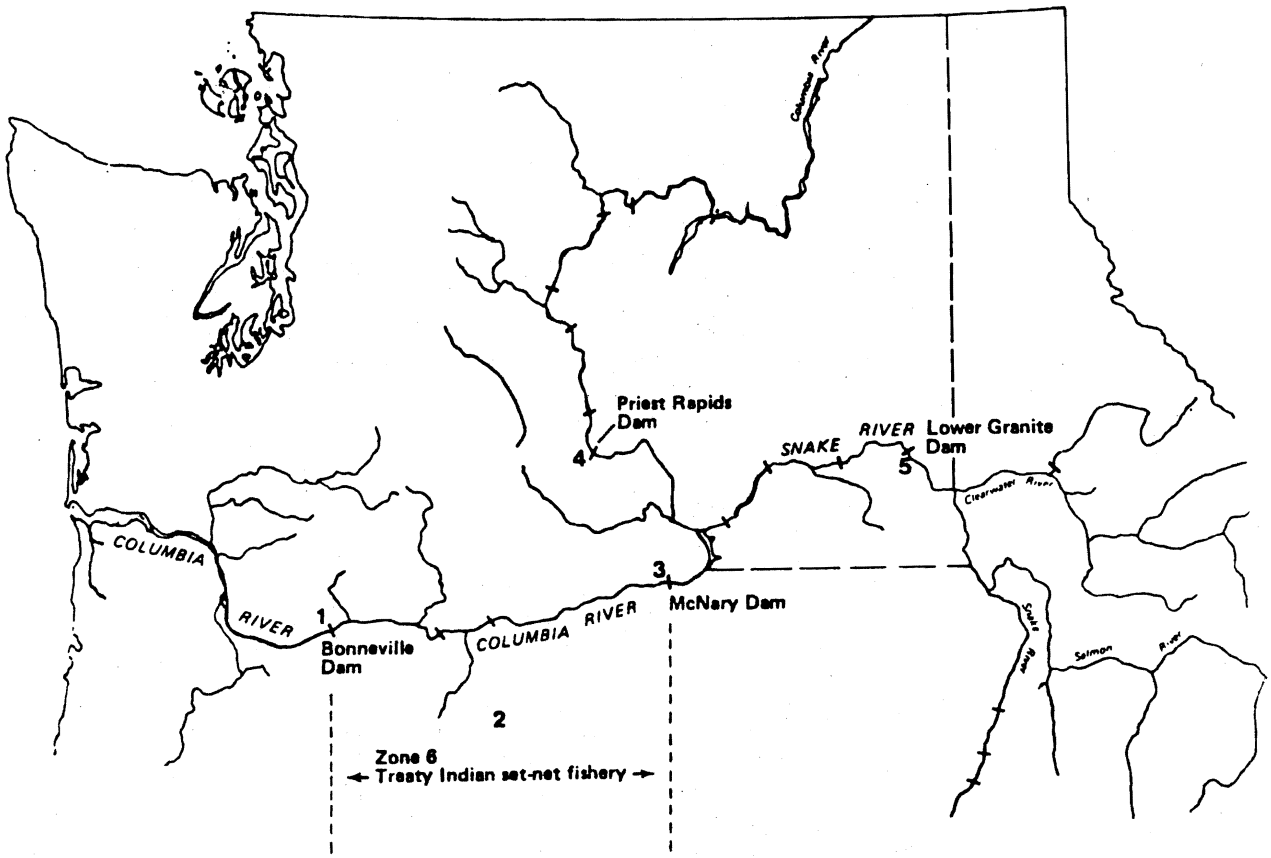

Figure 2.--Map of Columbia River system showing location of five in-river sampling locations.

Steelhead Experiments

Returns of adults from the 1978 experimental releases of smolts are essentially complete. The final analysis of results, with statistical treatment, for each of these experiments is presented in this report. Data on adult returns from the 1979 and 1980 experimental releases of smolts are incomplete. Preliminary results from the 1979 experiments, based on 1-ocean returns in 1980, were previously reported (Slatick et al. 1981). Additional results on these experiments will not be reported until 1982 when adult returns are complete and final analyses can be prepared. Stocks of fish used in the 1980 experiments are dominant 2-ocean and are not expected back as adults until 1982 and 1983.

Dworshak-1978

Experimental Design and Background.--Steelhead reared at Dworshak National Fish Hatchery (NFH) are indigenous to the North Fork of the Clearwater River and migrate 504 miles before reaching seawater. Previous NMFS studies (Park et al. 1980) showed that steelhead of Dworshak NFH origin that were intercepted at Lower Granite Dam [River Mile (RM) 431] and transported to Bonneville Dam (RM 145) homed successfully to Dworshak NFH. The goal of the 1978 work at Dworshak NFH was to determine if exposure to at least 48 h of home stream water (North Fork of Clearwater River) would assure homing in juvenile steelhead that were denied all natural migration above Bonneville Dam.

The 1978 test design included a control group released at Dworshak NFH into the North Fork of the Clearwater and two test groups transported from Dworshak NFH to a release site below Bonneville Dam. Test fish were taken from the normal reconditioned water supply in System #3 by pumping them through irrigation pipe into raw North Fork Clearwater River water in System #2 raceways, where they were held for 6 days prior to transport.

One test group was moved to Lewiston, Idaho, (RM 463) by truck, then barged through the normal migration route. The other test group was moved by truck to the release site below Bonneville Dam. Additional details of the experimental design are given in a previous report (Slatick et al. 1981).

Results.--Previous results have been discussed in considerable detail (Slatick et al. 1981). Additional adult returns have been minimal and have not changed the results previously reported. Total returns with statistical treatment of results are summarized in Table 2. Estimated recoveries in the fisheries and actual returns to the hatchery are summarized in Table 3. Major findings were:

1. Survival was enhanced by transporting fish around dams. Adults from the barged group returned at significantly higher rates ($P<0.05$, df = 1) than the controls except at Bonneville Dam where numbers were insufficient to detect differences (Table 2). Total contribution (adult return percentage) to user groups was 1.86% for barged fish, 1.39% for trucked fish, and 0.83% for control fish (Table 3).

2. Homing of both barged and trucked groups was impaired as indicated by test to control ratios. A ratio of over 5:1 was indicated for transported fish in the lower river compared to 1.63:1 for barged, and 0.96:1 for trucked fish back at the hatchery (Table 2).

3. Even though homing of both test groups was impaired, sufficient homing cues were imparted to fish in the barged group to cause a significantly higher ($P<0.01$, df = 1) return of barged fish than control fish to the hatchery (Table 2).

Discussion.--The majority of Dworshak NFH steelhead return to the Columbia River System as 2-ocean age adults. Effects of transportation and

Table 2 .--Returns to five sampling locations and to the Dworshak homing site of steelhead from control and test releases of smolts imprinted to the Dworshak NFH in 1978. Recoveries were from September 1979 to 12 May 1981.

Sampling location and experiment	Control or test	Number juveniles released	No. of adults[a] recaptured: 1-ocean age	2-ocean age	Total 1 & 2's	Adult[d] return % of juveniles	Test to control ratio
Bonneville Dam[b]							
Dworshak	Control	30,074	1	13	14	0.047	
Trucked	Test	20,661	1	14	15	0.321	6.82:1 NS
Barged	Test	24,006	1	8	9	0.158	3.36:1 NS
Indian fishery[c]							
Dworshak	Control	100,600[e]	1	39	40	0.040	
Trucked	Test	20,661	1	44	45	0.218	5.45:1**
Barged	Test	24,006	2	51	53	0.221	5.53:1**
McNary Dam[b]							
Dworshak	Control	30,074	3	18	21	0.070	
Trucked	Test	20,661	0	4	4	0.088	1.26:1 *
Barged	Test	24,006	1	8	9	0.158	2.26:1 *
Lower Granite Dam[b]							
Dworshak	Control	30,074	14	170	184	0.612	
Trucked	Test	20,661	2	15	17	0.352	0.58:1 **
Barged	Test	24,006	1	48	49	0.930	1.52:1 **
Clearwater and Snake River sport fishery							
Dworshak	Control	100,600	1	75	76	0.076	
Trucked	Test	20,661	0	8	8	0.039	0.51:1 NS
Barged	Test	24,006	0	20	20	0.146	1.92:1 **
Dworshak homing site							
Dworshak	Control	100,600	26	249	275	0.273	
Trucked	Test	20,661	1	53	54	0.261	0.96:1 NS
Barged	Test	24,006	6	101	107	0.446	1.63:1 **
Total branded		74,741	62	938	1,000		
Wire-tagged only		70,526					

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

b/ Data from branded fish only.

c/ Data from coded wire tags only.

d/ Adjusted for the difference in detectability between binary and color-coded wire tags as indicated by returns to Dworshak Hatchery.

e/ A total of 100,600 were wire tagged for the hatchery control release, of this number 30,074 were branded for inriver adult evaluation.

NS Nonsignificant

* $P<0.05$, df= 1; indicates significant difference between the test and control group.

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

Table 3.--Minimum estimated recovery of 2-ocean age steelhead in Indian fishery (Zone 6), Clearwater River harvest, and actual recoveries at Dworshak NFH homing site from control and test releases of smolts imprinted to the Dworshak NFH in 1978.

Recovery location[a]		Number and % of 2-ocean age adults recovered					
		Control (100,600)[b]		Truck (20,661)[b]		Barge (24,006)[b]	
		N	%	N	%	N	%
Indian fishery[c] (zone 6)	fall	102		27		50	
	spring	15		107		105	
	Total	117	0.116	134	0.647*	155	0.645*
Clearwater River[d] harvest		471	0.468	100	0.484 NS	191	0.796*
Dworshak NFH (homing site)		249	0.248	53	0.257 NS	101	0.421*
TOTAL		837	0.832	287	1.389*	447	1.862*

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 of the Zone 6 Indian fishery.

d/ Estimated recovery of both Indian and sport fisheries based on total estimated Clearwater River harvest by Idaho Fish and Game--personal communication with Steve Pettit IFG.

NS Nonsignificant.

