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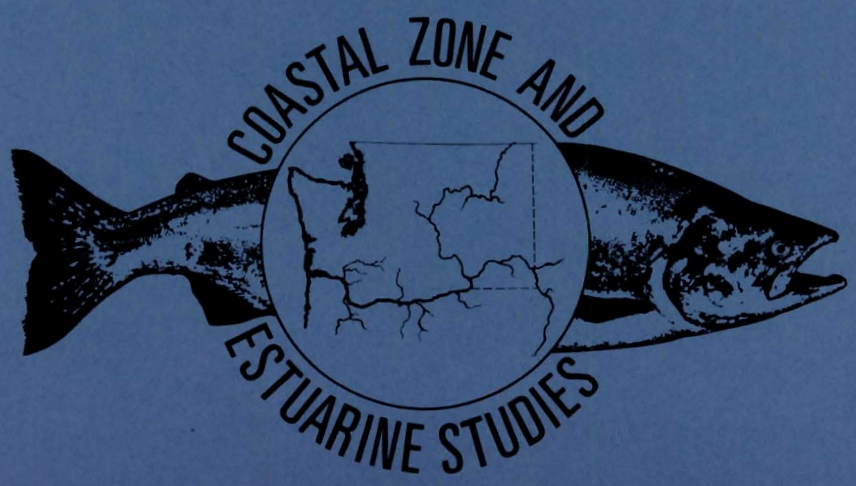

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ABSTRACT

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 1982 concentrated on: (1) recovering returning adults from previous experiments, (2) analyzing completed 1979 steelhead and chinook salmon experiments, and (3) preliminarily analyzing 1980 fall chinook salmon experiments.

Six experimental groups are discussed: two steelhead, two spring chinook salmon, and two fall chinook salmon. In four test groups, survival was enhanced by the imprinting-transportation procedures. Homing back to the hatchery area was partly successful in two test 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. 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 4 years of juvenile marking activities and preliminary analyses of adult returns were reported by Slatick et al. (1979, 1980, 1981, 1982) and Novotny and Zaugg (1979, 1981). This report summarizes adult returns through 1982, with statistical treatment of completed experiments.

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 CWTs at the homing site, from in-river sites (Figure 2), 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. These traps generally consisted of a denil fishladder

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[a]	--	99,135	1980-83
Tucannon	36,686[a]	67,573	--	1980-82
Tucannon-L. Goose Dam	--	--	78,091	1981-82
Spring chinook salmon				
Kooskia	186,597[b]	--	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[a]	137,817	--	1979-81
Wells-Winthrop	96,978[a]	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[c]	--	--	1978-79
Willard-Stavebolt Cr.	414,907[c]	--	--	1978-79
Willard	--	--	436,118 [a]	1980-81
Fall chinook salmon				
Big White Salmon-Stavebolt	--	473,027	--	1980-82
Big Creek-Stavebolt Cr.	--	--	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. 1982.
b/ Results in Slatick et al. 1981.
c/ Results in Slatick et al. 1980.

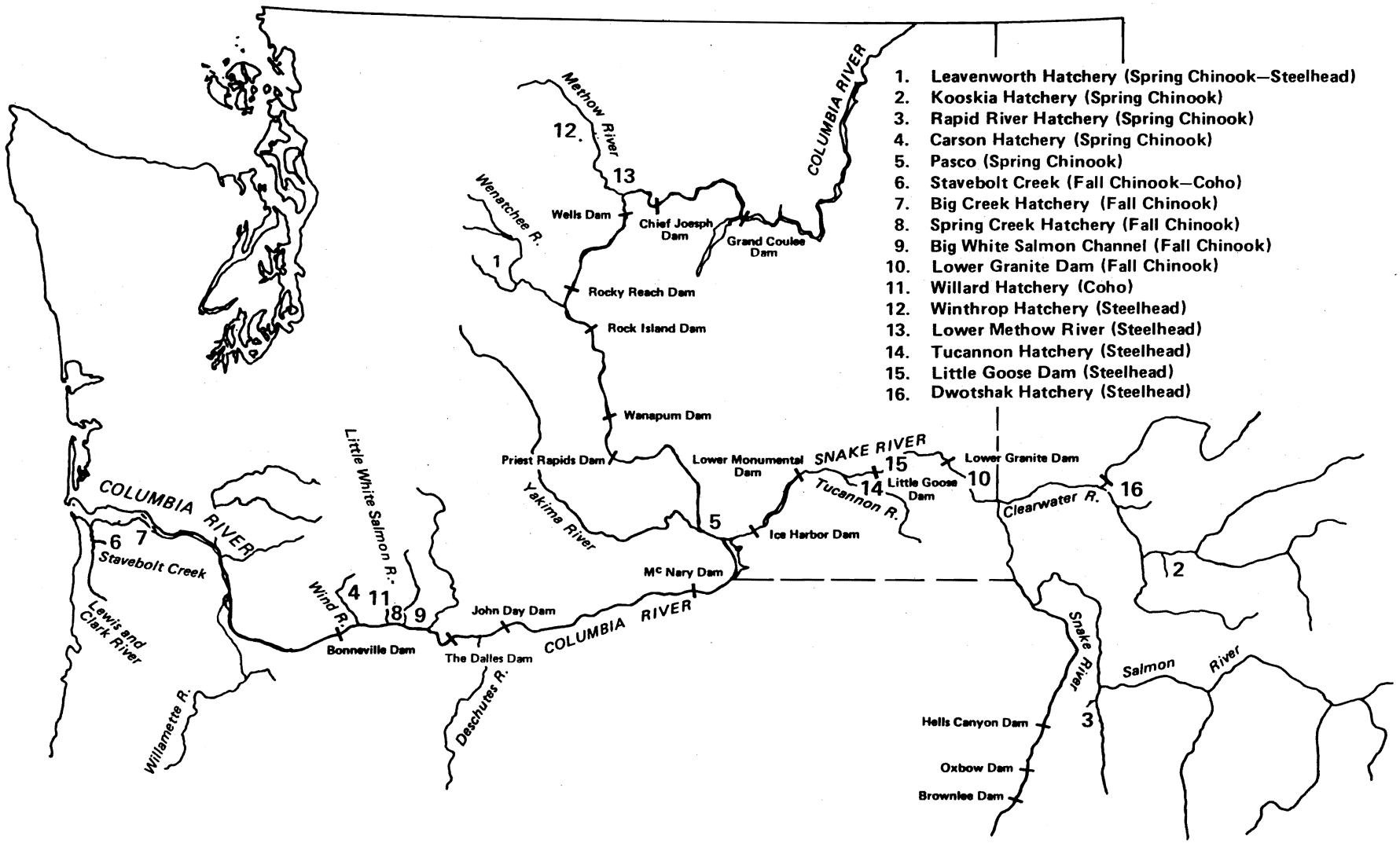

Figure 1.--Area map indicating experimental homing sites, 1978-1980.

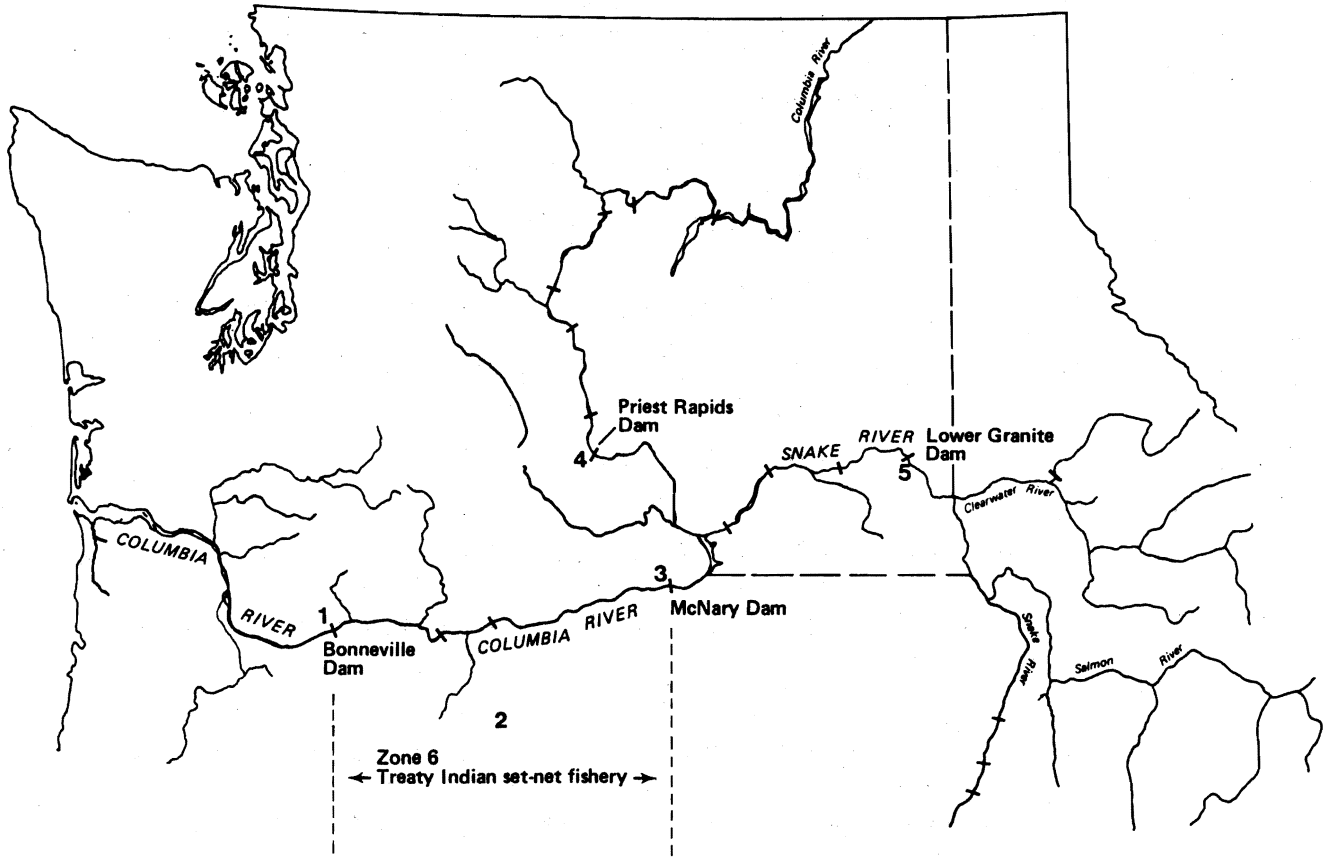

Figure 2.--Map of Columbia River system showing location of five in-river sampling locations.

leading adults up to a tag detection system which would shunt 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 it 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 establised at $P<0.05$, df=1.

