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Transplantation and Homing Experiments  
on Salmon, *Oncorhynchus* spp.,  
and  
Steelhead Trout, *Salmo gairdneri*,  
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the Columbia River System:  
Fish of the 1939-44 Broods

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Leonard A. Fulton  
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July 1981

**U.S. DEPARTMENT OF COMMERCE**  
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TRANSPLANTATION AND HOMING EXPERIMENTS ON  
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## ABSTRACT

The major objective of the study was to obtain information on the survival and homing of fish that been reared and released in areas other than the native stream of their parents. This information was obtained by removing various fins of the juveniles for identification prior to their seaward migration and then recovering these marked fish as adults during their spawning migration in the Columbia River system. Forty-one experiments were carried out: 22 on sockeye salmon (Oncorhynchus nerka), 12 on chinook salmon (O. tshawytscha), four on coho salmon (O. kisutch), and three on steelhead trout (Salmo gairdneri). With the exception of one experiment on sockeye salmon, all of the juvenile fish were reared in hatcheries. A related objective of the study was to obtain information on the practice of artificial propagation to enhance the natural production of salmon and steelhead trout.

A total of 619,514 marked juvenile sockeye salmon was released and 4,685 adults were recovered for a percentage recovery of 0.76; 92% of the adults were taken by commercial fisheries, 6% were collected from the areas of their release, and 2% were taken from spawning areas other than the areas of release.

A total of 450,511 marked juvenile chinook salmon was released and 2,204 were recovered as adults for a percentage recovery of 0.49. Eighty-seven percent of these adults were taken by commercial fisheries and 13% were collected from the

areas of their release. Only three adults were taken from spawning areas other than the areas of release.

A total of 113,479 marked juvenile coho salmon was released and 683 were recovered as adults for a percentage recovery of 0.60. Detailed recovery data was only available for 319 of the 683 adult fish; all of the 319 fish were taken by commercial fisheries.

Of 75,000 marked juvenile steelhead trout released, 137 adults were recovered for a percentage recovery of 0.18. With the exception of one fish, which was collected near the area of release, all of the recovered adults were taken by commercial fisheries.

Also presented is information on the success or failure of each of the 41 experiments, as well as data on the weight and length, sex ratio, and age of recovered adult fish.

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## PREFACE

This NOAA Technical Memorandum is based on an internal report, "Salmon Marking Experiments on the Upper Columbia River, 1939-1944," of the NMFS Northwest and Alaska Fisheries Center that was written in 1954 by Mitchell G. Hanavan and Leonard A. Fulton. Because of recent interest in the salmon and steelhead trout resources of the upper tributaries of the Columbia River system and increasing requests for copies of the report from scientists outside of the Center, it seemed appropriate to publish the results of the experiments in a publication more accessible to the public after these many years. Additional information on the number of fish released and dates of release, based upon the original data that were missing from the 1954 report, was added. The report was revised for this publication by Roger E. Pearson, NMFS Northwest and Alaska Fisheries Center, Seattle, Washington, and Leonard A. Fulton, one of the authors (now retired) of the original 1954 report. For review of drafts of this NOAA Technical Memorandum and useful suggestions, the authors are grateful to Roy J. Wahle, NMFS Northwest Regional Office, Portland, Oregon; James W. Mullan, U.S. Department of the Interior, Fish and Wildlife Service, Leavenworth, Washington; and Samuel Waterman, NMFS Northwest and Alaska Fisheries Center, Seattle, Washington.



## INTRODUCTION

Construction of Grand Coulee Dam, which is 597 river miles from the ocean, made extensive spawning grounds in the upper Columbia River inaccessible to valuable runs of salmon (*genus Oncorhynchus*) and steelhead trout (*Salmo gairdneri*). The dam rises 350 feet above the river and does not have facilities for fish passage because in the planning stage it was decided that no fish could pass over such a high barrier. Beginning in 1939, the runs of salmon and steelhead trout that came up to Grand Coulee were completely blocked by the dam and it became necessary to transfer them to tributaries that entered the river downstream. Four tributaries were available for this purpose--the Entiat, Methow, Okanogan, and Wenatchee Rivers.