* $P<0.05$, df = 1; indicates significant difference between the test and control group.

imprinting on the survival and homing of the test groups which were trucked or barged are demonstrated by recoveries in the two principal fisheries (Zone 6 Indian fishery and Clearwater River harvest) and returns to the Dworshak NFH homing site. The total estimated (minimum) recovery of 2-ocean age adults was 1.389% for the trucked fish, 1.862% for the barged fish, and 0.832% for the control fish (Table 3). These figures reflect the increased survival and subsequent contribution to user groups of the test lots which were transported directly from the Dworshak NFH compared to the higher losses from the control lot (nontransported from Dworshak NFH). As discussed previously by Slatick et al. (1981), the difference in rate of return of test and control fish is even more impressive when one considers that approximately 67% of the control fish surviving to Lower Granite Dam were also transported below Bonneville Dam.

Homing was impaired as indicated by the difference between the test/control ratios of both groups (5.5:1) in the Indian fishery as compared to the test/control ratios back at the hatchery of 0.96:1 for trucked fish and 1.63:1 for barged fish. Since survival of both groups were comparable (similar test/control ratios in Indian Fishery), the difference in test/control ratios back at the hatchery indicates that barged fish had a greater ability to home back to the hatchery than trucked fish.

The impaired homing resulted in a large number of the test fish delaying or remaining in the Bonneville Pool as evidenced by the catches in the Indian Fishery. Nearly 90% of the control fish were taken in the fall fishery during the ustream migration. In contrast, nearly 75% of the test fish taken were those that had overwintered in the Bonneville Pool and were caught in the spring gillnet fishery (Table 3).

A key point to keep in mind is that even though homing of the barged group was impaired, there were still enough fish imprinted to provide a significantly greater ($P<0.01$, df = 1) percent return to the hatchery and to the Clearwater River sport fishery than those released at the hatchery. These positive data led to the development of a more elaborate followup study, funded by BPA, in 1982 to determine if differences in time release and/or levels of gill Na^+-K^+ ATPase (difference in smolting activity) would result in an increased ability to home to the hatchery.

Tucannon-1978

Experimental Design and Background.--The objective of the 1978 Tucannon Hatchery (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-hour holding period, the fish were transported by truck around the 34 miles of the Tucannon River they would have encountered during a natural outmigration, and loaded into a barge moored on the Snake River at Lyons Ferry Grain Terminal (RM 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 release into the Tucannon River could not be made because of management restraints. A group of marked steelhead released by the WDG into the Grande Ronde River (RM 493) served as the control release for this experiment. Additional details of the experimental design are given in a previous report (Slatick et al. 1981).

Results.--Previous results have been discussed (Slatick et al. 1981). Additional adult returns have not substantially changed the results previously reported. Total returns with statistical treatment of results are summarized in Table 4. Estimated recoveries in the fisheries and back at Lower Granite Dam are summarized in Table 5. Miscellaneous returns in sport fisheries and hatcheries are summarized in Appendix Table A1. Major findings were:

1. Returns of adults indicate that the methods used in 1978 were unsuccessful in returning the test groups of steelhead to the Tucannon Hatchery homing site. No fish were recovered at the hatchery or in our sampling of the Tucannon River.

2. Imprint methods used, however, did implant sufficient homing cues to enable as many of the spring water barge group to return to the Snake River as the control fish (1.06:1 test/control ratio at Lower Granite Dam) (Table 4).

3. The higher test/control ratios at Bonneville Dam and in the Indian Fishery as compared to Lower Granite Dam indicate that a substantial number of the test fish failed to imprint to the Snake River (Table 4).

4. There was no straying of test fish into the Columbia River above the confluence of the Snake River based on sampling at Priest Rapids Dam and the sport fishery. By comparison, five of the control fish

Table 4.--Complete returns to four sampling locations of 1-2-and 3-ocean age steelhead from control and test releases of smolts from the Tucannon Hatchery in 1978. Test fish were imprinted to the Tucannon Hatchery and trucked to a barge on the Snake River at Lyons Ferry grain terminal, and then barged downriver to below Bonneville Dam. Control fish were released into the Grande Ronde River. Recoveries were from June 1979 to 30 November 1981.

Sampling location and experiment	Control or test	Number juveniles released	No. of adults recaptured[a/] 1-ocean age	2-ocean age	3-ocean age	Total 1, 2, & 3's	Adult return % of juveniles released	Test to control ratio
Bonneville Dam								
Grande Ronde River	Control	55,557	0	9	15	24	0.043	
100% spring water	Test	18,137	1	27	28	56	0.309	7.19:1*
20% spring water	Test	18,549	0	6	22	28	0.151	3.51:1*
Indian fishery								
Grande Ronde River	Control		0	4	3	7	0.013	
100% spring water	Test		0	23	4	27	0.149	11.46:1*
20% spring water	Test		1	20	5	26	0.140	10.76:1*
McNary Dam								
Grande Ronde River	Control		0	1	0	1	0.002	
100% spring water	Test		0	2	1	3	0.017	8.50:1 NS
20% spring water	Test		0	7	0	7	0.038	19.00:1 NS
Lower Granite Dam								
Grande Ronde River	Control		0	87	20	107	0.193	
100% spring water	Test		1	33	3	37	0.204	1.06:1 NS
20% spring water	Test		1	9	0	10	0.054	0.28:1*
TOTAL		92,243	4	228	101	333		

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

NS Nonsignificant

* $P < 0.05$, df = 1; indicates significant difference between the test and control group.

released in the Grande Ronde River were recovered in the Wenatchee River sport fishery Appendix table A1). This would indicate that straying can be caused by a myriad of reasons, not just transportation and lack of imprinting.

5. Survival was enhanced by transporting fish around dams as evidenced by the significantly higher ($P<0.05$, df = 1) rate of returns of test fish over control fish at Bonneville Dam and in the Indian Fishery. Rate of return of test fish to McNary Dam was also much higher than returns of control fish, but numbers were insufficient to detect significant differences (Table 4).

6. The combination of impaired homing and enhanced survival of transported fish resulted in barged releases providing approximately 10 times as many fish to user groups as control fish (total recovery in fisheries and to lower river hatcheries-0.570% for barged fish vs 0.054% for control fish) (Table 5).

Discussion.--Barged fish contributed over 13 times as many fish to the Indian Fishery as control fish (Table 5). Besides higher survival, the main reason for the higher catch rate of test fish was probably the fact that many of the test fish were not imprinted, milled or remained in the vicinity of their original release site, and were therefore more susceptible to the fishery. Recoveries of this stock of steelhead at Lower Granite Dam indicate they enter and migrate up the Columbia River early in the season. In 1980 and in 1981, 80% of the controls and 100% of the 100% spring water fish had passed Lower Granite Dam by 1 September. Therefore, the majority of returning adults bearing a positive Snake River imprint moved through the lower Columbia River before the fall Zone 6 Indian fishery was opened. Those fish that did not receive an upriver homing imprint remained in the Bonneville pool area. If they did move

Table 5.--Minimum estimated recovery of steelhead in Indian fishery (Zone 6), and at Lower Granite Dam sampling site, and actual recoveries in the sport fishery and hatcheries below Lower Granite Dam from control and test releases of smolts imprinted to the Tucannon Hatchery and the Grand Ronde River in 1978.

Location and period of recovery[a]	Number and % of adults recaptured					
	Control (55,557)[b]		100% spring water (18,137)[b]		20% spring water (18,547)[b]	
	N	%	N	%	N	%
Indian fishery[c] (Zone 6)						
Fall	5		25		36	
Spring	12		52		37	
Subtotal	17	0.031	77	0.425	73	0.394
Sport fisheries & hatcheries[d]						
Fall	13		36		23	
Spring	0		0		0	
Subtotal	13	0.023	36	0.198	23	0.124
Total	30	0.054	113	0.623[f]	96	0.518[f]
Lower Granite Dam[e]						
Fall	437		149		39	
Spring	0		0		0	
Total	437	0.787	149	0.822	39	0.210
Grand Total	467	0.841	262	1.444	135	0.728

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/ 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 in 1978.

f/ Total for barged fish: $\frac{113 + 96}{18,137 + 18,547} = \frac{209}{36,684} = 0.570$

upstream, they did not migrate up as far as Lower Granite Dam. No marked fish were recovered in the spring at Lower Granite Dam in either 1981 or 1982. By contrast, substantial numbers were caught in the spring (Zone 6) fishery (Table 5). Additional evidence from the lack of returns to upriver sport fisheries and hatcheries as contrasted to a large catch in the Deschutes River, other sport catches in the lower river, and the returns to lower river hatcheries (Appendix Table A1) strongly suggest the adults returning from the test groups remained in the Bonneville area.

At lower Granite Dam, 3.8 times as many fish returned from the 100% spring water group as returned from the 20% spring water group. Sampling of the 1978 juvenile migration at Jones Beach (RM 47) (Dawley et al. 1979) also showed a 3.8:1 difference between the 100% and 20% spring water groups, respectively. From the Jones Beach juvenile sampling, it would appear that the differential survival between test groups occurred in the Lower Columbia River between the barge release site near Bonneville Dam and the Jones Beach sampling site. It cannot be determined whether the cause of this difference between the test groups was due to mortality or a lack of smoltification. Test fish appeared to be healthy at time of release, and were released on 17 May, slightly after the peak of the gill Na^+-K^+ ATPase activity (Novotny et al. 1979). The smolts, which migrated, moved rapidly downriver passing Jones Beach between 20 May and 2 June.

The data obtained from this study indicated that techniques used could enhance survival and provide a partial homing cue to the Snake River. Because of this, the WDG and NMFS initiated a follow-up study in 1980 using Chelan Hatchery stock. Controls were released in the Walla Walla River and test fish trucked to Dalton Point (See Slatick et al. 1981 for more detail on test procedures). No adult return data will be available until 1982-1983.

Wells-Winthrop-1978

Experimental Design and Background.--The object of this experiment was to imprint steelhead from the Wells Hatchery (WDG) with a homing cue to the Winthrop NFH (a hatchery other than the hatchery of origin) on the Methow River and determine if a single or sequential homing imprint will cause steelhead to return to the Winthrop NFH homing site.

The experimental design used five groups of steelhead of aproximately 20,000 fish per group; a control group held 2 days at Winthrop NFH prior to release at the hatchery, the production release made directly into the Methow River 0.25 mile upstream from the mouth, and three transport groups. Transport groups were held 2 to 8 days at the hatchery in an attempt to imprint them to the hatchery water prior to transporting them downriver by barge or truck. One group was then trucked in raceway water and released at Ringold, Washington; the second was trucked in raceway water to a barge at Richland, Washington, and barged downstream to below Bonneville Dam; the third group was trucked in raceway water to a release site below Bonneville Dam. Evaluation was based on comparisons of adult returns from transport releases and the production release with those released as controls at the hatchery. Additional details of the experimental design are given in a previous report (Slatick et al. 1979).