STEELHEAD EXPERIMENTS

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

Returns of adults from the 1979 experimental releases of smolts from the upper mid-Columbia River area are essentially complete. The final analysis is presented in this report.

Data on adult returns from the 1979 and 1980 experimental releases of smolts from the Snake River system are incomplete. Results for these experiments will not be reported until 1983 when adult returns are complete and final analyses can be prepared.

Wells-Winthrop, 1979

Background and Experimental Design

The object of this experiment was to imprint steelhead from the Wells Hatchery [Washington Department of Game (WDG)] with a homing cue to the

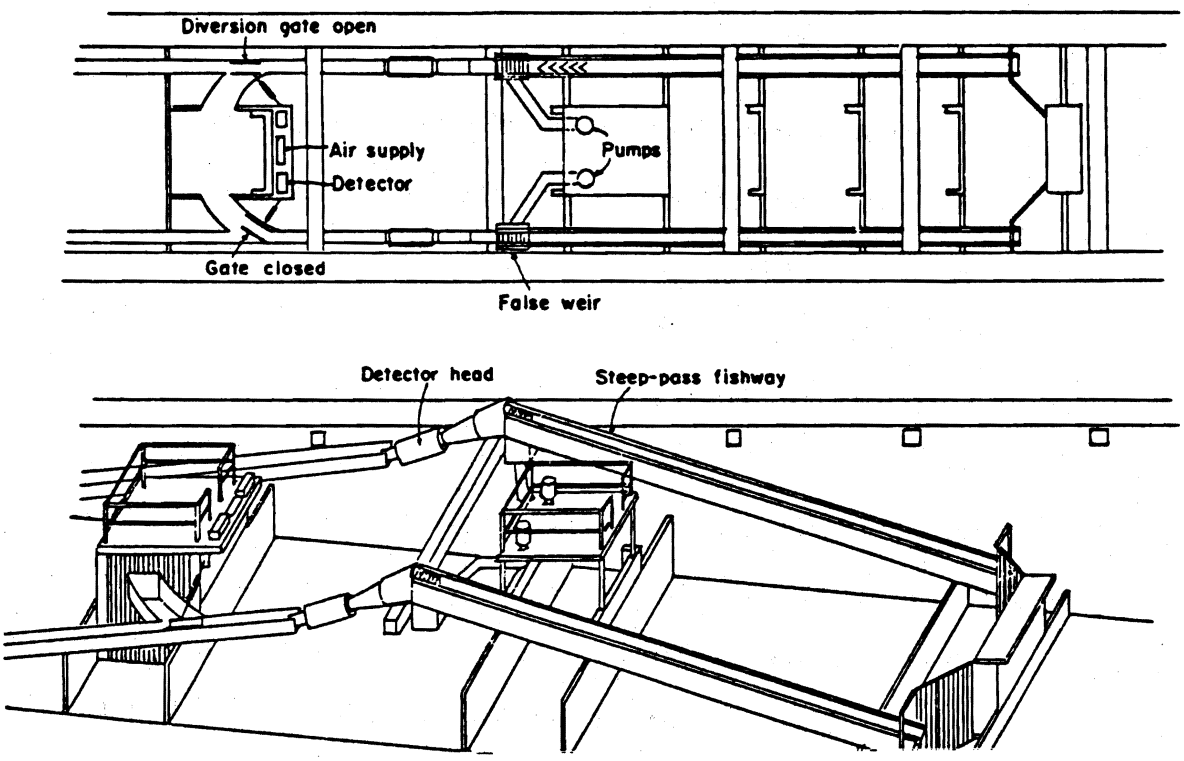

Figure 3.--Plan view and isometric diagrams of wire tag detector and fish separator systems used at Bonneville, McNary, and Lower Granite Dams.

Winthrop National Fish Hatchery (NFH) (a hatchery located upriver from 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 was identical to the 1978 design except there was no Ringold release; the control and transported test groups were marked at the Winthrop NFH, and the WDG production release group was marked at the Wells Hatchery. Juveniles were held 2 to 4 d after marking before they were released or transported. Four groups of experimental fish were used: a group of approximately 20,000 fish was released as a control at the Winthrop NFH; a production group release of approximately 20,000 fish was made directly into the Methow River, 0.25 mile upstream from the mouth; a test group of 10,000 fish was transported by truck in raceway water to a release site below Bonneville Dam; and a second test group of 17,000 fish was transported by truck in raceway water to a barge at Richland, Washington, and then barged downstream to below Bonneville Dam (Figure 4). Evaluation was based on comparing adult returns from transport releases with adult returns from the production release and those released as controls at the hatchery. Additional details of the experimental design are given in Slatick et al. (1980).

Results

Adult returns to the in-river sampling sites and to the sport fisheries through 1982 complete the expected returns from this experiment. Preliminary results were discussed in Slatick et al. (1981). Total adult

1979 STEELHEAD HOMING EXPERIMENT, Wells - Winthrop

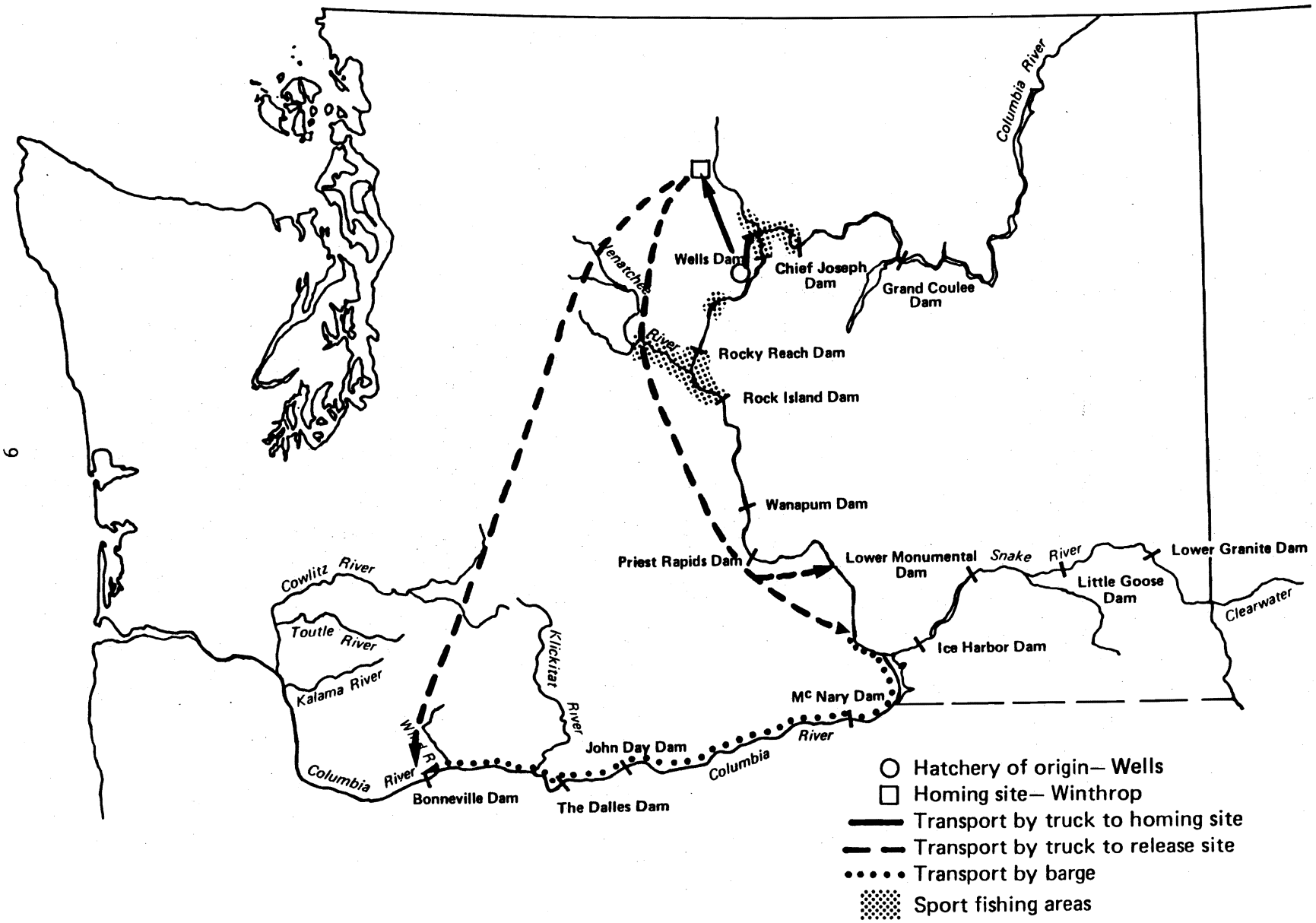

Figure 4.--Study area germane to 1979 homing experiment from Wells-Winthrop Hatcheries.

returns with statistical treatment of results are summarized in Table 2. Estimated contributions of 1-ocean age steelhead to the Indian and sport fisheries (intensive sport fish sampling by WDG was terminated prior to the 1982 migration) are summarized in Table 3.

Homing.--Imprint methods used were unsuccessful in returning any barged and trucked fish to the homing site (Winthrop NFH) but did implant a limited homing cue which enabled a portion of these fish to home to areas above McNary Dam (Table 2). The estimated percentage of marked fish returning could not be determined as was done for the 1978 experiment. The return rates (especially control releases) were much lower to all sites compared to returns from the 1978 experiment and there were conflicting transport to control (t/c) ratios for 1979 returns at Bonneville and McNary Dams. Homing above McNary Dam was impaired as indicated by a decline in t/c ratios for both transported test groups at Priest Rapids Dam (RM 397). The differences in t/c ratios at Priest Rapids Dam reflects the varying degree of homing cues that resulted from each treatment. The test group trucked to Bonneville Dam (1.08:1) was highest and returned at about the same rate as the controls. The group barged from Richland, Washington, was lowest (0.48:1) and returned significantly less fish ($P<0.05$, df=1) than the control group (Table 2). Similar t/c ratios were observed on returns from the 1978 experimental releases.