The relocation, or transplantation, of the runs to tributaries downstream of the dam was undertaken by the Fish and Wildlife Service, U.S. Department of the Interior, in conformity with a program developed by the Washington State Department of Fisheries. From May 1939 to late in the fall of 1943, all adult salmon and steelhead trout were captured in the fishways at Rock Island Dam, 144 river miles downstream of Grand Coulee. Adult sockeye salmon (*O. nerka*) were carried in tank trucks to Lakes Wenatchee and Osoyoos, the latter in the Okanogan River system, where they were released for natural propagation. Returning adult chinook salmon (*O. tshawytscha*) and steelhead trout were also transported in tank trucks and then impounded for natural propagation within extensive fenced sections of the Wenatchee,

Entiat, and Methow Rivers. The returning runs of adult coho salmon (O. kisutch) passing Rock Island Dam were very small (less than 30 fish per year) and were captured in the fishways and carried to hatcheries for artificial propagation. Following completion of the federal hatchery at Leavenworth, Washington, in 1940 some of the returning adult fish at Rock Island Dam were also diverted to the hatchery's Icicle Creek holding ponds for artificial propagation. These, essentially, were the transplantation procedures that were followed through 1943; the activities were discontinued after it was observed that progeny of the transported fish successfully returned as adults to the tributaries downstream of Grand Coulee Dam.

During the years that the runs were being transplanted, experiments were performed by the Fish and Wildlife Service to evaluate the success of the program and to obtain information on the practice of artificial propagation to enhance the natural production of salmon and steelhead trout. Fish and Hanavan (1948) reported the results of some of these experiments, and we are reporting the results of others.

Presented here are the results of 41 of these experiments. The number of experiments carried out on each species was as follows: 22 on sockeye salmon, 12 on chinook salmon, 4 on coho salmon, and 3 on steelhead trout. The purposes of the experiments varied within and between species but the major objective was to obtain information on the survival and homing of salmon and steelhead trout that had been reared and released in areas other than the native stream of their parents. This

information was obtained by removing various fins of the fish as juveniles for identification prior to their seaward migration and then recovering them as adults during their spawning migration in the Columbia River system.

In the Results and Discussion parts of our text, information on the sockeye salmon experiments is presented first, followed in consecutive order of experiments by information on the chinook salmon, coho salmon, and steelhead trout experiments. Also presented, by species, in the Results part of the text are data on the weight and length, sex ratio, and age of recovered adult fish.

#### PROCEDURES

With the exception of one sockeye salmon experiment, all of the fish used in these experiments were reared in hatcheries. Prior to the time of release, for identification, designated fins were removed with surgical shears. The fish were then held for a few days to observe the mortality caused by the surgery and handling.

In the excepted sockeye salmon experiment, wild juvenile fish were captured with a beach seine at the outlet of Osoyoos Lake during their downstream migration. Since there was no facility at the lake for holding them, they were released immediately after the capture and marking operations.

Officials of cannneries that processed Columbia River salmon and steelhead trout were notified of the expected return of

marked adult fish, and a reward of fifty cents was offered for information on each marked fish. Biologists visited the butchers at the canneries to explain how the fish were marked. They also explained that information on the sex of all marked fish and on their fork length and weight was needed, as well as the need for scale samples and the removal of partially regenerated fins for study.

When the adult salmon were due back from the ocean, the streams where they had been planted earlier as juveniles were checked to see if they had returned, and other Columbia River tributaries were checked for strays. A thorough check of each stream, consisting of several surveys, had been planned; but it was curtailed, because of shortage of funds, personnel, and gasoline during World War II. However, the streams were surveyed for marked fish at least once each season after the spawned fish had died. Dead fish were removed from the stream and examined for the absence of fins. At hatcheries, all returning fish were examined for marks. Number of recoveries shown in this report are actual counts and are not statistically expanded counts to compensate for possible losses.