Results--Previous results have been discussed in detail (Slatick et al. 1981). Additional returns in 1981 to the in-river sampling sites and to the sport fishery completes the expected returns of adults from this experiment. Total adult returns with statistical treatment of results are summarized in Table 6. Estimated contributions to the Indian and sport fisheries are summarized in Table 7. Major findings were:

Table 6.--Complete returns to five sampling locations of 1-2-and 3-ocean age steelhead from control and test releases of smolts from the Wells Hatchery which were imprinted to the Winthrop NFH homing site and the Methow River in 1978. Recoveries were from June 1979 to 30 November 1981.

Experiment and sampling location	Homing site	Control or test	Number juveniles released	Number of adults recaptured b/ 1-ocean age	2-ocean age	3-ocean age	Total 1, 2, & 3's	Adult return % of juveniles	Test to control ratio	
Bonneville Dam										
Winthrop NFH	Winthrop	Control	20,330	4	1	0	5	0.025		
L. Methow River	Methow R.	Test a/	19,901	8	4	1	13	0.065	2.6:1	NS
Truck to Bonneville	Winthrop	Test	19,131	26	5	5	36	0.188	7.5:1	*
Barge to Bonneville	Winthrop	Test	19,979	14	7	4	25	0.125	5.0:1	*
Truck to Ringold	Winthrop	Test	17,637	23	5	2	30	0.170	6.8:1	*
Indian fishery										
Winthrop NFH	Winthrop	Control		7	1	0	8	0.039		
L. Methow River	Methow R.	Test a/		12	2	0	14	0.070	1.8:1	NS
Truck to Bonneville	Winthrop	Test		29	14	2	45	0.235	6.0:1	*
Barge to Bonneville	Winthrop	Test		19	11	1	31	0.155	4.0:1	*
Truck to Ringold	Winthrop	Test		13	3	1	17	0.096	2.5:1	*
McNary Dam										
Winthrop NFH	Winthrop	Control		18	2	0	20	0.098		
L. Methow River	Methow R.	Test a/		28	6	0	34	0.171	1.7:1	*
Truck to Bonneville	Winthrop	Test		85	4	0	89	0.465	4.7:1	*
Barge to Bonneville	Winthrop	Test		52	5	0	57	0.286	2.9:1	*
Truck to Ringold	Winthrop	Test		62	4	0	66	0.374	3.8:1	*
Priest Rapids Dam										
Winthrop NFH	Winthrop	Control		33	5	0	38	0.187		
L. Methow River	Methow R.	Test a/		44	11	0	55	0.276	1.5:1	NS
Truck to Bonneville	Winthrop	Test		32	13	0	45	0.235	1.3:1	NS
Barge to Bonneville	Winthrop	Test		14	8	0	22	0.110	0.6:1	*
Truck to Ringold	Winthrop	Test		63	17	0	80	0.454	2.4:1	*
Winthrop Homing Site										
Winthrop NFH	Winthrop	Control		18	0	-	18	0.089		
L. Methow River	Methow R.	Test a/		1	0	-	1	0.005	0.06	NS
Truck to Bonneville	Winthrop	Test		1	0	-	1	0.005	0.06	NS
Barge to Bonneville	Winthrop	Test		1	0	-	1	0.005	0.06	NS
Truck to Ringold	Winthrop	Test		1	0	-	1	0.006	0.07	NS
TOTAL			96,978	608	128	16	752			

a/ WDG production release

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

NS Nonsignificant

* $P < 0.05$, df = 1, indicates significant difference between the test and control group.

Table 7.--Estimated recovery in the sport and Zone 6 Indian fisheries of adult steelhead returning from control and test releases of juveniles from the 1978 Wells-Winthrop experiment. Recoveries were from June 1979 to March 1981.

Control or test groups	Number[b/] juveniles released (N)	Sport fishery[a/] Lower Columbia River (N)	Ringold area (N)	Entiat & Wenatchee area (N)	Methow area (N)	Total	Indian[c/] fishery (N)	Total recovery (N)	(%)	Test to control ratio
Winthrop NFH (control)	20,330	0	0	0	54	54	27	81	0.398	
Lower Methow River (prod. rel. site)	19,901	0	17	14	136	167	47	214	1.075	2.70:1*
Truck to Bonneville (test)	19,131	0	158	60	18	236	145	381	1.992	5.00:1*
Barge to Bonneville (test)	19,979	14	103	13	5	135	100	235	1.176	2.95:1*
Truck to Ringold (test)	17,637	14	52	53	41	160	53	213	1.208	3.04:1*
TOTAL	96,978	28	330	140	254	752	372	1,124	1.159	

a/ From Hisata et al. 1979-80, and Schuck et al. 1980-81.

b/ Adjusted for initial tag loss.

c/ Estimated recoveries based on sampling efficiency of the Zone 6 Indian Fishery.

* $P<0.05$, df = 1 indicates significant difference between test and control releases.

1. Although imprint methods used in these experiments were not successful in returning fish to the homing site, they did implant a limited homing cue which enabled approximately 60% of the returning adults transported as juveniles to home to areas above McNary Dam. This is based on the average difference in test/control ratios between Bonneville and McNary Dams (Table 6).

2. Homing above that point was further impaired as indicated by a decline in test/control ratios for all three transport groups at Priest Rapids Dam. The difference in test/control ratios at Priest Rapids Dam reflects the varying degree of homing cues that resulted from each treatment. The test group trucked to Ringold (2.4:1) was highest, followed by the group trucked to Bonneville (1.3:1), and the group barged from Richland (0.6:1) (Table 6).

3. Data obtained from the sport fishery (Table 7) generally verified the data obtained from sampling at Priest Rapids Dam. Of the total sport catch, Ringold releases resulted in the highest proportion (58%-94 fish) caught in the fishery above Priest Rapids; trucked fish released at Bonneville Dam were next at 33% (78 fish); whereas only 14% (18 fish) of the barged fish were caught in the sport fishing areas above Priest Rapids Dam. Of those transport fish that were caught above Priest Rapids Dam, more than twice as many of the Ringold group, compared to the other two transport groups, were able to home to the Methow River as evidenced by the Methow River sport catch (41 fish from Ringold, Washington, vs 18 from those trucked to Bonneville Dam and only 5 from those barged to Bonneville Dam).

4. Impairment of homing was also evident by the numbers of fish straying into the Snake River system where they were monitored at Lower Granite Dam (Snake River Mile 107). Recoveries of marked fish show that

although some straying occurred from all transport groups; the only major number of strays were from the trucked-to-Bonneville Dam test group (Appendix Table A2).

5. Transporting fish around dams significantly enhanced survival. Up to 7.5 times as many transported fish returned as adults to the Bonneville Dam sampling site as controls. Survival of the trucked group was highest (7.5:1) (Table 6). Returns to the sport fishery provided additional verification that survival of trucked fish was higher than the treatment utilizing both trucking and barging. Total contribution to user groups was nearly 2% for the trucked fish vs 1.2% for the truck-barge group.

6. Significantly higher survival ($P<0.05$, df = 1) of the transport groups resulted in the transported fish contributing significantly greater numbers of fish ($P<0.05$, df = 1) than the control fish to the sport and Indian fisheries (Table 7). Overall, the total contribution from the transport releases to various sport and Indian fisheries was 829 fish or over 1.5% of those released compared to 295 fish for those released in the Methow River or 0.7% of those released.

7. Survival of the Winthrop control release was significantly lower ($P<0.05$, df = 1) than the Lower Methow River production release based on recoveries of adults in the Indian and sport fishery and at Bonneville and McNary Dams. The lower survival probably resulted from mortality during the juvenile outmigration in 1978. Sampling of the 1978 smolt outmigration at McNary and John Day Dams in 1978 showed that the lower Methow production release group had a three times greater survival than the Winthrop NFH control group at both of these juvenile sampling sites.[1/]

[1/] Personal Communication, Carl Sims, NMFS NWAFC, 2725 Montlake Blvd. E., Seattle, WA 98112.

8. The various transport releases provided 531 (752 minus 54 Winthrop controls and 167 Lower Methow production release) fish (nearly a 1% return) to the various sport fisheries. Most were caught in the Ringold area (Table 7). This compares to a 0.5% return for those released by WDG at Ringold Hatchery (Hisata et al. 1979-80; Shuck et al. 1980-81). The ability to increase the sport harvest in selected areas by providing a limited homing imprint and enhancing survival by transporting smolts by truck around dams could be a useful tool for future management of these mid-Columbia River stocks.

Chelan-Leavenworth-1978

Experimental Design and Background.--The object was to determine the length of time required to imprint steelhead from Chelan Hatchery (WDG) with a homing cue to the Leavenworth NFH homing site (a hatchery other than the hatchery of origin) and to determine if holding fish at Leavenworth NFH in combination with a sequential homing imprint (induced by barging) will cause adult steelhead to return to the Leavenworth NFH site.

The experimental design (by Larry Brown, WDG) used three paired test/control groups, of approximately 24,000 fish per group, held at Leavenworth NFH 10 days, 2 days, and 4 h. The test groups were transported by truck from the Leavenworth NFH homing site to a barge at Richland, Washington, and then down river to a release site below Bonneville Dam. Controls were released directly into the Icicle River. Additional details for the experimental design, number of fish per group, etc., are provided in a previous report (Slatick et al. 1979).

Results.--Previous results have been discussed in detail (Slatick et al. 1981). Additional returns in 1981 to the in-river sampling sites and

to the sport fishery complete the expected returns of adults from this experiment. Total adult returns by treatment group with statistical treatment of results are summarized in Table 8. Estimated contributions to the Indian and sport fisheries are summarized in Table 9. Major findings were:

1. Imprint methods used, combined with a truck-barge transport of fish were unsuccessful in returning fish to the upper river and back to the homing site. Test/control ratios of returning adults to the five sampling locations illustrate the increasing loss of homing as these fish moved upstream. The adults from most of the various test groups returned to Bonneville Dam and the Indian fishery at a significantly higher ($P<0.05$, df = 1) rate than the control fish. By the time these adults reached Priest Rapids Dam, there were significantly greater numbers of control fish than test fish ($P<0.05$, df = 1) (Table 8).