Recoveries of tagged fish in the sport fishery and at Lower Granite Dam on the Snake River provided additional data on homing of the various test groups to areas above McNary Dam. The major sport fisheries between McNary and Priest Rapids Dams are at Ringold, Washington, and a stretch of

Table 2.--Complete returns to five sampling location of 1- and 2-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 1979. Recoveries were from June 1980 to June 1982.

Sampling location and experiment	Homing site	Control or test	Number juveniles released	Number of adults recaptured[a/] 1-ocean age	2-ocean age	Total 1 & 2s	Adult returns as % of juveniles	Test to control ratio
Bonneville Dam								
Winthrop NFH	Winthrop	Control	18,298	0	8	8	0.044	
L. Methow River	Methow R.	Test[b/]	20,052	1	3	4	0.020	0.45:1
Truck to Bonneville	Winthrop	Test	9,741	9	22	31	0.318	.23:1 **
Barge to Bonneville	Winthrop	Test	17,152	7	28	35	0.204	4.64:1 **
Indian Fishery								
Winthrop NFH	Winthrop	Control		0	2	2	0.011	
L. Methow River	Methow R.	Test[b/]		0	1	1	0.005	0.45:1
Truck to Bonneville	Winthrop	Test		14	31	45	0.462	42.00:1 **
Barge to Bonneville	Winthrop	Test		51	39	90	0.525	47.73:1 **
McNary Dam								
Winthrop NFH	Winthrop	Control		2	3	5	0.027	
L. Methow River	Methow R.	Test[a/]		0	0	0	0.000	
Truck to Bonneville	Winthrop	Test		3	6	9	0.092	3.41:1 *
Barge to Bonneville	Winthrop	Test		21	12	33	0.192	7.11:1 **
Priest Rapids Dam								
Winthrop NFH	Winthrop	Control		28	5	33	0.180	
L. Methow River	Methow R.	Test[b/]		10	1	11	0.055	0.31:1
Truck to Bonneville	Winthrop	Test		15	4	19	0.195	1.08:1 NS
Barge to Bonneville	Winthrop	Test		11	4	15	0.087	0.48:1 *
Winthrop NFH								
Winthrop NFH	Winthrop	Control		2	2	4	0.022	
L. Methow R.	Methow R.	Test[b/]		0	0	0	0.000	
Truck to Bonneville	Winthrop	Test		0	0	0	0.000	NS
Barge to Bonneville	Winthrop	Test		0	0	0	0.000	NS
Total			65,243	174	171	345		

NS Nonsignificant.
* $P < 0.05$, df=1, indicates significant difference between test and control groups.
** $P < 0.01$, df=1; indicates significant difference between test and control groups.
a/ Because of differences in sampling intensity (efficiency) at each trapping site, results are not comparable between sites.
b/ WDG production release. (Sample sizes were too small for use in the statistical analysis.)

Table 3.--Estimated recoveries at four sampling locations of 1-ocean age adult steelhead from control and test releases of juveniles from the 1979 Wells-Winthrop experiment. Recoveries were from June 1980 to March 1982.

Control or test groups	Number[b] juveniles released	Adult recoveries							
		Sport fishery[a]					Total		Test to control ratio
		Ringold area (no.)	Entiat & Wenatchee area (no.)	Methow area (no.)	Total (no.)	Indian fishery (no.)	no.	% of juveniles	
Winthrop NFH (Control)	18,298	0	0	34	34	0	34	0.186	
Lower Methow River (Test[c])	20,052	0	0	20	20	0	20	0.100	0.54:1
Truck to Bonneville (Test)	9,741	18	10	6	34	43	77	0.790	4.25:1
Barge to Bonneville (Test)	17,152	36	19	0	55	154	209	1.219	6.55:1
TOTAL	65,243	54	29	60	143	197	340		

a/ From Schuck et al. 1980-1981.

b/ Adjusted for initial tag loss.

c/ WDG production release.

several miles immediately below Priest Rapids Dam. The major sport fishing areas above Priest Rapids Dam are in the Wenatchee area and at the mouths of the Entiat and Methow Rivers (Figure 4). The data obtained in both years generally indicated that: (1) barged fish that received an imprint homed to the proximity of the barge loading area rather than to areas upstream from Priest Rapids Dam or into the Snake River--larger catches were observed in the Ringold sport fishery than in the Wenatchee-Entiat sport fishery (Table 3), and only one fish from the 1979 release strayed into the Snake River (Appendix Table 1)--and (2) trucked fish, in contrast, did not appear to home to any one area. Trucked fish were the only group with significant straying into the Snake River (Appendix Table 1), and sport catches were spread out from Ringold to the Methow River (Table 3). (See Slatick et al. 1981, 1982 for comparable data on returns from the 1978 experiments).

A portion of the juveniles in both the trucked and barged groups were apparently not physiologically ready and/or able to accept a homing cue at the time they were transported. These adults returned to the area near their point of release near Bonneville Dam, and remained there over winter instead of continuing their migration upriver. As a result, they were more vulnerable to the Indian gill net fishery for a longer period of time. This was demonstrated by the recovery of 101 test fish and no control fish in the winter fishery compared to 34 test and 3 control fish in the fall fishery (Appendix Table 2). Comparable results were obtained in returns from the 1978 experiment (Slatick et al. 1982).

Survival and Contribution to Fishery.--Transporting fish around dams

as in 1978 significantly enhanced survival. Up to 7.2 times as many transported fish returned as adults to the Bonneville Dam sampling site as controls. Survival of the trucked group was highest (7.2:1) (Table 2). Significantly higher survival ($P<0.05$, df=1) of the transported groups resulted in the transported fish contributing greater numbers of 1-ocean age fish than the control release to the sport and Indian fisheries (Table 3). Overall, the total contribution of 1-ocean age fish from the transport releases to various sport and Indian fisheries was 286 fish or over 1.0% of those released compared to 54 fish for those released in the Methow River or 0.14% of those released. The contribution of transported fish was similar to that observed in the 1978 release, indicating comparable survival between years. However, the 0.14% contribution of control fish released in 1979 was much lower than the 0.69% contribution of 1978 control releases indicating much lower survival of control fish released in 1979.

Survival of the lower Methow River production release in 1979 was substantially lower than the Winthrop NFH control release based on recoveries of adults in the sport fishery and at McNary and Priest Rapids Dams. The lower survival probably resulted from mortality during the juvenile outmigration in 1979. Sampling of the 1979 smolt outmigration at Wanapum, Priest Rapids, McNary, and John Day Dams in 1979 showed that the Winthrop NFH control group had a five times greater survival than the lower Methow River production release group based on the average rate of recovery from these four juvenile sampling sites (Raymond and Sims 1980). This was just the opposite of the returns from the 1978 experiment where the lower Methow River production group had a higher survival rate than the Winthrop NFH control group.

The various transport releases provided 89 fish (1-ocean age steelhead) to the various sport fisheries; over twice as many fish than the control release (Table 3). The majority of the transported fish (61%) were caught in the Ringold area. Adults from the transported group provided 48% of sport recovery above Priest Rapids Dam, the majority of these (82%) were caught in the Entiat and Wenatchee Rivers.

Conclusions

1. Imprint methods used in 1979 were unsuccessful in returning barged and trucked fish to the homing site but did implant a limited homing cue which enabled many of these fish to home to areas above McNary Dam.

2. Transporting fish around dams by truck or barge significantly enhanced survival.

3. The limited homing imprint and enhanced survival resulted in over twice as many transported fish as control fish being caught in the various sport fisheries. 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, 1979

Background and Experimental Design

The objectives of this experiment were to determine: (1) 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 (2) to determine if holding fish at Leavenworth NFH in combination with a sequential homing imprint (induced by barging) would enable adult steelhead to return to the Leavenworth NFH site.

The experimental design[1/] used three paired t/c groups, of approximately 24,000 fish per group, held at Leavenworth NFH 10 d, 2 d, and 6 h. Test groups were transported by truck from the Leavenworth NFH homing site to a barge at Richland, Washington, and then downriver to a release site below Bonneville Dam (Figure 5). Controls were released directly into the Icicle River. This is a replicate of the experiment conducted in 1978 with a minor modification (a control and test group were held 6 h at Leavenworth NFH instead of 4 h). Additional details of the experimental design, number of fish per group, etc. are provided in Slatick et al. (1980).

Results

Preliminary results were discussed in Slatick et al. (1981). Additional returns to the in-river sampling sites and sport fishery in 1982 completed the expected adult returns for this experiment. Total adult returns by treatment group to in-river sampling sites and Leavenworth NFH and the statistical treatment of results are summarized in Table 4. A comparison of estimated contributions of 1-ocean age steelhead to the Zone 6 Indian and sport fisheries are summarized in Table 5. Results obtained were similar to those obtained from the 1978 releases (Slatick et al. 1982).

Homing.--Adults from the control treatment groups successfully returned to the Leavenworth NFH homing site (Table 4) and were also taken in large numbers in the nearby Wenatchee and Entiat Rivers sport fishery areas (Table 5).

1/ By Larry Brown, Washington Department of Game, Wenatchee, Washington.