Scales from the adult fish were examined with a microscope to determine age of the fish and to confirm the brood year and identification of species. In this paper, the age of the fish is defined as the number of winters from the time of egg-taking (or deposition in the gravel) to the time of maturity (or capture); the brood year of the fish is the year of egg-taking (or deposition in the gravel) at the start of life.

The clipped fins, and information on the fish from which the fins were taken, were examined to detect fish with missing or clipped fins that were not part of the study. A few fish with missing fins were discovered that were not part of the study or had been incorrectly marked.

## RESULTS

### Sockeye Salmon

Twenty-two experiments were conducted on sockeye salmon from brood years 1939 to 1944. With the exception of experiment 1 (Table 1), all of the 619,514 marked fingerlings were hatchery reared. Experiments are grouped and presented according to their primary purpose, as follows: 1) transplantation, 2) time and place of release, 3) sea-run tendencies and homing of kokanee, and 4) survival of the wild (i.e., naturally reared) fish of experiment 1.

#### Transplantation

Eight experiments were carried out to determine whether sockeye salmon that had been reared in a hatchery and then released in an area other than the native stream of their parents would return to the area of release to spawn in numbers sufficient to maintain a run. Two types of stock were used in these experiments: one was not native to the Columbia River and the other was native to the river. The nonnative stock was taken from Lake Quinault in western Washington (Figure 1), and progeny of this stock were released in the upper river--in the Entiat

Table 1.--Summary of results of experiments with marked sockeye salmon.

Type of experiment and no.	Brood year	Origin of stock	Place of release	Release and marking info.		No. released	Recovery data				Percentage recovered
				Mark <sup>1/</sup>	No. released		Commer. fish.	No. recovered 2/	Home 3/	Stray	
<b>Transplantation</b>											
6	1941	L. Quinault	Entiat R.	A-D	60,010	666	1	2	669	1.11	
7	"	"	Icicle Cr.	A-RP	1,945	4	-	1	5	0.26	
15	1943	Bonneville D.	Spirit L.	D-An	24,990	4	-	-	4	0.02	
16	"	"	"	A-An	18,336	10	-	-	10	0.05	
17	"	"	L. White Salmon R.	An-RP	19,669	578	8	32	618	3.14	
18	"	"	Lake Cr. (Metolius R.)	An-LP	10,455	54	16	1	71	0.68	
19	1944	"	L. White Salmon R.	D-BV	25,351	15	6	13	34	0.13	
20	"	"	"	A-D	25,598	70	134	38	242	0.94	
<b>Time and place of release</b>											9
2	1940	Rock Isl. D.	L. Osoyoos	An-LV	50,000	846	13	-	859	1.72	
3	"	"	"	An-RV	25,000	20	4	-	24	0.10	
4	"	"	L. Wenatchee	D-RV	25,000	6	-	-	6	0.02	
5	"	"	Icicle Cr.	D-LV	25,000	24	3	-	27	0.11	
8	1942	"	L. Osoyoos	An-RV	31,264	40	-	-	40	0.13	
9	"	"	"	An-LV	33,864	380	6	-	386	1.14	
10	"	"	L. Wenatchee	A-LV	35,022	676	24	-	700	2.00	
11	"	"	"	A-RV	30,186	118	3	-	121	0.40	
13	1943	L. Wenatchee	"	D-RP	25,183	158	1	-	159	0.63	
14	"	"	"	D-LP	25,051	278	8	-	286	1.14	
<b>Kokanee</b>											
12	1942	L. Chelan	Entiat R.	D-LV	22,341	1	-	-	1	0.004	
21	1944	L. Wenatchee	Icicle Cr.	D-RV	29,189	47	32	-	79	0.27	
22	"	"	L. Wenatchee	D-LV	60,128	268	34	-	302	0.50	
<b>Survival, naturally reared fish</b>											
1	1939	L. Osoyoos	L. Osoyoos	A-An	15,932	36	6	-	42	0.26	
					619,514	4,299	299	87	4,685	(Aver.) 0.756	

1/ Mark abbreviations are as follows: L, left; R, right; D, dorsal; V, ventral; A, adipose; An, anal; P, pectoral; and B, both fins.