2. The impaired homing above Bonneville Dam resulted in an accompanying delay in migration. As a result of this delay, test fish, especially the 10-day imprint group, were more vulnerable or available to the Indian gill-net fishery as evidenced by the large number of test fish recoveries from all treatments in this fishery. Delay in the Zone 6 fishery area is further demonstrated by recovery of 29 test fish and 1 control fish in the 1981 winter fishery (Appendix Table A4).

3. The most apparent loss of homing for the transported groups, as with the Wells-Winthrop experiment, occurred in the 104-mile section of river between McNary and Priest Rapids Dams. This was verified by the average 0.17:1 test/control ratio at Priest Rapids Dam (Table 8) and the recoveries of test and control fish in the major sport fishery areas (Table 9). Most of the test fish were caught below Priest Rapids Dam in the

Table 8.--Complete returns to five sampling locations of 1-, 2-, and 3-ocean age steelhead from paired control and test releases of smolts from the Chelan Hatchery which were imprinted to the Leavenworth NFH homing site in 1978. The test juveniles were transported from the Leavenworth NFH by truck to a barge at Richland, Washington, and then barged downstream to below Bonneville Dam. Recoveries were from June 1979 to 30 November 1981.

Experiment and sampling location	Control or test	Number juveniles released	Number adults recpatured[a/] 1-ocean age	2-ocean age	3-ocean age	Total 1,2 & 3's	Observed adult returns % of juveniles	Test to control ratio
10 DAY IMPRINTING								
Bonneville Dam	Control	24,119	16	2	0	18	0.075	
	Test	22,841	27	4	0	31	0.136	1.81:1*
Indian fishery (Zone 6)	Control		10	2	0	12	0.050	
	Test		49	18	0	67	0.293	5.86:1*
McNary Dam	Control		32	3	0	35	0.145	
	Test		27	10	2	39	0.171	1.18:1 NS
Priest Rapids Dam	Control		47	2	0	49	0.203	
	Test		9	0	0	9	0.039	0.19:1*
Leavenworth homing site	Control		20	2	-	22	0.091	
	Test		1	0	-	1	0.004	0.04:1*
TOTAL		46,960	238	43	2	283		
2-DAY IMPRINTING								
Bonneville Dam	Control	23,787	5	2	0	6	0.029	
	Test	21,694	38	4	0	42	0.194	6.69:1*
Indian fishery (Zone 6)	Control		29	1	0	30	0.126	
	Test		34	19	0	53	0.244	1.94:1*
McNary Dam	Control		31	3	0	34	0.143	
	Test		52	11	3	66	0.304	2.13:1*
Priest Rapids Dam	Control		47	10	0	57	0.240	
	Test		5	1	0	6	0.028	0.12:1*
Leavenworth homing site	Control		23	2	-	25	0.105	
	Test		1	0	-	1	0.005	0.05:1*
TOTAL		45,481	265	53	3	321		
4-HOUR IMPRINTING								
Bonneville Dam	Control	21,957	6	1	0	7	0.032	
	Test	23,551	12	0	0	12	0.051	1.59:1 NS
Indian fishery (Zone 6)	Control		16	3	0	19	0.087	
	Test		47	12	0	59	0.251	2.89:1*
McNary Dam	Control		26	5	0	31	0.141	
	Test		29	6	0	35	0.149	1.06:1 NS
Priest Rapids Dam	Control		47	2	0	49	0.223	
	Test		7	2	0	9	0.038	0.17:1*
Leavenworth homing site	Control		20	4	-	24	0.109	
	Test		1	0	-	1	0.004	0.04:1*
TOTAL		45,508	211	35	0	246		
GRAND TOTAL		137,949	714	131	5	850		

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

NS Nonsignificant

* $P<0.05$, df = 1; indicates significant difference between the test and control group.

Table 9.--Estimated recovery of adult steelhead returning from control and test releases of juveniles from the 1978 Chelan-Leavenworth experiment in seven sampling locations. Recoveries were from June 1979 to March 1981.

Control or test groups	Number[b] juveniles released (N)	Sport fishery[a] Lower[c] Columbia River (N)	Ringold area (N)	Entiat & Wenatchee area (N)	Methow area (N)	Total	Indian fishery (N)	Total recovery (N)	%	Test to control ratio	
10-Day Imprint											
Control	24,119	2	0	190	0	192*	40	232	0.962		
Test	22,841	3	52	9	2	66	222*	288	1.261	1.31:1	NS
2-Day Imprint											
Control	23,787	0	34	253	14	301*	102	403	1.694		
Test	21,694	4	120	13	0	137	171*	308	1.420	0.84:1	NS
4-Hour Imprint											
Control	21,957	0	0	179	15	194 NS	64	258	1.175		
Test	23,551	0	153	26	3	182	197*	379	1.609	1.37:1	NS
TOTAL	137,949	9	359	670	34	1,072	796	1,868	1.354	ave. 1.17:1	NS

a/ From Hista et al. 1979-80, and Schuck et al 1980-81.

b/ Adjusted for initial tag loss.

c/ From observed recoveries--no estimates available.

d/ From steelhead trapped at Priest Rapids Dam for Chelan Hatchery (WDG) brood stock.

* Indicates significant ($P<0.05$, df = 1) difference between test and control releases.

NS Nonsignificant.

free-flowing stretch between Ringold and Priest Rapids Dam. In contrast, most of the control fish continued their upriver migrations and were caught in the Wenatchee sport fishing area or returned to the hatchery.

4. Straying into the Snake River was minimal based on the few recoveries at Lower Granite Dam (Snake River Mile 107). Only 15 fish from the barged groups were observed and none from the control groups (Appendix Table 5).

5. Transporting fish around dams appeared to have significantly ($P<0.05$, df = 1) enhanced survival as indicated by the test to control ratios at Bonneville Dam (Table 8). However, returns to the fishery indicated very little difference in test to control ratios (1.17:1) (Table 9). The lack of enhanced survival may have resulted from the truck-barge method used. It's possible that the long truck transport before off-loading in to a barge increased the stress level of the fish and reduced their survival rate. This was also indicated by the 1978 Wells-Winthrop experiment where the test group transported directly to below Bonneville Dam by truck had higher test/control ratios and produced nearly twice as many adults to the fishery as the truck-barge groups. Additional research to optimize mode of transportation is obviously needed if further direct transport from hatcheries is contemplated.

6. Overall recovery of steelhead to the various user groups was quite high, ranging from 0.96% to 1.69% of the juveniles released (Table 9). Control releases contributed significantly greater numbers of fish to the sport fishery than test fish; whereas test releases contributed significantly greater numbers to the Indian fishery than control releases.

7. Techniques used in this experiment to imprint and enhance survival of fish did not provide a positive benefit to the sport fishing areas of the mid-Columbia River.

Salmon Experiments

Analyses of the 1978 experiments on spring chinook salmon from Kooskia Hatchery and coho salmon from Carson and Willard Hatcheries (Table 1) were previously reported by Slatick et al. (1980, 1981). Returns of adult coho salmon from the 1980 Willard experiment are essentially complete. The final analysis of results, with statistical treatment, is presented in this report. Preliminary analysis of results from the 1979 and 1980 fall chinook salmon experiments are also included in this report. Results from remaining 1979 and 1980 experimental releases will be reported when adult returns are complete.

Coho Salmon-Willard-1980

Experimental Design and Background.--The primary objective of this experiment was to implant a homing imprint in juvenile coho salmon transported and released at various sites below Bonneville Dam, for return as adults to the Little White Salmon River. The study was designed to determine:

1. Effectiveness of various methods used to activate a homing imprint in coho salmon.

2. Effect of various release locations on the homing ability and survival of coho salmon.

3. Effect on survival of fish marked in the fall as juveniles vs the fish marked as smolting fish in the spring.

The previous report by Slatick et al. (1981) was quite brief as to the purpose of this experiment, its application to management of fishery resources, the usefulness of the Willard-Little White NFH Complex for such studies, and the need for such research in the Bonneville Pool area. The following background discussion has therefore been added to this year's report.

Willard NFH is part of the Little White Salmon-Willard Hatchery Complex operated by the USFWS and located on the Little White Salmon River in southwestern Washington (Figure 3). Coho salmon released at Willard NFH migrate through 3.5 miles of free-flowing river before entering slack water at Drano Lake. Waters from the Little White Salmon River remains distinct in Drano Lake before merging with the Columbia River at RM 162.0. A barrier-dam and fish collection facility a few hundred feet above slack water at the Little White Salmon NFH blocks access of returning adults to Willard NFH. All adult coho salmon returning from Willard NFH releases are collected and held for brood stock at Little White Salmon NFH.

The Willard-Little White Salmon Hatchery Complex was chosen as a site for homing research for both practical and technical reasons. The availability of production fish for test purposes is a limiting factor in fisheries research, especially for homing studies where adult returns are not guaranteed. At Willard NFH the annual production of approximately 4 million coho salmon was large enough to allow diversion of fish for test purposes without affecting the ability of the hatchery to maintain its brood stock. The major contribution of Willard NFH coho salmon is to ocean sport and commercial fisheries. Past experiences with this stock (Slatick et al. 1980) indicated the contribution would not be seriously reduced and might possibly be enhanced.