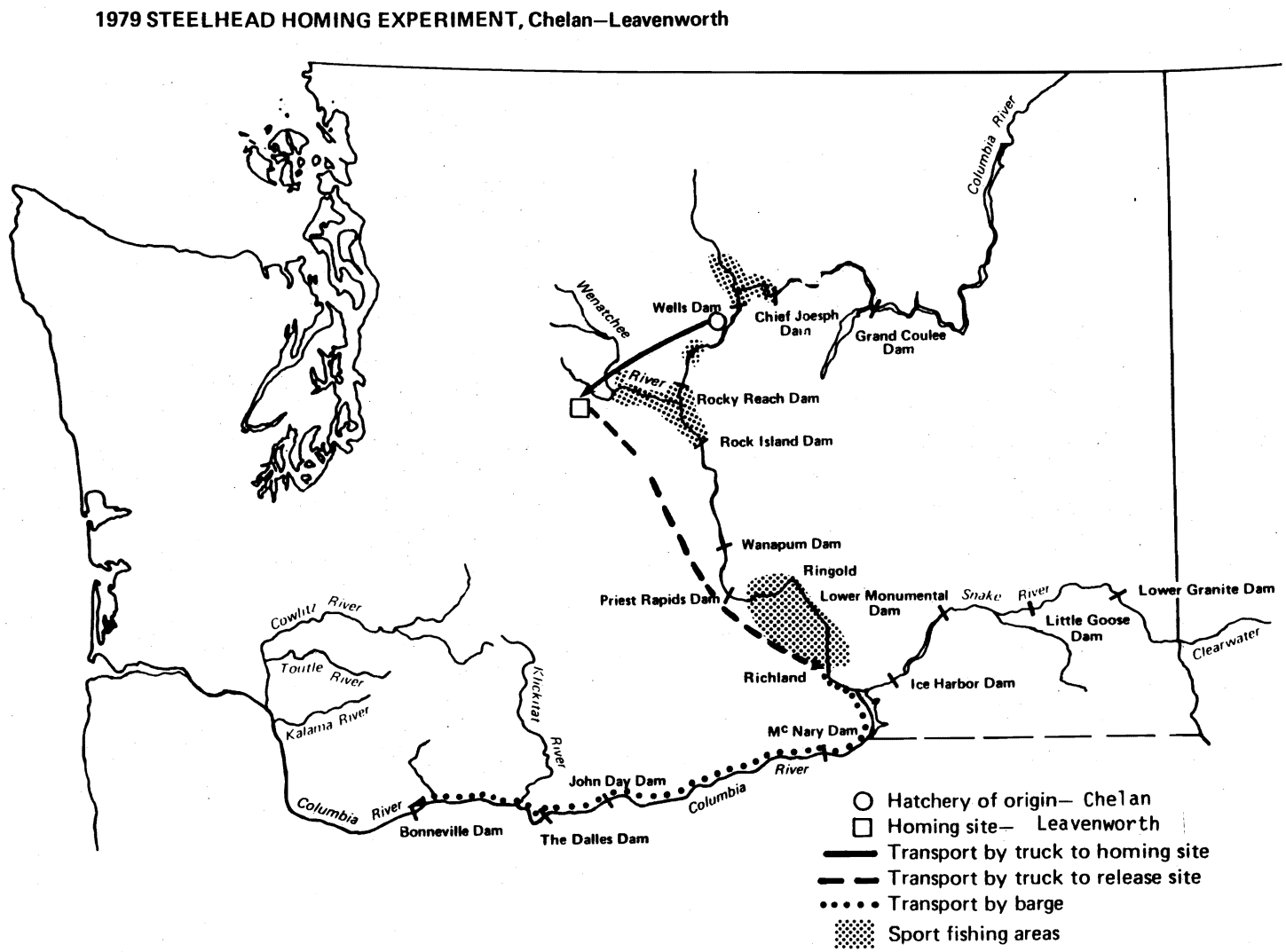

Figure 5.--Study area germane to 1979 homing experiment with steelhead from Chelan - Leavenworth Hatcheries.

Table 4.--Complete returns to five sampling locations of 1- and 2-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 1979. The test juveniles were transported by truck from the Leavenworth NFH to a barge at Richmond, Washington, and then barge downstream to below Bonneville Dam. Recoveries were from June 1980 to June 1982.

Experiment and sampling location	Control or test	Number juveniles released	Number of adults recaptured[a/] 1-ocean age	2-ocean age	total 1 & 2's	Adult return % of juveniles	Test to control ratio
10-Day Imprinting							
Bonneville Dam	Control	23,960	8	7	15	0.063	
	Test	23,331	27	8	35	0.150	2.38:1 **
Indian fishery	Control		7	7	14	0.058	
	Test		103	40	143	0.613	10.57:1 **
McNary Dam	Control		20	4	24	0.100	
	Test		24	6	30	0.129	1.29:1 NS
Priest Rapids	Control		71	8	79	0.330	
Dam	Test		6	0	6	0.026	0.08:1 **
Leavenworth NFH	Control		12	9	21	0.088	
	Test		1	0	1	0.004	0.05:1 *
TOTAL		47,291	279	89	368		
2-Day Imprinting							
Bonneville Dam	Control	19,186	11	6	17	0.087	
	Test	24,335	12	12	24	0.099	1.14:1 NS
Indian Fishery	Control		5	2	7	0.036	
	Test		95	46	141	0.579	16.08:1 **
McNary Dam	Control		7	0	7	0.036	
	Test		4	0	4	0.016	0.44:1 NS
Priest Rapids	Control		52	10	62	0.323	
Dam	Test		1	0	1	0.004	0.01:1 **
Leavenworth NFH	Control		12	5	17	0.089	
	Test		0	0	0	0.0	
TOTAL		43,521	199	81	280		
6-Hour Imprinting							
Bonneville Dam	Control	24,171	4	9	13	0.054	
	Test	22,834	8	14	22	0.096	1.78:1 =
Indian fishery	Control		9	2	11	0.046	
	Test		110	53	163	0.714	15.52:1 **
McNary Dam	Control		18	4	22	0.091	
	Test		21	2	23	0.101	1.11:1 NS
Priest Rapids	Control		62	5	67	0.277	
Dam	Test		4	1	5	0.022	0.08:1 **
Leavenworth NFH	Control		18	13	31	0.128	
	Test		0	0	0	0.0	
TOTAL		47,005	254	103	357		
GRAND TOTAL		137,817	732	273	1005		

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.
** P <0.01, df=1; indicates significant difference between the test and control group.
= P <0.10, df=1; indicates significant difference between the test and control group.

Table 5.--Estimated recovery of 1-ocean age adult steelhead from control and test releases of juveniles from the 1979 Chelan-Leavenworth experiment in four sampling locations. Recoveries were from June 1980 to March 1982.

Control or test groups	Number[b] juveniles released (N)	Sport fishery[a] Ringold area (N)	Sport fishery[a] Entiat and Wenatchee area (N)	Sport fishery[a] Methow area (N)	Sport fishery[a] Total (N)	Indian fishery (N)	Total recovery (N)	Total recovery (%)	Test to control ratio
10-day Imprint									
Control	23,960	0	392	3	395	21	416	1.736	
Test	23,331	108	0	0	108	311	419	1.796	1.03:1
2-day Imprint									
Control	19,186	0	265	0	265	15	280	1.459	
Test	24,335	36	19	0	55	288	343	1.409	0.97:1
6-hour Imprint									
Control	24,171	0	303	11	314	27	341	1.411	
Test	22,834	162	0	0	162	334	496	2.172	1.54:1
TOTAL	137,817	306	979	14	1,229	996	2,295		average: 1.16:1

a/ From Schuck et al. 1980-81.

b/ Adjusted for initial loss.

The length of time fish were held as juveniles for imprinting did not make any difference in the rate of return of adults to the hatchery. There was no significant difference ($G = 2.37$, $df = 1$, $P = 0.4$) between the 6-h, 2-d, and 10-d imprint times.

Imprint methods used with this stock of steelhead, combined with a truck to barge transport of juveniles were unsuccessful in returning adults to areas above Priest Rapids Dam. However, a large number of transported fish did receive a homing cue which enabled them to migrate upstream as far as McNary Dam. The behavior of these fish indicated they received a homing cue to the mid-Columbia River between Richland and Priest Rapids Dam when they were loaded and held (approximately 12 to 24 h) in the barge as documented by the following data: (1) adults from the transported group returned up-river as far as McNary Dam (RM 293) at the same rate as fish from the control groups [no significant difference ($P<0.05$, $df=1$) between the recovery of control and test adults in all imprint groups at McNary Dam (Table 4)]; (2) by the time these adults reached Priest Rapids Dam (RM 397) there were significantly smaller numbers of test fish than control fish ($P<0.01$, $df=1$); (3) over 90% of the test adults recovered in the sport fishery were taken in the Ringold area (free flowing portion of the mid-Columbia River between McNary and Priest Rapids Dams, Table 5); and (4) straying into the Snake River was minimal [recoveries at Lower Granite Dam consisted of only five fish from the barged groups and one from the control group (Appendix Table 3)].

A portion of the juveniles in the test groups were apparently not physiologically ready and/or able to accept a homing cue at the time they were transported. These adults returned to the area near their point of

release near Bonneville Dam and remained there over the winter instead of continuing their migration up-river. This was demonstrated by the recovery of 308 test fish compared to four control fish in the winter (February-March) Indian-gill-net harvest (Appendix Table 4). In the combined fall/winter Indian fishery, the recovery of test fish was significantly greater ($P<0.01$, df=1) than control fish in all imprint groups (Table 4).

Survival and Contribution to Fishery.--Transporting juveniles around dams significantly ($P<0.10$, df=1) enhanced survival of adults returning to the Lower Columbia River, this was indicated by t/c ratios at Bonneville Dam and in the Zone 6 Indian fishery (Table 4). Overall recovery of 1-ocean age steelhead by the various user groups was quite high, ranging from 1.41 to 1.74% of the control juveniles released and from 1.41 to 2.17% of the test juveniles released (Table 5). Control releases contributed significantly greater numbers of fish to the sport fishery above Priest Rapids Dam than test fish; whereas, test releases contributed significantly greater numbers of fish to the Indian fishery and the sport fishery in the Ringold area than control releases.

Conclusions

1. There was no significant difference between the rates of return to the homing site as adults in relation to length of time (6 h, 2 d, and 10 d) the control juveniles were held for imprinting.

2. Imprint methods used in 1979 in conjunction with truck to barge transportation of juvenile steelhead were unsuccessful in returning adults to the homing site.

3. A portion of the fish in the transported treatment groups imprinted to the mid-Columbia River when they were loaded on to the barge as juveniles.

4. Transporting juvenile steelhead around dams significantly enhanced the survival of adults returning to the lower Columbia River.