2/ Home designates recoveries from the stream where fish were released.

3/ Stray designates recoveries from streams other than the stream where fish were released.

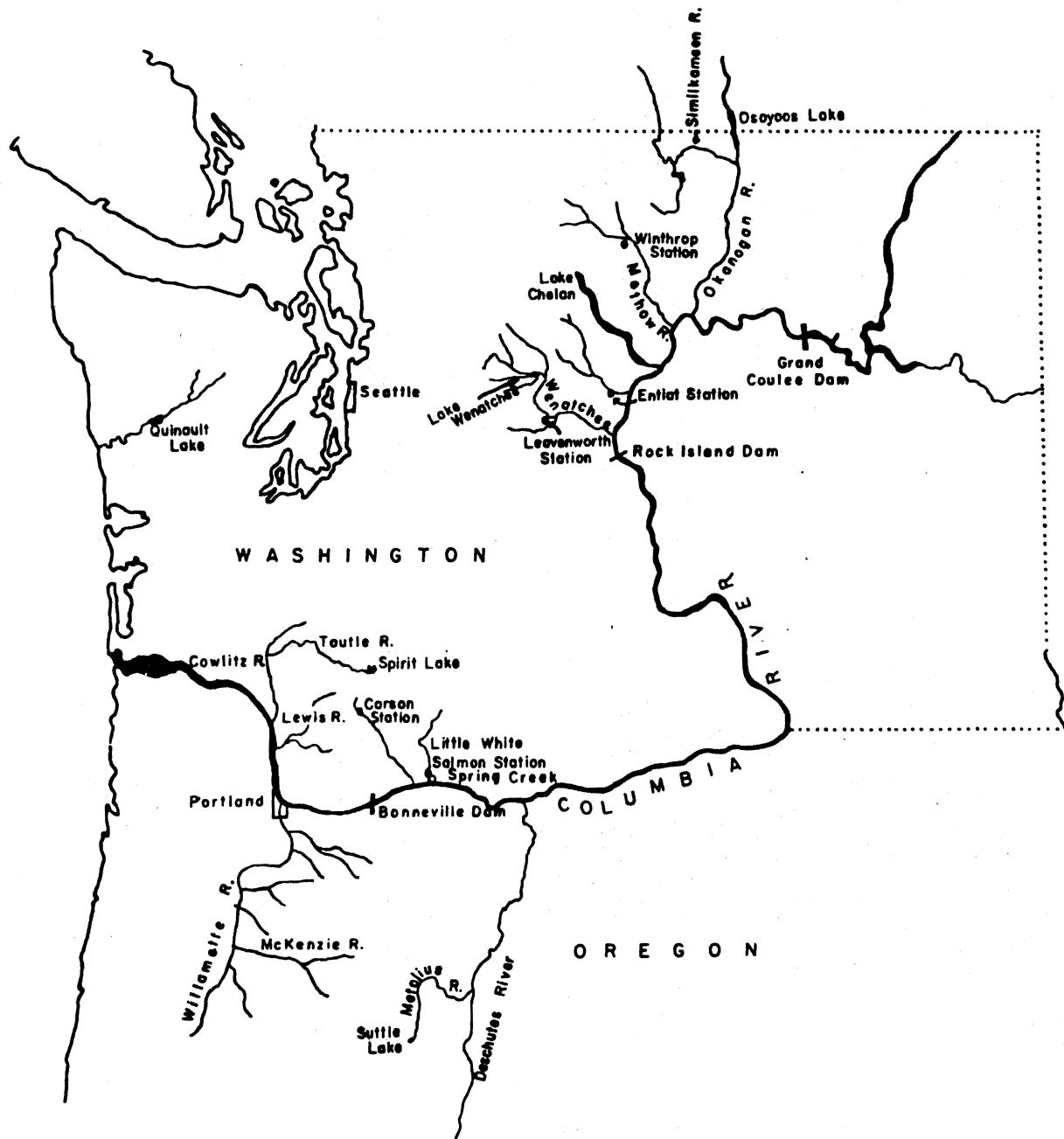


Figure 1.--Map showing study area.