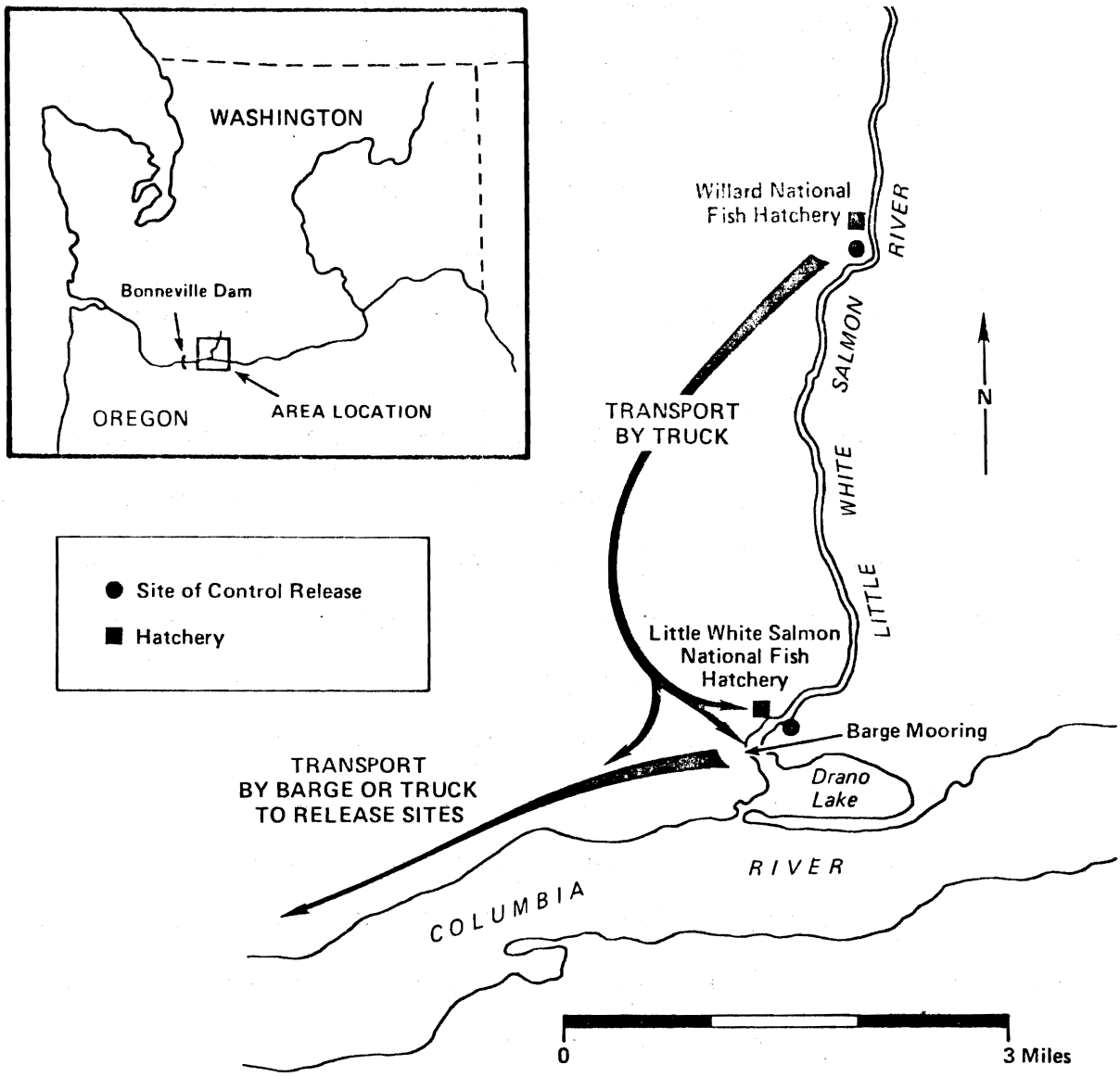

Figure 3.--Little White Salmon - Willard National Fish Hatchery Complex and Transport Routes.

The site was conducive to technical requirements of the study, particularly the recapture of juvenile migrants. The capability of mooring a fish transport barge in the Little White Salmon River arm of Drano Lake, within 200 yards of the Little White Salmon NFH, was also an important consideration. A timely evaluation of the study results would be possible, since virtually all rack recoveries of adult coho salmon reared at Willard NFH are completed within approximately 16 months after their release as smolts.

The results of homing research at the Willard-Little White Salmon Hatchery Complex have implications for the future management of all Bonneville Pool Hatcheries. In the past, releases from these hatcheries have passed Bonneville Dam during periods of high spill. However, with the completion of the second powerhouse at Bonneville Dam a higher percentage of the river flow and downstream migrants will pass through turbines. Turbine passage is expected to increase the mortality of the downstream migrants, resulting in lower adult production. Development of successful methods for imprinting hatchery fish, coupled with barge transport around Bonneville Dam could be used as a stock enhancement alternative to increased hatchery production of smolts.

The experimental design called for releases of three control groups and six test groups of approximately 50,000 marked coho salmon each. Two control groups were released on 23 May at Willard NFH, and one group was trucked to Little White Salmon NFH and released on 14 May. Three of the test releases were given a sequential imprint (truck from hatchery to barge at Drano Lake) and barged from Drano Lake to a single release site below Bonneville Dam on 25 May. The remaining three test releases received a

single imprint (truck from hatcheries) and were trucked to three sites below Bonneville Dam and released on 21 May at RM 142, 22 May at RM 50, and 23 May at RM 8 (Table 10). (See Appendix Table A6 for additional details.) Fish were marked with an adipose clip and coded wire tag by USFWS personnel for this study. Transfers and releases of fish were accomplished with either a 1,500-gallon hatchery tanker (Control Group #1) or a 5,000-gallon unit (Test Groups 1-6). The CofE provided the fish transport barge (McCabe et al. 1979) used to transport Test Groups 1-3 from Drano Lake to below Bonneville Dam.

Recapture of juvenile migrants from the Little White Salmon River was attempted using a self-cleaning scoop trap (Raymond and Collins 1974), but trap efficiency was too low to supply the 50,000 fish goal for Test Group 2 (limited migration). Migrants which entered the water intake to the adult holding ponds at the Little White Salmon NFH were captured and used to supplement the trap catch, resulting in a smaller than desired group of 33,372 finally released.

Spring vs Fall Marking of Coho Salmon.--Handling, and especially marking of smolted salmonids are generally considered to result in decreased survival. The inclusion of Test Group 2 (recaptured natural migrants) in the study design made it necessary to mark this group during the smolting period. To avoid bias, other groups were also marked in the spring. Concern over the possible adverse effect of spring marking led to the inclusion of Control Group 2 which was marked in November 1979. Their survival was compared with Control Group 3 marked in the spring (both were released in the Little White Salmon River on 23 May). Statistical analysis of hatchery and ocean recoveries determined that there was no significant

Table 10.--A comparison between control and test groups of adult coho salmon recovered at the Little White Salmon NFH and in the ocean fisheries from releases of smolts from the Willard NFH which were imprinted to the Little White Salmon River and released at six different sites in 1980. Recoveries are through 26 February 1982.

Control or test group	Treatment	Release site	Release date	Number[a/] juveniles released	Hatchery			Ocean		
					Number	% of juveniles released	Test to control ratio	Number	% of juveniles released	Test to control ratio
Control groups (natural imprint)										
Control 1	Fall mark	L. W. Salmon NFH	14 May	43,045	40	0.093		43	0.100	
Control 2	Fall mark	Willard NFH	23 May	42,371	107	0.253		128	0.302	
Control 3	Spring mark	Willard NFH	23 May	51,525	145	0.281		151	0.293	
Control 2 & 3 (pooled)		Willard NFH		93,896	252	0.268		279	0.297	
Barged groups (sequential imprint)										
Test 1	Prior event	Bonneville (RM140)	25 May	51,417	75	0.146	0.55:1	104	0.202	0.68:1
Test 2	Limited migration	Bonneville (RM140)	25 May	33,732	47	0.139	0.52:1	63	0.187	0.63:1
Test 3	Barged only	Bonneville (RM140)	25 May	47,923	79	0.165	0.62:1	104	0.217	0.73:1
Tests 1, 2, & 3 (pooled)		Bonneville (RM140)		133,072	201	0.151	0.56:1	271	0.204	0.69:1
Truck groups (single imprint)										
Test 4	Simulated release[b/]	Dalton Point (RM142)	21 May	50,786	8	0.016	0.06:1	67	0.132	0.44:1
Test 5	Simulated release	Hammond (RM8)	23 May	50,619	0	0.0		107	0.211	0.71:1
Test 6	Simulated release	Beaver Terminal (RM50)	22 May	51,683	0	0.0		102	0.197	0.66:1
Test 5 & 6 (pooled)		Estuary areas		102,302	0	0.0		209	0.204	0.69:1

a/ Adjusted for tag loss.

b/ Loaded in truck for 2 h then released into raceway containing L.W. Salmon River water for 48 h minimum then transported by truck containing L.W. Salmon water.

difference ($P>0.05$, df = 1) between Control Group 2 (fall marked) and Control Group 3 (spring marked) recovered in the ocean or back to the hatchery (Comparison 1, Table 11). Since there was no significant difference between Control Groups 2 and 3, they have been combined to strengthen the statistical analysis.

Homing.--Homing of the barged groups to the hatchery was quite effective, as indicated by only a 0.13 difference between the test/control ratios in the ocean and at the homing site (0.69:1 and 0.56:1, respectively) (Table 10). Most of this 0.13 differential in homing ability was accounted for in increased contribution to the Indian fishery and strays into other hatcheries in the Bonneville Dam area (Table 12). When the Indian fishery (Zone 6) and stray fish recoveries are added to the numbers of fish which returned to the homing site, the test/control ratio of adults which returned to the Bonneville area from the barged groups was approximately the same as in the ocean (0.66:1 and 0.69:1, respectively. The data further indicated that when imprinting coho salmon smolts to the Little White Salmon River, the direct truck to barging process alone was reasonably effective and that additional stimulation or a short natural migration was not necessary (Comparison 2, Table 11--no significant difference between recoveries of the three barge treatments in either the ocean or back to the hatchery).

By contrast, the single imprint method (direct trucking from the hatchery) used in this experiment was unsuccessful for homing of adult coho salmon to the hatchery (homing site). None of the fish trucked and released at Beaver Terminal and Hammond returned to the hatchery (Table

Table 11.--Statistical treatment of Willard NFH coho salmon homing experiment.

Comparison	Recovery area	
	Ocean	Hatchery
1. Control 2 vs Control 3	NS	NS
2. Barge Test 1 vs 2 vs 3	NS	NS
3. Truck Test 5 vs 6	NS	--
4. Pooled barge (Tests 1, 2, 3) vs pooled truck (Tests 5 & 6)	NS	--
5. Pooled truck (Tests 5 & 6) vs Truck Test 4	*	--
6. Pooled barge (Tests 1, 2, 3) vs Truck Test 4	*	--
7. Pooled barge (Tests 1, 2, 3) vs pooled control (Groups 2 & 3)	*	*
8. Pooled truck (Tests 5 & 6) vs pooled control (Tests 2 & 3)	*	--
9. Control 1 vs pooled Control 2 & 3	*	*
10. Pooled truck (Tests 5 & 6) vs Control 1	*	--
11. Pooled barge (Tests 1, 2, 3) vs Control 1	*	*

* Significant difference between test and control releases ($P<0.05$, df = 1).