SALMON EXPERIMENTS

Analysis of the 1978 experiment on spring chinook salmon from Kooskia NFH and the 1978 and 1980 experiments on coho salmon from Carson and Willard NFHs (Table 1) were previously reported by Slatick et al. (1980, 1981, 1982). Returns of adult spring and fall chinook salmon from the 1979 experiments are essentially complete. The final analysis of results, with statistical treatment, is presented in this report. The preliminary analysis of results from the 1980 fall chinook salmon experiment at Spring Creek NFH is also included in this report. Results from the 1980 experimental releases from the Snake and Columbia River systems will be reported when adult returns are complete.

Spring Chinook Salmon, 1979

Background and Experimental Design

Two experiments were conducted with spring chinook salmon from Carson NFH in 1979. One experiment was designed to determine if spring chinook salmon from Carson NFH could be imprinted to Pasco, Washington, (Pasco, Washington, is a mid-river homing site 173 miles farther up the Columbia River than the hatchery of origin) with a single or sequential homing cue and to determine relative survival (from returns in the fishery) of the various treatment groups. The experimental design used three groups of

spring chinook salmon of approximately 39,000 fish per group. A control group was released at Pasco, and two groups were transported by truck and barge to below Bonneville Dam. Fish were released 21 to 28 April 1979. Additional details of the experimental design are given in Slatick et al. (1980).

The second experiment was designed to determine if a single or sequential imprint to hatchery and Wind River water for juvenile spring chinook salmon which were denied any natural migration above Bonneville Dam would enable them to return to Carson NFH as adults. Our experimental design called for a control and three test groups of approximately 40,000 fish per group. The control group was released through the hatchery outlet creek into the Wind River. The imprint method used was a simulated truck release of fish into the desired water and holding them for a 48-h exposure. The single imprint group was then trucked in hatchery water (Tyee Springs) and released below Bonneville Dam; fish in the sequential imprinting groups were also exposed to Wind River water for 48 h and then transported in Wind River water to their respective release sites below Bonneville Dam and at Hammond, Oregon. Fish were released from 3 to 8 May 1979. Additional details of the experimental design are given in a Slatick et al. (1980).

Results

Returns from both experiments were insufficient for analysis. Only one adult was observed returning from the first experiment (a Pasco control at McNary Dam) and four adults from the second experiment (three control fish back to the hatchery and one control fish at Bonneville Dam).

Both the Carson NFH and Carson-Pasco experiments were comprised of spring chinook salmon reared at Carson NFH. Fish were marked 4 through 15 December 1978 and held approximately 4 months in the hatchery before being released. Losses incurred from time of marking to release (derived from weight sample by USFWS) ranged from 1.2 to 9.6%, with an average of 6.4%. Loss from the Carson NFH control release (fish subjected to the least amount of handling) was only 1.2% from marking to release; however, only three adults (0.007%) returned to the hatchery.

Results of physiological sampling (Novotny and Zaugg 1981) showed that the short-term 30-day survival of Carson NFH fish in seawater net-pens was poor (approximately 60%). Approximately 20% of the fish were anemic, and bacterial kidney disease (BKD) organisms were found in every fish with hematocrits below 25%. BKD was found in about 33% of the fish, and the intensity of infection was heavy in 25% of the infected fish. The presence of granulomatous lesions typical of BKD in 25% of the olfactory sacs also reflects the serious nature of this disease in the Carson NFH fish and may well have affected imprinting as well as survival.

Sampling at Jones Beach (Dawley et al. 1980) showed a similar rate of recovery for juveniles from control and test (transported) releases from the Carson NFH experiment. However, survival of test (transported) fish from the Carson-Pasco experiment was up to one-and-one-half times higher than from the control releases. There were no recoveries of fish from the various ocean fisheries.

If we assume from the sampling at Jones Beach that the Carson NFH stock juveniles were surviving to the lower Columbia River, then the principal period of high losses for this stock occurred from the

Columbia River estuary to the time these fish would have grown to a size that would be retained in the various ocean fisheries. The poor short-term survival of the Carson NFH fish held in seawater plus the latent mortality from the heavy infestation of BKD strongly indicates that the period of greatest mortality occurred from entry into seawater through the first winter at sea.

Studies on holding spring chinook salmon in seawater for 3 months lends credence to this hypothesis.[2/] Groups of these fish experienced high losses in seawater due to BKD. Some groups of fish which showed an incidence of BKD as low as 1% [as determined by Indirect Fluorescent Antibody Tests (IFAT)] when introduced to seawater, showed increasing incidence up to 70% and subsequent high mortalities following seawater entry. Fish which had a high incidence of BKD comparable to our Carson NFH fish sustained a severe loss when held in seawater.

Conclusions

1. Returns of adults from both experiments involving Carson NFH fish were insufficient for evaluation.

2. Physiological sampling showed that short-term (30 d) survival in seawater net-pens was poor, that 20% of the fish were anemic, and that BKD was found in 33% of the fish.

Fall Chinook Salmon - Big White Salmon
Stavebolt Creek, 1979

Background and Experimental Design

The objective of this experiment was to imprint juvenile fall chinook

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a/ Personal communication; Dr. T.C. Bjornn, Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho.

salmon with a homing cue to a lower-river homing site. The study was designed to assess:

1. The relationship between the physiological condition of the fish (e.g., gill Na^+-K^+ ATPase enzyme activity and various health parameters) and their ability to imprint a homing cue.

2. Whether 4- or 48-h exposures to Stavebolt Creek water would provide an adequate homing imprint.

3. 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 near Hammond, Oregon.)

Eleven groups totaling 554,586 fish were marked at Spring Creek NFH and moved to the Big White Salmon River Rearing Channel (a satellite rearing facility) where discrete holding was possible. Fish were held and reared for 9 to 44 days before release. Test groups were transported by truck to the homing site on Stavebolt Creek, a tributary of the Lewis and Clark River near Astoria, Oregon (Figure 6). Following holding periods of 4 and 48 h, releases were made into Stavebolt Creek or into the Columbia River at Hammond, Oregon. Control groups were released into the Big White Salmon River.

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. Release and recovery areas are shown in Figure 6. Additional details of the experimental design were given in Slatick et al. (1980). Random samples from the study population of fall chinook salmon were sacrificed to determine physiological condition and health. Live samples were transported to

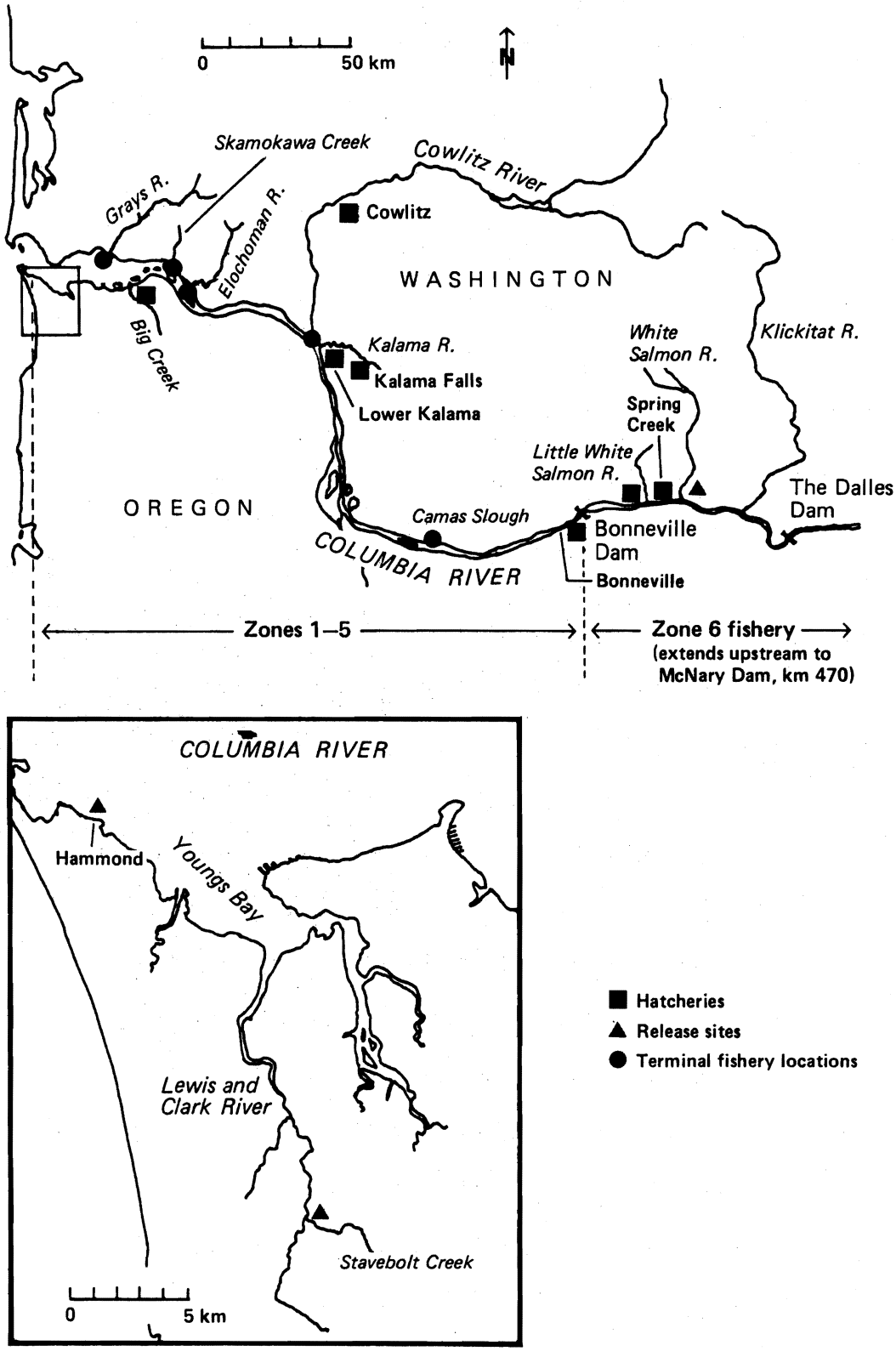

Figure 6.--Location map of release sites and recovery areas for the 1979 Big White Salmon River-Stavebolt Creek homing study.

Manchester, Washington, and held in marine net-pens for observation of seawater adaption. Additional details on methods used to measure fish condition and health are contained in the report by Novotny and Zaugg (1981).