River in one experiment and in Icicle Creek, a tributary of the Wenatchee River, in another experiment. The native stock was taken from a fish collecting apparatus at Bonneville Dam, and progeny of this group were released in the lower river--at Spirit Lake in two experiments, in the Little White Salmon River in three experiments, and in Lake Creek, a tributary of the Metolius River, in another experiment.

The Entiat River release of Lake Quinault stock is summarized below:

#### Experiment 6

Eye stage eggs from: Quinault Lake stock

Reared and marked at: Entiat National Fish Hatchery

Mark used: Adipose and dorsal

Number released: 60,010

Release site and date: Entiat River; 2-8 April 1943

Age: 17 months

Brood: 1941

Results: Recovered, 669 fish; 1.11% recovered

The fingerlings were in good condition when released. The percentage of marked fish recovered in this experiment was higher than average. Only one fish was recovered in the Entiat River. The stream was blocked in the fall to take returning fish for eggs for the hatchery, and had any quantity of marked fish returned to this river it was expected that more than one would have been recovered by hatchery personnel. Two strays were found at Dryden Dam on the Wenatchee River and all the other fish were recovered downstream from Rock Island Dam.

The Icicle Creek release of Lake Quinault stock is summarized below.

Experiment 7

Eggs from: Quinault Lake

Reared and marked at: Entiat and Leavenworth

National Fish Hatcheries

Mark used: Adipose and right pectoral

Number released: 1,945

Release site and date: Icicle Creek; 22, 23 October 1943

Age: 24 months

Brood: 1941

Results: Recovered, 5 fish; 0.26% recovered

Eggs used in this experiment were from fish of the same brood stock that was used in experiment 6, and were hatched at the Leavenworth Hatchery, but the fingerlings were reared 7 months longer before being released in Icicle Creek. The condition of the fingerlings when released was poor, although they were large in size.

Of the five fish recovered from this experiment, one had strayed to the Okanogan River and was taken in 1945, and the other four were taken by the commercial fisheries in 1947.

The first Spirit Lake release of native stock is summarized below.

Experiment 15

Eggs from: Native stock taken at Bonneville Dam

Reared and marked at: Carson National Fish Hatchery  
and Big White Salmon River  
rearing ponds

Mark used: Dorsal and anal

Number released: 24,990

Release site and date: Spirit Lake; 22 November 1944

Age: 14 months

Brood: 1943

Results: Recovered, 4 fish; 0.02% recovered

Native, Columbia River, adult sockeye salmon were taken from the Bonneville Dam fish ladders in June and July of 1943 and held at the Carson National Fish Hatchery on the Wind River until they were sexually mature. The offspring from this stock were reared there until 10 July 1944. Because of slow growth in the Carson ponds they were transferred to a pond at Big White Salmon National Fish Hatchery.

The fish were marked from 8 to 11 November 1944. On 22 November, these marked fish, along with an equal number of unmarked fish, were released at Spirit Lake. Except for a planting mortality of 200 fish, thought to be caused by injury from the valve of the planting hose, the fish were in good condition, with a weight of 229 fish per pound. Only 4 adults were recovered by the commercial fisheries. None were seen at

Spirit Lake.

The second Spirit Lake release of native stock is summarized below.

Experiment 16

Eggs from: Native stock taken at Bonneville Dam

Reared and marked at: Carson National Fish Hatchery  
and Big White Salmon River  
rearing ponds

Mark used: Adipose and anal

Number released: 18,336

Release site and date: Spirit Lake; 3 April 1945

Age: 18 months

Brood: 1943

Results: Recovered, 10 fish; 0.05% recovered

The fish from this experiment were held in the hatchery 4 months longer than those of the previous experiment before being released into Spirit Lake. A wide variation in body length (from 1-1/2 to 4 inches) made it necessary to grade the fish. The fish were apparently in excellent condition when released. Since these fish were kept in the hatchery 4 months longer than in experiment 15, they were considerably larger -- 90 fish per pound as against 229.