NS Nonsignificant

-- No test

Table 12.--A comparison between recoveries in various fisheries and as strays to hatcheries in the Columbia River system. These returns are based on nine groups of juvenile coho salmon from the Willard NFH which were imprinted to the Little White Salmon River and released at six different release sites in 1980. Recoveries are through 26 February 1982.

Control or test group	Treatment	Release site	Number[a/] juveniles released	Number of adult recoveries by location: Gill-net: Zone 1-5	Youngs Bay	Indian Zone 6	Washington[b/] terminal	Sport fishery	Hatchery strays: Bonneville	Cascade	Spring Creek	Total all areas
Control groups (natural imprint)												
Control 1	Fall mark	L. W. Salmon NFH	43,045	0	0	1	0	0	0	0	0	1
Control 2	Fall mark	Willard NFH	42,371	0	0	2	0	0	1	3	0	6
Control 3	Spring mark	Willard NFH	51,525	0	0	2	0	0	0	0	0	2
Control 2 & 3 (combined)		Willard NFH	93,896	0	0	4	0	0	1	3	0	8
Barged groups (sequential imprint)												
Test 1	Prior event	Bonneville (RM140)	51,417	0	0	8	3	0	6	2	0	19
Test 2	Limited migration	Bonneville (RM140)	33,732	0	1	4	1	0	3	3	0	12
Test 3	Barged only	Bonneville (RM140)	47,923	0	0	5	0	0	6	5	0	16
Tests 1,2, & 3 (combined)		Bonneville (RM140)	133,072	0	1	17	4	0	15	10	0	47
Truck groups (single imprint)												
Test 4	Simulated release[c/]	Dalton Point (RM142)	50,786	2	0	1	0	1	6	10	1	21
Test 5	Simulated release	Hammond (RM8)	50,619	12	19	0	0	0	1	0	0	32
Test 6	Simulated release	Beaver Terminal (RM50)	51,683	21	2	0	0	0	1	0	0	24
Tests 5 & 6 (combined)		Estuary areas	102,302	33	21	0	0	0	2	0	0	56

a/ Adjusted for tag loss.

b/ Columbia River Terminal Fisheries are gill-net seasons set by WDF for various lower river locations. The reported recoveries were taken during early September 1981 in the Skamokowa Creek, Cowlitz River, and Grays River units.

c/ Loaded in truck for 2 h then released into raceway containing L. W. salmon water for 48 h minimum then transported by truck containing L. W. salmon water.

10). Instead, these fish returned to the release site area as indicated by 53 recoveries in the lower river fishery (Zone 1-5 and Youngs Bay) compared to no recoveries above Bonneville Dam either in the Indian (Zone 6) fishery or the hatcheries (Table 12).

Survival.--Survival measured by recovery of adults in ocean fisheries indicates no significant differences ($P>0.90$, df = 1) between barged groups (3) or between the trucked groups released at Beaver Terminal and Hammond (Comparisons 2 and 3, Table 11). With the exception of the Dalton Point truck release group (RM 142), the ocean contribution of the barged and trucked groups were basically identical (Comparison 4, Table 11). Both the barged and lower river truck release groups contributed significantly ($P<0.05$, df = 1) more fish (55%) to the ocean fisheries than did the Dalton Point release group (Comparison 5 and 6, Table 11). The increased contribution to ocean fisheries of the barged releases (RM 140) over the Dalton Point shore release (RM 142) in basically the same area, indicates that the mid-river release in the main channel was more productive than the shore release site. However, the eruption of Mount St. Helens could also have been a factor in the lower survival of the Dalton Point release (discussed later).

Survival of the pooled controls (Groups 2 and 3) was significantly greater ($P<0.05$, df = 1) than for either the barged or trucked test groups (Comparisons 7 and 8, Table 11). This was unexpected, since previous studies (Slatick et al. 1980; Ebel 1970; and McCabe et al. unpublished manuscript) had demonstrated equal or better survival for fish transported and released below Bonneville Dam than fish released at the hatchery. Preliminary data on returning adult fish from fall chinook salmon released below Bonneville Dam in 1979 and 1980 (discussed later in this report) also indicate better survival of transported fish.

In addition to the apparent poor survival of transported fish in this experiment there was an even lower survival indicated for the first control release. Their return rate was significantly lower ($P<0.05$, df = 1) than either of the transported groups (Comparisons 10 and 11, Table 11). Possible reasons for the poor returns of the transport groups and the first control groups include: (1) stress placed on fish during handling, marking, loading, and transportation; (2) bias from different quality fish between raceways (fish were not randomized prior to marking); and/or (3) the eruption of Mount St. Helens.

With respect to stress, Control Group 1 was transported in a 1,500-gallon hatchery truck from Willard NFH and released below the Little White Salmon NFH. The other two controls (fall vs spring marking comparisons) were released at Willard NFH without added handling or transportation. Two of the barged groups were handled and marked within 5 days of release. The third barge group, as well as the truck releases, were marked approximately 1 month prior to release. It is possible that the added stress of crowding, loading, and transportation shortly after marking could impact survival. Saltwater challenge tests for measuring stress indicated that stress levels of handled and marked fish become significantly higher than unmarked fish when those fish are subsequently handled and transported (Park et al. 1982).

Bias could have resulted in rate of return of transported and control fish if quality of fish varied significantly between raceways. The experimental design made it nearly impossible to randomize fish prior to

marking. The NMFS did request though, that the fish be comparable in size and weight and be representative of the production release.

Mount St. Helens erupted on 18 May and the subsequent peak runoff of suspended solids affecting the Columbia River was in place by 19 May. Control Group 1 inadvertently released on 14 May may have been extremely impacted by the relatively hot, turbid flows in the vicinity of the confluences of the Cowlitz River. Data from NMFS sampling programs indicate that juveniles from the first control release reached Jones Beach (RM 47) on 19 May, coincident with the peak runoff from the eruption (Dawley et al. 1981). In contrast, the pooled control (Groups 2 and 3) arrived at Jones Beach around 1 June, after river conditions had significantly improved.

Mount St. Helens' may also have impacted the test groups. The barged fish (Test Groups 1, 2, and 3) were released below Bonneville Dam on 25 May. Test Group 4 (Dalton Point), with lower survival, was released on 21, May 4 days earlier. Test Groups 5 and 6 were trucked downstream and released directly into the Columbia River impacted by Mount St. Helens effluent on 22 May. Timing of the releases appears critical. The high water temperatures and turbidity from the eruption only lasted a few days. Survival of the earlier release of the first control and the Dalton Point test release probably were affected to some degree by the

effluent. While not evident from the recovery data, some of the fish in the remaining test groups which were migrating downriver earlier than Control Groups 2 and 3 could have been impacted to a lesser degree by the eruption. There is evidence from Dawley et al. (1981) that juvenile salmonids migrating through the estuary shortly after the eruption were adversely impacted by the poor environmental conditions encountered. Because of the low runs in 1982 and the fact that similar stresses have occurred in previous experiments in which transported fish returned at a higher rate than control fish, we suggest that the eruption of Mount St. Helens may have been the major problem in the reduced survival of the transported fish in this experiment.

Recommendations.--The data presented have shown that nearly complete homing of barged fish back to the hatchery can be obtained by trucking fish from Willard NFH to a barge moored in the mouth of the Little White Salmon River, holding them for 24 hours, and then barging them below Bonneville Dam. Unfortunately survival of the transported fish was significantly lower than the controls. This may have resulted from stress imposed by loading and transporting, non-randomizing of fish prior to marking, and/or the eruption of Mount St. Helens. Complications of stress can be overcome by marking all experimental releases at least 60 days prior to release, and improving the methods used to load and transport fish. Repeat of this study in a year without an eruption of Mount St. Helens, randomizing fish prior to marking, and using improved loading and transport techniques might show a more positive benefit to fish transported to the lower estuary. Application of the techniques developed could lead to increased contribution of the Willard-Little White Salmon NFH complex to user groups while assuring returns of brood stocks to the hatchery.

Fall Chinook Salmon-Big White Salmon River Rearing Channel-
Stavebolt Creek-1979

The objectives were to: (1) determine if gill Na^+-K^+ ATPase enzyme activity could be used to indicate time periods when fish would be most receptive to homing cues, (2) determine if 4-h or 48-h exposures to Stavebolt Creek water would provide an adequate imprint, and (3) determine if an imprint to Stavebolt Creek would result in homing of fish that were denied exposure to the Lewis and Clark River and Youngs Bay (intermediate routes between Stavebolt Creek and the release point on the Columbia River).

The 1979 Stavebolt Creek homing test utilized 11 marked groups totaling 473,027 fall chinook salmon of Spring Creek NFH origin. The first release series was made between 28 and 31 March, the second between 17 and 22 May, and the third on 26 June 1979. Additional details of the experimental design are given in a previous report Slatick et al. 1980.

Recoveries to date are for 1- and 2-ocean age fish. Additional adult returns in 1982-83 will be added to these data and provide the basis for subsequent statistical analysis of the test. To date we have recovered tags from the ocean fisheries and Columbia River system. Although the data are preliminary, they indicate some interesting trends between the various treatment groups.

Major trends apparent at this time are:

1. The survival of fall chinook salmon from the test groups in the first gill Na^+-K^+ ATPase release are more than one and one-half times as great as the survival of fish from the control group. By contrast, survival of the test fish in the second release were only one-fourth that of the control release (Table 13).

2. Survival of fish (both tests and control groups) were much greater from the first gill Na^+-K^+ ATPase release than from the second and

Table 13--Preliminary recoveries of tags from test and control groups of 1- and 2-ocean age fall chinook salmon taken in the Ocean and Columbia River fisheries and on the spawning grounds. As juveniles these fish were held in the Big White Salmon Rearing Channels and then transported and imprinted to Stavebolt Creek for 4-h and 48-h periods and released in two locations. Recoveries are from September, 1980 to December, 1980.