Results

Physiology and Survival.--At seawater entry on 22 May, 15% of the test group (63/lb) were visually classified as smolts with the remainder in a transitional stage between parr and smolt. Thirty-day survival exceeded 90%, followed by increasing mortality due to seawater diseases. (Novotny and Zaugg 1981).

The results of physiological condition tests were within normal limits. Disease surveys detected a low (8.3%) incidence of bacterial kidney disease (BKD) and conflicting reports were received regarding the presence of IPN virus. No external signs of disease or abnormal mortalities were observed in groups from the first and second release series. Groups from the third release series were severely affected by an outbreak of Enteric Redmouth disease (ERM) and gill amoeba shortly after their transfer from Spring Creek NFH to the Big White Salmon River Rearing Channels (Slatick et al. 1980). Although treatment was applied, cumulative mortality totaled 32% of the original number marked. At the conclusion of treatment, high water temperatures in the Stavebolt Creek holding impoundment prevented planned transfer of test groups, so all fish were released into the Big White Salmon River.

At the time of release, most of the fish in the third release series were clinically healthy (Novotny and Zaugg 1981). However, adult

recoveries from these control releases were extremely low--only four tags (0.004%) were recovered as compared to 135 controls from the second release and 204 controls from the first release (Table 6). The reason for this severe loss is unknown; it may be because of the late June release period, or more likely it is due to the latent effects of the epizootic disease outbreak.

Overall rate of recovery of fish from the first release (both test and control groups) was 0.66%--about six times the 0.11% recovery rate of the second release (Table 6).

A factor which may have influenced the lower survival of fall chinook salmon from the second release series may have been the latent effects of pathogenic infections combined with stress induced by handling and transport during the experimental releases. Organ tissue taken on 19 May from fish held for the second release series indicated exposure to some type of pathogenic infection--probably ERM and/or BKD (Novotny and Zaugg 1981). The control group (least stressed) produced 2.6 times more adults than those transported and released at Stavebolt Creek (0.282 vs 0.106% return), and those released in Stavebolt Creek produced 4.8 times as many adults as those transported to Stavebolt Creek, held, and transported again to Hammond for release. The differences were significant ($P<0.01$, df = 1).

In contrast, transported juveniles from the first release group produced over 1.5 times as many adult fish as the control releases and there was no significant difference between the rate of return of Stavebolt Creek and Hammond releases. The transport benefit was significant ($P<0.01$, df = 1). These data suggest a strong correlation between the degree of handling and stress and the latent effects of pathogenic infections on survival of chinook salmon.

Table 6.--Recoveries of tags from control and test groups of 1-, 2-, and 3-ocean age fall chinook salmon taken in the ocean and Columbia River fisheries, hatcheries, 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- and 48-h periods and released in two locations. Recoveries were from September 1980 to December 1982.

Experimental groups	Number[a] released (N)	Recovery area: Ocean (N)	Recovery area: Columbia River (N)	Total recovery (N)	Total recovery (%)	T/C[b] ratio
	First release series (28 to 31 March 1979)					
Control (Big White Salmon River release)	42,419	107	97	204	0.481	
Natural imprint (Stavebolt release) 48 h	44,401	189	177	366	0.824	1.71:1**
Single imprint (Hammond release) 48 h	47,337	160	166	326	0.689	1.43:1**
	Second release series (17 to 22 May 1979)					
Control (Big White Salmon River release)	47,788	72	63	135	0.282	
Natural imprint (Stavebolt release) 4 & 48 h	95,821	59	43	102	0.106	0.38:1**
Single imprint (Hammond release) 4 & 48 h	95,529	13	7	20	0.021	0.07:1**
	Third release series (26 June 1979)					
Control (Big White Salmon River release)	99,699	3	1	4	0.004	
TOTAL	473,057	603	554	1,157		

a/ Adjusted for intitial tag loss.

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

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

The three series of test releases were scheduled to coincide with rising, peak, and declining Na^+-K^+ ATPase enzyme levels (Figure 7). Timing of the releases was based on the 1978 Na^+-K^+ ATPase activity profile for fall chinook salmon at the Spring Creek NFH. The plan to release fish at three clearly different levels of enzyme activity was not executed for the following reasons: (1) peak Na^+-K^+ ATPase activity in 1979 was about 10 d earlier than in 1978, (2) fall chinook salmon held at the Big White Salmon Rearing Channel never reached the expected level of enzyme activity, and (3) the third release series was delayed by an outbreak of Enteric Redmouth disease.

A test of the hypothesis that fall chinook salmon released at different levels of Na^+-K^+ ATPase activity may show different degrees of homing requires significant adult returns to the homing site. Because of the disease problem and the reduced survival of the second and third releases, it was not possible to determine the relationship of gill Na^+-K^+ ATPase activity and homing of fall chinook salmon.

Homing.--Data obtained from stream surveys were insufficient to determine differences between 4- and 48-h imprint times but did show that the treatment provided a positive homing response to the Stavebolt Creek area. Whereas none of the fish were actually recovered in Stavebolt Creek, 20 marked fish were recovered in the Lewis and Clark River within 4 miles of the creek, and no marked fish were recovered in any of the other three river systems draining into Youngs Bay that contained spawning fall chinook salmon. The lack of spawning in Stavebolt Creek might have been due to rejection of the creek by adults because of extremely low water flows in the creek at the time of spawning.

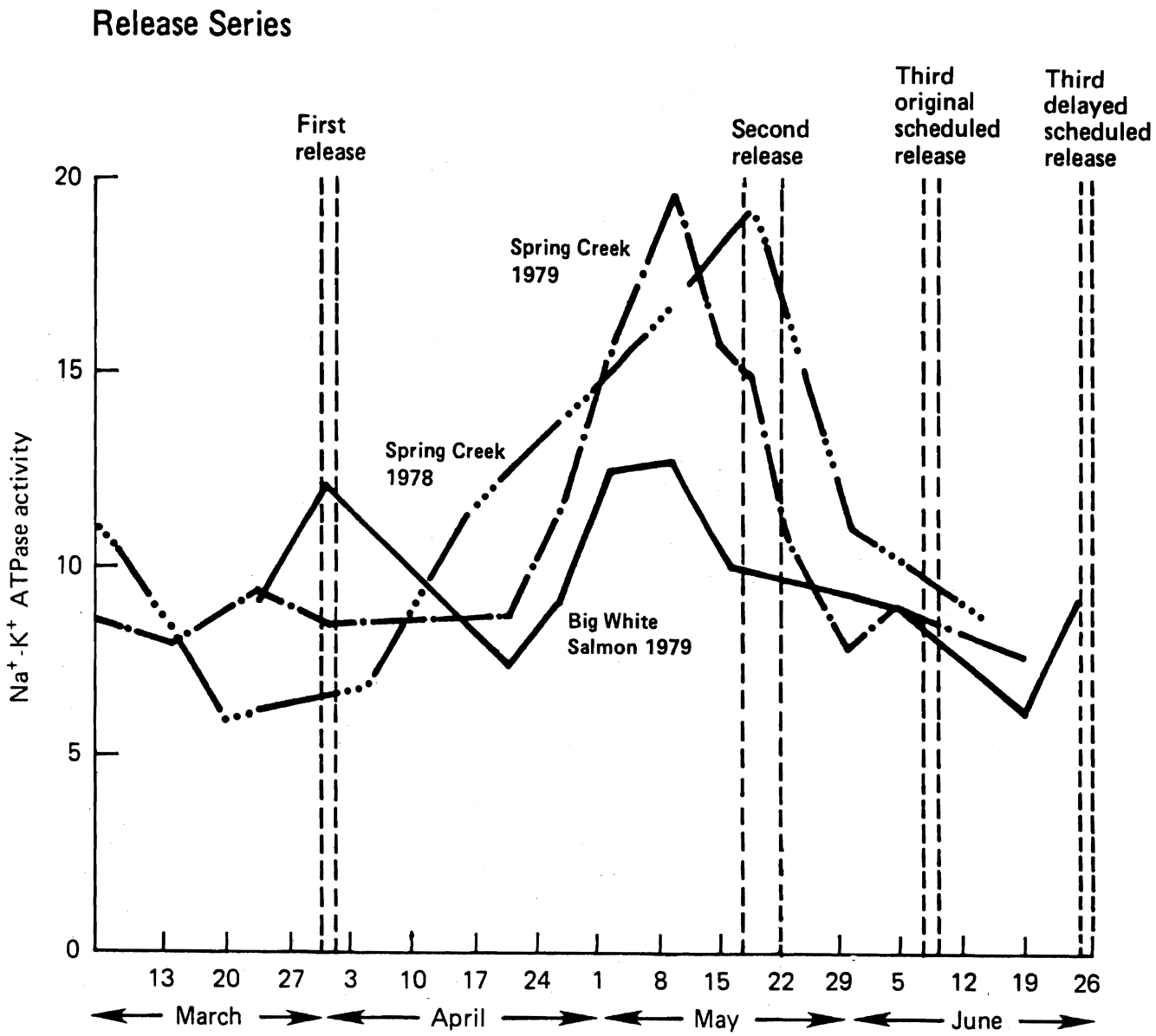

Figure 7.--Gill Na^+ -K^+ ATPase activity profiles for fall chinook salmon at Spring Creek NFH 1978 and 1979, and Big White Salmon River Rearing Channel 1979.

Data from stream surveys also indicated that homing of fish released in Stavebolt Creek (natural imprint) was better than on those released at Hammond (single imprint) after being imprinted in Stavebolt Creek. Ten of the fourteen fish recovered from the March release and five of the six fish from the May release were Stavebolt Creek releases (Appendix Table 5).

Comparisons between recoveries in the various fisheries, hatcheries, and spawning grounds best illustrate the positive homing response of test fish to Youngs Bay and vicinity (Table 7). Approximately 60% of all test fish recoveries were in Youngs Bay--of the 343 total recoveries of test fish from the first release series, all but 16 fish were recovered below the Cowlitz River, and only 6 fish were recovered above Bonneville Dam. Data from the second release were similar, but totals were much lower. The similar recovery rate for each of the treatment groups in Youngs Bay (range 53 to 86% and no significant difference between groups ($P<0.05$, df = 1) also suggests that homing to Youngs Bay was comparable between 4- and 48-h imprint times, and between releases in Stavebolt Creek and Hammond.