Experimental groups	Number released a/	Recovery area			Columbia River area		Total recovery	T/C ratio b/
		Ocean	Lewis and Clark River	Youngs Bay fishery	Below Bonneville Dam	Above Bonneville Dam		
	N	N	N	N	N	N	N	%
			Na^+-K^+ ATPase First release					
Control (Big White Salmon River release)	42,419	101	0	0	2	62	165	0.389
Single imprint (Hammond release) 48 h	44,401	151	4	62	49	6	272	0.613 1.58:1
Natural imprint (Stavebolt rel.) 48 h	47,337	178	9	63	63	1	314	0.663 1.70:1
			Na^+-K^+ ATPase Second release					
Control (Big White Salmon River release)	47,788	60	0	0	0	43	103	0.216
Single imprint (Hammond release) 4 h and 48 h	95,592	12	1	3	9	0	25	0.026 0.12:1
Natural imprint (Stavebolt rel.) 4 h and 48 h	95,821	48	4	10	11	1	74	0.077 0.36:1
			Na^+-K^+ ATPase Third release					
Control (Big White Salmon River release)	99,669	3	0	0	0	1	4	0.004
Total	473,027	553	18	138	134	114	957	

a/ Adjusted for initial tag loss.

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

third releases. The 0.56% recovery rate of the first group was over five times the 0.1% recovery rate of the second release, only three fish (0.004% were recovered from the third release. A factor which influenced the lower survival of fall chinook salmon from the second and third release series may have been the latent effects of pathogenic infections combined with stress induced by handling during the experimental releases. A serious outbreak of Enteric Redmouth disease (ERM) and gill amoeba occurred on fish held for the third release series in the Big White Salmon Rearing Channels (Slatick et al. 1980). Organ tissue from fish held for the second release series indicated exposure to some type of pathogenic infection--probably ERM and bacterial kidney disease (Novotny et al. 1981). Because of the disease problem and the reduced survival of the second and third releases it probably will not be possible to determine the influence of gill NA^+-K^+ activity on homing (objective 1).

3. Fall chinook salmon smolts imprinted to Stavebolt Creek or Hammond are returning as adults to the Youngs Bay fishery area and to the Lewis and Clark River. By contrast, no control fish have been recovered either in the fishery or in the river. Returns from the first release indicate that imprinting fish to Stavebolt Creek and trucking to Hammond resulted in as many returns to Youngs Bay as those released in Stavebolt Creek (objective 3). Returns to date are insufficient to determine whether 4-h or 48-h exposures to Stavebolt Creek provide an adequate imprint (objective 2). No fish were recovered at the Stavebolt Creek homing site in 1981, this may, however, have been due to dry weather conditions which caused low water flows in the Lewis and Clark River system at the time adult salmon were migrating upstream. The mouth of Stavebolt Creek had very little water at that time, and the adults may have bypassed the homing site. Spawning gravel in the Lewis and Clark River was available 0.25 mile upstream from Stavebolt Creek, and 18 marked fish were recovered in the Lewis and Clark River within 3 miles of the creek.

Fall Chinook Salmon-Spring Creek-1980

The objective was to imprint fall chinook salmon for return to the Spring Creek NFH. Our 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 loaded directly from the raceways into a barge; the second group passed through a 350-ft transport channel before being loaded into the barge. Both groups were given sequential homing cues by being transported by barge, initially containing Spring Creek water and then Columbia River water, to a release site below Bonneville Dam. The control group used was marked by USFWS personnel as part of the fall chinook salmon hatchery evaluation study (see Appendix Table A7 for additional details on numbers marked, treatments, and experimental design).

Recoveries to date are for jack chinook salmon which returned to hatcheries in the Bonneville area. Initial recoveries indicate a substantial survival benefit of the test groups (transported) compared to the control group (nontransported). Up to twice as many jack salmon from the test groups were recovered than were fish from the control group (Table 14).

Straying of fish from the test group was more prevalent than from the control group. Approximately 80% of the test fish recovered were strays to other hatcheries compared to 13% from the control group. However, due to the increased survival of transported fish, almost half as many fish from the test groups returned to the homing site as did control fish. The rate of return of test jack salmon to the homing site was four times higher than returns from test jack salmon which had been barged as juveniles directly in Columbia River water in 1977 (unpublished data; Steve Olhausen, USFWS). This suggests that the treatment providing Spring Creek water initially in the barge substantially improved homing. Additional manipulation of the time fish are held in Spring Creek water in the barge prior to release could improve homing.

Table. 14.--Preliminary recoveries of fall chinook jack salmon (1-ocean age) at hatcheries in the Bonneville area from control and test releases of smolts which were imprinted to the Spring Creek NFH in 1980. Recoveries are through December 1981.

Experimental groups	Number released[a/]	Jack chinook salmon recoveries at hatcheries						T/C ratio
		Spring Creek homing site	Bonneville Hatchery	Cascade Hatchery	Little White Salmon NFH	Total recovery		
	N	N	N	N	N	N	%	
Control (Spring Creek release)	60,500	28	4	0	0	32	0.053	
Test #1 (Loaded raceway and barged)	99,583	21	89	1	1	112	0.112	2.11:1
Test #2 (loaded channel and barged)	99,703	17	67	1	0	85	0.085	1.60:1
Total	259,786	66	160	2	1	229		

a/ Adjusted for initial tag loss.

SUMMARY

Efforts in the fourth year of research on imprinting salmon and steelhead for homing were concentrated on: (1) recovery of returning adults from 23 individual experiments in the fisheries, at dams, and at the hatcheries and (2) final analyses on the completed 1978 steelhead and 1980 coho salmon experiments and preliminary analyses of 1979 and 1980 fall chinook salmon experiments. Discrete multivariate analysis was used to statistically compare test and control treatments of completed experiments. A summary of major findings by experiment follows:

Dworshak-1978 Steelhead

1. Survival was enhanced by transporting fish around dams. Adults from the barged group returned at significantly higher rates than the trucked or control lots in the fishery, at dams, and at the hatchery.

2. Homing of barged fish was better than for trucked fish as indicated by the same rate of return for barged fish as trucked fish in the Indian fishery but a significantly higher rate of return for barged fish than trucked fish at Lower Granite Dam and at the hatchery.

3. Even though homing of both test groups was impaired, sufficient homing cues were imparted to fish in the barged group to cause a significantly higher return of barged fish than control fish to the hatchery.

4. Estimated contributions of adults to user groups was 0.8% for control releases, 1.4% for truck releases, and 1.9% for barge releases.

Tucannon-1978 Steelhead

1. Imprint methods used were unsuccessful in returning adults to the hatchery but were successful in returning as many of the barged fish imprinted in 100% spring water as control fish to Lower Granite Dam on the Snake River.

2. Those fish failing to imprint to the Snake River probably remained in the lower river as indicated by lack of returns to upriver sport fisheries and hatcheries in contrast to large catches in the lower river sport and Indian fisheries and some returns to lower river hatcheries.

3. The combination of impaired homing and enhanced survival of transported fish resulted in barged releases providing approximately 10 times as many fish to the user groups as control releases (estimated recovery in fisheries--0.57% for barged fish vs 0.05% for control fish).

Wells-Winthrop-1978 Steelhead

1. Imprint methods used were unsuccessful in returning adults to the hatchery but were successful in returning fish with minimal homing impairment to homing areas above McNary Dam.

2. Homing above that point was impaired as indicated by a decline in test/control ratios at Priest Rapids Dam.

3. Fish released at Ringold had the highest proportion homing to areas above Priest Rapids Dam.

4. Transporting fish around dams significantly enhanced survival. Trucked fish appeared to survive better than those trucked and barged below Bonneville Dam.

5. Survival of the Winthrop control release was significantly lower than the Lower Methow production release.

6. A total of 531 adults or about 1% of those transported as juveniles were caught in the various sport fisheries. An additional 298 adults were caught in the Zone 6 Indian fishery. The total of 829 fish (1.5% return) was over twice the contribution of the control releases (0.7% return).

7. Techniques developed in this experiment (limited imprint and enhanced survival of transported fish) could be used to enhance sport fishing in selected areas of the mid-Columbia.

Chelan-Leavenworth 1978 Steelhead

1. Imprint techniques used combined with a truck-barge transport of fish were unsuccessful in returning fish to the upper Columbia River.

2. The impaired homing resulted in an accompanying delay in migration that made these fish more vulnerable to the Indian (Zone 6) fishery.

3. Survival was not significantly enhanced by transporting fish around dams by the combined truck-barge technique. The long truck transport before off-loading to a barge may have increased the stress level and reduced survival. Results from the Wells-Winthrop experiment supports this hypothesis; returns from those trucked and barged were nearly 50% less than the trucked group.

Coho Salmon-Willard-1980

1. There was no significant difference in adult survival between paired releases of control groups of juveniles marked as pre-smolts in the fall and those which were marked during their smolting period in the spring.

2. Barged fish homed successfully to Little White Salmon NFH. The direct truck to barge process is adequate. No additional stimulation or short natural migration appears necessary.

3. Fish trucked and released at Beaver Terminal and Hammond, Oregon, homed to the lower river. None were recovered at the hatchery.

4. Survival did not appear to be enhanced by trucking to the lower river. There was no significant difference in rate of recovery in the ocean fishery between those barged and released at RM 142 and those trucked and released at RM 50 or RM 8.

5. Survival of transported fish was significantly less than the control releases. Possible reasons for the poorer returns of transport fish include stress placed on fish during handling, marking, and transport; fish not randomized prior to marking; or the eruption of Mount St. Helens.

The latter may have had the most influence. In nearly all previous work, transported fish have returned at a higher rate than control releases. Techniques used in previous work were similar with respect to potential stresses imposed.

6. A repeat of this study in a year without an eruption of Mount St. Helens; randomizing fish prior to marking; and using improved handling, loading, and transport techniques might show a more positive benefit to fish transported to the lower estuary. Application of the techniques developed could lead to increased contributions of the Willard-Little White Salmon NFH complex to user groups while assuring returns of brood stock to the hatchery.

Fall Chinook Salmon-Big White Salmon-Stavebolt Creek-1979

Preliminary analyses based on recoveries of 1- and 2-ocean fish indicate the following trends:

1. Survival of fish from the first gill Na^+-K^+ ATPase test release is more than one and one-half times as great as the survival of the control group. By contrast, survival of fish in the second test release was only one-fourth that of the control release.

2. A major outbreak of disease probably was the major cause of the low survival. As a result, it probably will not be possible to determine the influence of gill Na^+-K^+ ATPase activity on homing.

3. Smolts imprinted to Stavebolt Creek or Hammond, Oregon, are returning as adults to the Youngs Bay fishery and back to the Lewis and Clark River.