The proportions of test and control fish taken in the Zone 1-5 and Zone 6 fisheries reflect the location where imprinted fish were expected to home. There were no significant difference in the proportions of fish taken in the fisheries in the mainstream Columbia River between the control and test lots. Fish from the test releases contributed principally to the Zone 1-5 fisheries, and fish from the control releases contributed principally to the Zone 6 fishery.

Recovery locations where fish are listed as strays were separated into two general areas: (1) downriver from the Bonneville Hatchery and (2) Bonneville Hatchery and upriver. Strays from the test groups ranged from 7

Table 7.--A comparison between recoveries in various fisheries and spawning grounds, and as strays to hatcheries and spawning grounds of adult fall chinook salmon which were recovered in the Columbia River system. These results are based on 11 groups of juveniles which received a natural or single imprint and released at three different release sites in 1979. Recoveries are through December 1982.

Homing imprint	Release site	Number of adults recovered in Columbia River	Percentages of adults recovered at various locations in Columbia River a/									
			Lewis & Clark River	Youngs Bay	Pooled Youngs Bay area	Big White Salmon River	All fisheries in Zone 1-5	Fishery in Zone 6	Strays		Total	
									Below Bonneville	Bonneville and above	Below Bonneville	Bonneville and above
			%	%	%	%	%	%	%	%	%	%
1st release series												
Natural (control)	Big White Salmon River	97	0	0	0	0	9	23	1	66	10	90
Natural (test) 48 h	Stavebolt Creek	177	6	54	60	0	28	1	9	2	97	3
Single (test) 48 h	Hammond	166	2	56	58	0	31	0	7	3	97	3
2nd release series												
Natural (control)	Big White Salmon River	63	0	0	0	3	6	40	0	51	6	94
Natural (test) 4 & 48h	Stavebolt Creek	43	12	42	53	0	35	0	9	2	98	2
Single (test) 4 & 48 h	Hammond	7	14	71	86	0	14	0	0	0	100	0
3rd release series												
Natural (control)	Big White Salmon River	1	0	0	0	0	0	0	0	100	0	100

a/ Numbers rounded off to nearest percent.

to 9% downriver from Bonneville Hatchery and from 2 to 3% in the Bonneville area. The proportions of straying adults were greater from the control releases than from the test releases. Straying of adults from the first control release (67%) was significantly ($P<0.05$, df=1) greater than from the second control release (51%). A majority of the strays from the control lots returned to the Spring Creek NFH, their hatchery of origin (Appendix Table 5). The majority of all stray recoveries were within 25 miles of the release sites.

The straying behavior of adult fall chinook salmon in these experiments corresponds very closely to conclusions on straying drawn by Lister et al. (1981): (1) the rate of straying increases with decreasing distance between the release and rearing sites; (2) a relatively high proportion of the straying is back to the rearing site; and (3) that straying rates tend to decrease with increasing distance between the rearing and downstream release sites.

The influence of the homing imprint on the control and test lots is reflected in two major areas where the returning adults were recovered. Test fish, which were imprinted to Stavebolt Creek, were recovered principally in the Youngs Bay and lower Columbia River area (97 to 98%); whereas, 90 to 94% of the adults from the control releases were recovered in the Bonneville area.

Conclusions

1. Survival of fish released in March was six times higher than for those released in May. Survival of those released in June was nil.

2. Transported fish from the March release produced over 1.5 times as many adult fish as the control releases, and there was no significant difference between the rate of return of fish released in Stavebolt Creek and those released in brackish water at Hammond.

3. Data obtained suggest a strong positive correlation between the degree of handling and stress and the latent effect of pathogenic infections on survival of chinook salmon.

4. Homing of fish released in Stavebolt Creek was better than those released at Hammond after being imprinted in Stavebolt Creek.

5. Test fish generally homed to Youngs Bay and contributed principally to the Zone 1-5 fisheries. Control fish returned to areas above Bonneville Dam and contributed principally to Zone 6 fishery.

Fall Chinook Salmon-Spring Creek NFH, 1980

Background and Experimental Design

The objective was to imprint juvenile fall chinook salmon which were transported and released below Bonneville Dam to return as adults to the Spring Creek NFH. 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 passed through a 350-ft transport channel before being pumped 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 (RM 140). 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. (1981).

Preliminary Results

Recoveries to date are for 1- and 2-ocean age fish. Additional adult returns in 1983-84 will be added to these data and provide the basis for the final statistical analysis of the test. To date, 920 tags have been recovered from the ocean fisheries and 1,383 tags from the Columbia River system for a total of 2,303 tags.

These preliminary recoveries indicate a significant ($P<0.01$, df=1) survival benefit of 31% in the ocean fisheries and 39% in the Columbia River system for barged fish from test #1 (Table 8). The second test group showed a survival benefit of 10% in the ocean and 16% in the Columbia River, but these benefits were not statistically significant.

Barged fish provided up to twice the rate of return to hatcheries in the Bonneville area as fish from the control group. Approximately 75% of the test fish recovered were strays to other hatcheries, primarily Bonneville, compared to 15% from the control group. Due to the increased survival of the transported fish, however, the rate of return of the test groups to the homing site was up to 64% of the return rate of control fish (Table 8). The rate of return of these 1- and 2-ocean age salmon to the Spring Creek NFH homing site was twice as high as returns from 1- and 2-ocean age salmon which had been barged as juveniles directly in Columbia River water in 1977 and 1978.[3/] This suggests that the treatment of providing Spring Creek NFH 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.

3/ Unpublished data; Steve Olhausen; USFWS, Vancouver, Washington.

Table 8.--Preliminary recoveries of fall chinook salmon (1- and 2-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 1982.

		Recoveries of 1- and 2-ocean age fall chinook salmon												
		Hatcheries					River fisheries							
Experimental groups	Number[a/] released	Spring Creek homing site		Bonneville area hatcheries	Totals hatchery recovery		Zone 1-5	Zone 6	Sport	Combined Columbia River	Ocean	Total recovery		T/C ratio
	N	N	%	N	N	%	N	N	N	N	N	N	%	
Control (Spring Creek release)	60,500	105	0.174	19	124	0.205	54	88	1	267	185	452	0.747	--
Test #1 (Loaded raceway and barged)	99,583	111	0.111**	331	442	0.444**	96	70	0	608**	400**	1008	1.012**	1.35:1
Test #2 (Loaded channel and barged)	99,703	82	0.082**	262	344	0.345**	89	74	1	508[NS]	335[NS]	843	0.846[NS]	1.13:1
Total	259,786	298		612	910		239	232	2	1383	920	2302		

a/ Adjusted for initial tag loss.
NS Nonsignificant
** $P<0.01$, df=1; indicates significant difference between test and control group.

SUMMARY

Efforts in the fifth year of research on imprinting salmon and steelhead for homing concentrated on: (1) recovery of returning adults from 15 individual experiments in the fisheries, at dams, and at the hatcheries and (2) final analyses on the completed 1979 steelhead and salmon experiments and a preliminary analysis of the 1980 fall chinook salmon experiment at Spring Creek NFH. Discrete multivariate analyses were used to statistically compare test and control treatments of completed experiments. A summary of major findings by experiment follows:

Steelhead-Wells-Winthrop, 1979

1. Imprint methods used were unsuccessful in returning adults to the Winthrop NFH homing site but did implant a limited homing cue which enabled adults to successfully home to areas above McNary Dam with minimal homing impairment.

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

3. Fish trucked and released at Bonneville Dam homed to areas above Priest Rapids Dam as adults at about the same rate as controls; whereas, barged fish primarily homed to the proximity of the barge loading area near Richland, Washington.

4. Trucked fish did not appear to home to any one area; significant numbers strayed into the Snake River, and sport catches were spread out from the Ringold area to the Methow River.

5. Many fish from the test groups did not receive a homing cue and remained in the vicinity of Bonneville Dam where they were taken in large numbers in the Zone 6 fishery.

6. Transporting fish around dams significantly enhanced survival. Enhanced survival and the limited homing imprint resulted in over twice as many transported fish as control fish being caught in the various sport fisheries.

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 River system.

Steelhead-Chelan-Leavenworth, 1979

1. Imprinting techniques used combined with a truck-barge transport of fish were unsuccessful in returning adults to the Leavenworth NFH homing site or to the mid-Columbia River system above Priest Rapids Dam.

2. A portion of the transported juveniles received a homing cue when they were loaded onto the barge which enabled these adults to home to the mid-Columbia River above McNary Dam.

3. Transported fish which had not received a homing imprint when they were loaded on the barge as juveniles, returned as adults to the area near their point of release and contributed substantial numbers of fish to the Zone 6 Indian fishery in the Bonneville pool area.

4. Transporting-fish around dams significantly enhanced survival of adults returning to the lower Columbia River. Homing of transported fish, however, was impaired, which resulted in near equal numbers of control and test fish returning to the mid-Columbia River at McNary Dam.

5. Overall recoveries of 1- ocean age steelhead to various user groups were quite high, ranging from 1.41 to 2.17% of the juveniles released.

Spring Chinook Salmon, 1979

1. Both the Carson NFH and Carson-Pasco experiments were comprised of spring chinook salmon reared at Carson NFH. The poor survival of these fish precluded statistical analyses of these experiments.

2. Results of physiological sampling showed that short-term (30 d) survival in seawater net-pens was poor.

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

1. Survival of fish released in March was six times higher than those released in May. Survival of those released in June was nil.

2. Survival of fish from the first test release series was more than one and one-half times greater than the survival of the control group. By contrast, survival of fish in the second test release was only about one-fifth that of the control release. Latent effects of pathogenic infections combined with stress induced by handling and transport of experimental fish may have been responsible for their poor survival.

3. Survival of fish released directly into seawater at Hammond, Oregon, in March was comparabe to those released in Stavebolt Creek.

4. It was not possible to determine the influence of gill Na^+-K^+ ATPase activity on homing because of disease problems and reduced survival of the second and third releases.

5. The majority of juveniles released in Stavebolt Creek or at Hammond, Oregon, returned as adults to the Youngs Bay fishery and back to the Lewis and Clark River. The treatment provided a positive homing response to the Stavebolt Creek area. All of the recoveries were on

spawning grounds in the Lewis and Clark River within 4 miles of the creek.

6. Homing of fish released in Stavebolt Creek was better than for those released at Hammond after being "imprinted" to Stavebolt Creek.

7. The proportions of adults which strayed were greater from the control releases than from the test releases. A majority of the strays from the control lots returned to their hatchery of origin, Spring Creek NFH.

8. Tag recoveries showed that 97 to 98% of the adults from the test groups were recovered in Youngs Bay and the lower Columbia river area; whereas, 90 to 94% of the adults from the control groups were recovered in the Bonneville area.

Fall Chinook Salmon - Spring Creek, 1980

Preliminary analysis based on 2,303 recoveries of 1- and 2-ocean age fish indicated the following trends:

1. Survival of fish from the transported groups was up to 35% greater than from the control group.

2. Homing of test releases was impaired. Approximately 75% of the adults from the test releases strayed to other hatcheries (primarily Bonneville Hatchery) compared to 15% from the control releases.

3. The imprint techniques employed in 1980 were an improvement over the direct barging in Columbia River water done in 1977-1978. Rate of return of test fish to the homing site from the 1980 experiment was twice as high as the 1977-78 experiments.

CONTRACT EXPENDITURES

Contract expenditures for BPA project 78-1 for FY82 came to a total of $109,000.02. See Appendix Table 6 for a summary of expenditures. No major property was purchased during the fiscal year.

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APPENDIX A

Tables 1 - 6

Appendix Table 1.--Adult 1- and 2-ocean age steelhead from the 1979 Wells-Winthrop experiment which strayed into the Snake River and were recaptured at Lower Granite Dam (RM 107), 1980 to 1982.

Control test	Number of adults recovered			Adult returns 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 (test[b])	0	0	0	0.0	0.0
Truck to Bonneville (test)	9	12	21	0.216	0.903
Barge to Bonneville (test)	1	0	1	0.006	0.03

a/ Based on comparison of known recovery of fish with magnetized tags at Lower Granite Dam and the subsequent recovery of these and other marked fish at Dworshak and Pahsimeroi Hatchery upstream from Lower Granite Dam.

b/ WDG production release.

Appendix Table 2.--Number and percent recovery of 1- and 2-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 and the Methow River in 1979. Recoveries were from August 1980 to March 1982.

Control or test	Number of juveniles released	Number and percentage of adults recaptured										
		1-ocean age				2-ocean age				1-, 2-ocean age		
		Fall		Winter		Fall		Winter		Total		
		N	%	N	%	N	%	N	%	N	%	Est. %[a]
Winthrop (control)	18,298	0	0.0	0	0.0	2	0.011	0	0.0	2	0.011	0.019
Lower Methow River (test[b])	20,052	0	0.0	0	0.0	1	0.005	0	0.0	1	0.005	0.009
Truck to Bonneville (test)	9,741	3	0.031	11	0.113	4	0.041	27	0.277	45	0.462	1.054
Barge to Bonneville (test)	17,152	16	0.093	35	0.204	11	0.064	28	0.163	90	0.525	1.331

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

b/ WDG production release.

Appendix Table 3.--Adult steelhead from the 1979 Chelan-Leavenworth experiment which strayed into the Snake River and were recaptured at Lower Granite Dam (RM 107), 1980 to 1982.

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	3	0	3	0.013	0.104
2-Day Imprint					
Control	0	0	0	0.0	
Test	1	0	1	0.004	0.032
6-Hour Imprint					
Control	1	0	1	0.004	0.016
Test	1	0	1	0.004	0.032

a/ Based on comparison of known recovery of fish with magnetized tags at Lower Granite Dam and the subsequent recovery of these and other marked fish at Dworshak and Pahsimeroi Hatcheries upstream from Lower Granite Dam.

Appendix Table 4.--Number and percent recovery of 1- and 2-ocean age steelhead in the Zone 6 Indian fishery from control and test releases of smolts from the Chelan Hatchery which were imprinted to the Leavenworth NFH in 1979. Recoveries were from August 1980 to March 1982.

Control or test	Number of[a] juveniles released	Number and percentage of adults recaptured										
		1-ocean age				2-ocean age				1-, 2-ocean age		
		Fall		Winter		Fall		Winter		Total		
		N	%	N	%	N	%	N	%	N	%	Est.%[b]
10-day Imprint												
Control	23,960	7	0.029	0	0.0	5	0.21	2	0.008	14	0.058	0.139
Test	23,331	33	0.141	70	0.300	14	0.060	26	0.111	143	0.613	1.659
2-day Imprint												
Control	19,186	4	0.021	1	0.005	1	0.005	1	0.005	7	0.036	0.096
Test	24,335	23	0.095	72	0.296	24	0.099	22	0.090	141	0.579	1.538
6-hour Imprint												
Control	24,171	9	0.037	0	0.0	2	0.08	0	0.0	11	0.046	0.124
Test	22,834	28	0.123	82	0.359	17	0.074	36	0.158	163	0.714	1.904

a/ Adjusted for initial tag loss.

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

Appendix Table 5.—Summary of adult fall chinook salmon recoveries from the 1979 Big White Salmon Rearing Channel-Stavebolt Creek homing experiment. Recoveries through December 1982.

Recovery locations	Control or test, holding time, release site, wire tag code, number released, and number of adult recoveries										
	1st release series (28 to 31 March)			2nd release series (17 to 22 May)					3rd release series (26 June)		
	Control #1 Big White Salmon R. 03/47/01 42,419	Test #1 48 h Hammond 03/48/01 44,401	Test #2 48 h Stavebolt 03/49/01 47,337	Control #2 Big White Salmon R. 03/52/01 47,788	Test #3 48 h Hammond 03/51/01 49,300	Test #4 4 h Hammond 03/54/01 46,292	Test #5 48 h Stavebolt 03/50/01 48,153	Test #6 4 h Stavebolt 03/53/01 47,668	Control #3 Big White Salmon R. 03/55/01 28,542	Control #4 Big White Salmon R. 03/56/01 34,779	Control #5 Big White Salmon R. 03/57/01 36,348
Ocean Fisheries											
Sport	27	39	55	21	0	4	7	10	0	0	0
Troll	76	110	116	49	3	6	18	21	1	2	0
Net	0	3	11	1	0	0	1	1	0	0	0
Purse seine	1	0	0	0	0	0	0	0	0	0	0
Indian troll	3	4	5	1	0	0	1	0	0	0	0
Indian net	0	3	1	0	0	0	0	0	0	0	0
Mixed net	0	1	1	0	0	0	0	0	0	0	0
Ocean totals	107	160	189	72	3	10	27	32	1	2	0
Columbia River fisheries											
Zones 1-5[a]											
Early fall season	8	9	6	4	1	0	1	1	0	0	0
Late fall season	0	4	7	0	0	0	1	0	0	0	0
Zones 1-5 totals	8	13	13	4	1	0	2	1	0	0	0
Youngs Bay	0	93	96	0	3	2	12	6	0	0	0
WDF Terminal Fisheries[b]											
Grays River	0	20	30	0	0	0	5	4	0	0	0
Skamokawa Creek	0	11	6	0	0	0	1	1	0	0	0
Elokoman River	0	2	1	0	0	0	0	1	0	0	0
Cowlitz River	1	2	0	0	0	0	0	0	0	0	0
Camas Slough	0	1	0	0	0	0	0	0	0	0	0
Terminal totals	1	36	37	0	0	0	6	6	0	0	0

Appendix Table 5.--(Continued)

Recovery locations	Control or test, holding time, release site, wire tag code, number released, and number of adult recoveries										
	1st release series (28 to 31 March)			2nd release series (17 to 22 May)					3rd release series (26 June)		
	Control #1	Test #1	Test #2	Control #2	Test #3	Test #4	Test #5	Test #6	Control #3	Control #4	Control #5
	Big White	48 h	48 h	Big White	48 h	4 h	48 h	4 h	Big White	Big White	Big White
	Salmon R.	Hammond	Stavebolt	Salmon R.	Hammond	Hammond	Stavebolt	Stavebolt	Salmon R.	Salmon R.	Salmon R.
	03/47/01	03/48/01	03/49/01	03/52/01	03/51/01	03/54/01	03/50/01	03/53/01	03/55/01	03/56/01	03/57/01
	42,419	44,401	47,337	47,788	49,300	46,292	48,153	47,668	28,542	34,779	36,348
Columbia River fisheries (continued)											
CDF&W Test fisheries	0	3	0	0	0	0	0	0	0	0	0
Zone 6	22	0	1	25	0	0	0	0	0	0	0
Columbia River totals	31	145	147	29	4	2	20	13	0	0	0
Hatcheries											
Big Creek	0	7	15	0	0	0	3	1	0	0	0
Cowlitz	1	1	0	0	0	0	0	0	0	0	0
Lower Kalama	0	1	0	0	0	0	0	0	0	0	0
Kalama Falls	0	1	0	0	0	0	0	0	0	0	0
Bonneville	12	5	1	12	0	0	1	0	0	0	0
Little White	3	0	1	1	0	0	0	0	0	0	0
Spring Creek	50	0	2	19	0	0	0	0	0	1	0
Hatchery Totals	66	15	19	32	0	0	4	1	0	1	0
Stream Survey											
Big Creek	0	1	1	0	0	0	0	0	0	0	0
Lewis and Clark River	0	4	10	0	1	0	0	5	0	0	0
Elokoman River	0	1	0	0	0	0	0	0	0	0	0
Big White Salmon River	0	0	0	2	0	0	0	0	0	0	0
Stream survey totals	0	6	11	2	1	0	0	5	0	0	0
TOTAL RECOVERIES	204	326	366	135	8	12	51	51	1	3	0

a/ Early fall recoveries were at the following times: 3 September, 1980; 31 August - 1 September, 1982. There was no early fall season in 1981. Late fall recoveries were made 28-29 September, 1981.

b/ During 1981, WDF conducted Columbia River terminal fisheries at Grays River, Skamokawa Creek, Elokoman River, Cowlitz River and Camas Slough. Recoveries were made 26 August to 11 September.

Appendix Table 6.--Summary of FY82 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	$ 78,600.04
Travel	9,805.98
Vehicles	6,977.07
Rent	2,996.93
Printing	9.00
Contractual Services	7,600.00
Supplies	3,011.00
	$109,000.02