Fall Chinook Salmon-Spring Creek-1980

1. Initial recoveries of jack returns indicate that survival of transported fish was nearly twice that of control releases.

2. Homing of test releases was again impaired. Up to 80% of the test releases strayed to other hatcheries (primarily Bonneville Hatchery).

3. The imprint techniques employed in 1981 were an improvement over the direct barging in Columbia River water done in 1977. Rate of return of test fish to the homing site in 1980 was four times higher than that in 1977.

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APPENDIX A

Tables 1 - 7

Appendix TableA1.--Recoveries of adult steelhead from miscellaneous locations in sport fisheries and hatcheries, from control and test releases of smolts imprinted to Tucannon Hatchery and the Grande Ronde River in 1978. Recoveries are from June 1979 to 30 November 1981.

	Number of adults recaptured[a/]					
	Test #1 100% spring water		Test #2 20% spring water		Control Grande Ronde River	
Sampling location	N	% of release	N	% of release	N	% of release
Columbia River						
Lower river below Bonneville Dam	3	0.017	1	0.005	2	0.004
Bonneville Hatchery	0	0.0	1	0.005	0	0.0
Cascade Hatchery	5	0.028	9	0.049	0	0.0
Klickitat River	2	0.011	2	0.011	0	0.0
Deschutes River	22	0.121	8	0.043	1	0.002
John Day River	0	0.0	1	0.005	0	0.0
Mid-river below McNary Dam	1	0.006	0	0.0	1	0.002
Sub-Total	33	0.182	22	0.119	4	0.007
Upper Mid-Columbia River						
Ringold Area	1	0.006	0	0.0	0	0.0
Wenatchee River	0	0.0	0	0.0	5	0.009
Sub-Total	1	0.006	0	0.0	5	0.009
Snake River						
Snake River	1	0.006	0	0.0	0	0.0
Clearwater River	1	0.006	0	0.0	0	0.0
Grande Ronde River	0	0.0	0	0.0	1	0.002
Salmon River	0	0.0	1	0.005	1	0.002
Sub-Total	2	0.011	1	0.005	2	0.004
Miscellaneous						
Quinault River	0	0.0	0	0.0	2	0.004
TOTAL	36	0.198	23	0.124	13	0.023

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

Appendix Table A2.--Adult 1- and 2-ocean age steelhead from the 1978 Wells-Winthrop experiment which strayed into the Snake River and were recaptured at Lower Granite Dam (RM 107), 1979 to 1981.

Control Test	Number adults recovered			Adult return in % of juveniles released	
	1-ocean age	2-ocean age	Total 1 & 2	Observed	Estimated[a/]
Winthrop NFH (control)	0	0	0	0.0	0.0
Lower Methow River (control)	1	1	2	0.010	0.029
Truck to Bonneville (test)	60	3	63	0.329	0.605
Barge to Bonneville (test)	3	1	4	0.020	0.046
Truck to Ringold (test)	5	2	7	0.040	0.093

a/ Park et al. 1981.

Appendix Table A3.--Number and percent recovery of 1-, 2-, and 3-ocean age steelhead in Zone 6 Indian fishery from control and test releases of smolts from the Wells Hatchery which were imprinted to the Winthrop NFH homing site and the Methow River in 1978. Recoveries were from September 1979 to September 1981.

Control or Test	Numbers juveniles released	Number of adults recaptured										
		1-ocean age		2-ocean age				3-ocean age		1-, 2-, & 3-ocean age		
		Fall		Fall		Winter		Fall				
		N	%	N	%	N	%	N	%	N	%	Est %[a]
Winthrop NFH (control)	20,330	7	0.034	1	0.005	0	0.0	0	0.0	8	0.039	0.131
Lower Methow River (control)	19,901	12	0.060	2	0.010	0	0.0	0	0.0	14	0.070	0.235
Truck to Bonneville (test)	19,131	29	0.152	4	0.021	10	0.052	2	0.010	45	0.235	0.757
Barge to Bonneville (test)	19,979	19	0.095	5	0.025	6	0.030	1	0.005	31	0.155	0.499
Truck to Ringold (test)	17,637	13	0.074	2	0.011	1	0.006	0	0.0	16	0.091	0.303

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

Appendix Table A4.--Number and percent recovery of 1-, 2-, and 3-ocean age steelhead in Zone 6 Indian fishery from control and test releases of smolts from the Chelan Hatchery which were imprinted to the Leavenworth NFH homing site in 1978. Recoveries were from September 1979 to September 1981.

Experiment control or test	juveniles released	Number of adults recaptured										
		1-ocean age		2-ocean age				3-ocean age		1-,2-,& 3-ocean age		
		Fall		Fall		Winter		Fall		Total		
		N	%	N	%	N	%	N	%	N	%	Est %[a]
10-DAY IMPRINTING												
Control	24,119	10	0.041	2	0.008	0	0.0	0	0.0	12	0.050	0.164
Test	22,841	49	0.215	7	0.031	11	0.048	0	0.0	67	0.293	0.972
2-DAY IMPRINTING												
Control	23,787	29	0.122	1	0.004	0	0.0	0	0.0	30	0.126	0.428
Test	21,694	34	0.157	7	0.032	11	0.051	0	0.0	52	0.240	0.787
4-HOUR IMPRINTING												
Control	21,957	16	0.073	2	0.009	1	0.005	0	0.0	19	0.087	0.291
Test	23,551	47	0.200	5	0.021	7	0.030	0	0.0	59	0.251	0.836

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

Appendix Table A5.--Adult steelhead from the 1978 Chelan-Leavenworth experiment which strayed into the Snake River and were recaptured at Lower Granite Dam (RM 107), 1979 to 1981.

Control or test	Number of adults recovered			Adult return in % of juveniles released	
	1-ocean age	2-ocean age	Total 1 & 2	Observed	Estimated[a]
10-DAY IMPRINT					
Control	0	0	0	0.0	
Test	6	1	7	0.031	0.061
2-DAY IMPRINT					
Control	0	0	0	0.0	
Test	6	0	6	0.028	0.048
4-HOUR IMPRINT					
Control	0	0	0	0.0	
Test	0	2	2	0.008	0.033

a/ Park et al. 1981.

Appendix Table A6.--Coho salmon marked at Willard and Little White Salmon Hatcheries for release in 1980. Test number, mark used, number released, date released, type of imprint, and treatment for various groups are indicated.

Test Control	C.W.T. code	Number[a] released	Date released	Homing imprint	Treatment
Marked in Fall, 1979					
Control #1	05-03-58	43,045	5/14	Natural Migration	Trucked from Willard Hatchery and released into L. W. Salmon River below lower barrier at L. W. Salmon Hatchery.
Control #2	05-03-59	42,371	5/23	Natural Migration	Released from Willard Hatchery into L. W. Salmon River.
Marked in Spring, 1980					
Control #3	05-06-54	51,525	5/23	Natural Migration	Released from Willard Hatchery into L. W. Salmon River.
Test #1	05-06-55	51,417	5/25	Sequential	At Willard Hatchery unmarked fish were passed through 175 ft of pipe and held in a raceway for 4 days, then trucked to L. W. Salmon Hatchery where they were marked and held in a raceway 4½ days. Fish were then trucked and loaded into a barge in the L. W. Salmon River and held for 19h 18 min, then barged downstream to a release site below the Bonneville Dam (RM 140).
Test #2[b]	05-06-60	33,732	5/25	Sequential	Limited migration - unmarked fish were released from Willard Hatchery into L. W. Salmon River, migrated approximately 3.5 mi, were recaptured below lower barrier at L. W. Salmon Hatchery, and marked and held in a raceway for 2-5 days. They were then trucked and loaded into a barge in the L. W. Salmon River and held 18 h 53 min, then barged downstream to a release site below Bonneville Dam (RM 140).

Appendix Table A6.--continued-- Coho salmon marked at Willard and Little White Salmon Hatcheries for release in 1980. Test number, mark used, number released, date released, type of imprint, and treatment for various groups are indicated.

Test Control	C.W.T. code	Number[a/] released	Date released	Homing imprint	Treatment
Marked in Spring, 1980					
Test #3	05-06-50	47,923	5/25	Sequential	Trucked directly from Willard Hatchery and loaded into a barge in the L. W. Salmon and held for 21 h 12 min, then barged downstream to a release site below Bonneville Dam (RM 140).
Test #4[c/]	05-06-51	50,786	5/21	Single	Loaded in truck for 2 h then released into raceway containing L. W. Salmon River water for 48 h minimum then transported by truck (L.W.Salmon River water) to a release site at Dalton Point on the Columbia River (RM 142).
Test #5	05-06-53	50,619	5/23	Single	Loaded in truck for 2 h then released into raceway containing L. W. Salmon River water for 48 hr minimum then transported by truck (L.W. Salmon River water) to a release site at Hammond, Oregon on the Columbia River (RM 8).
Test #6	05-06-52	51,683	5/22	Single	Loaded in truck for 2 h then released into raceway containing L. W. Salmon River water for 48 h minimum then transported by truck (L.W. Salmon River water) to a release site at Beaver Terminal (RM 50) on the Columbia River (upstream of the salt water intrusion).

a/ Adjusted for initial tag loss.

b/ Migration mileage was reported incorrectly in Table 7, Slatick et al. (1981).

c/ Name of release location was reported incorrectly in Table 7, Slatick et al. (1981).

Appendix Table A7.--Fall chinook salmon marked at Spring Creek 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	C.W.T. code	Number[a] released	Date released	Homing imprint	Treatment
Control[b]	05-06-41	60,500	9 May	Natural Migration	Released from Spring Creek NFH into Columbia River (RM 166).
Test #1	05-06-48	99,583	19 May	Sequential	Fish were loaded directly from a raceway into a barge containing Spring Creek Hatchery water. Pumps for Columbia River water started 20 min. after fish were loaded. Fish were barged to a release site below Bonneville Dam (RM 140).
Test #2	05-06-49	99,703	19 May	Sequential	Fish traveled 350 ft through a transport channel (crowded with a seine) then were loaded into a barge containing Spring Creek Hatchery water. Pumps for Columbia River water started 1 h 55 min. after fish were loaded. Fish were barged to a release site below Bonneville Dam (RM 140).

a/ Adjusted for initial tag loss.

b/ This group was marked by the USFWS for the fall chinook salmon hatchery evaluation study.