When the fish were released, Spirit Lake was frozen over except for an opening about 200 feet square near the boat house. They were carried in pails to this opening and released. All 10 marked adult fish were taken in the commercial fisheries.

The first Little White Salmon River release of native stock is summarized below.

Experiment 17

Eggs from: Native stock taken at Bonneville Dam

Reared and marked at: Little White Salmon National  
Fish Hatchery

Mark used: Anal and right pectoral

Number released: 19,669

Release site and date: Little White Salmon River;  
27 April 1945

Age: 18 months

Brood: 1943

Results: Recovered, 618 fish; 3.14% recovered

This experiment was designed to determine whether fish reared in the Little White Salmon National Fish Hatchery and released there would return to the hatchery when mature. This experiment had the highest percentage of return for all marking experiments (3.14%), but only eight fish returned to the hatchery where they were reared. Thirty-two had strayed beyond the Little White Salmon River, some as far away as Celilo Falls, about 40 miles upstream of the mouth of the Little White Salmon River. The remainder were recovered in the lower Columbia River by commercial fishermen.

The second and third releases of native stock in the Little White Salmon River are summarized below:

	<u>Experiment 19</u>	<u>Experiment 20</u>
Eggs from:	Bonneville Dam	Same
Reared and marked at:	Carson and Little White Salmon National Fish Hatcheries	Same
Mark used:	Dorsal & both ventral fins	Adipose & dorsal fins
Number released:	25,351	25,598
Release site and date:	Little White Salmon Hatchery; 22 Oct. 1945	Same 19 March 1946
Age:	12 months	18 months
Brood:	1944	Same
Results:	Returned, 34 fish; 0.13% recovered	Returned, 242 fish; 0.94% recovered

The purposes of these experiments were to determine:

- 1) whether a run of sockeye salmon could be established in the Little White Salmon River by means of artificial propagation, and
- 2) to determine the best time for release of sockeye salmon fingerlings in the Little White Salmon River.

The weight of the fish when released was 130 per pound in experiment 19 and 54 per pound for experiment 20. Considerable grading of fish was carried out as there was wide variation in size. The fingerlings were in excellent condition when released.

As can be seen in the summary, poor returns were obtained in experiment 19 and above average returns for experiment 20.

The Lake Creek release of native stock is summarized below.

Experiment 18

Eggs from: Native stock taken at Bonneville Dam

Reared and marked at: Little White Salmon Hatchery

Mark used: Anal and left pectoral

Number released: 10,455

Release site and date: Lake Creek, Metolius River;

4 May 1945

Age: 19 months

Brood: 1943

Results: Recovered, 71 fish; 0.68% recovered

The purpose of this experiment was to determine the relative survival of fish released in the Suttle Lake area. In an effort to maintain good sport fishing in Suttle Lake, its outlet, Lake Creek, was screened. This prevented fish from leaving the lake and so it was necessary to release the marked fish into Lake Creek just below Suttle Lake.

One adult marked fish, a 3.2-pound, 5-year-old male, was recovered in the Metolius River in 1948. Fifteen adult fish (14 males, 1 female) were recovered at the Little White Salmon Hatchery where these fish were reared and marked. It is possible that a few fish were inadvertently released into the Little White Salmon River via the hatchery drain while they were being marked. Therefore, we are not absolutely certain that these fish were strays. All of the fish returning to the hatchery were in their

third year and averaged a little over one pound in weight. The percentage recovery of 0.68 is almost average, although a relatively large percentage, about 21%, of the fish were sexually precocious 3-year-olds.

Time and Place of Release

Ten experiments were performed to determine whether a better return could be expected by rearing sockeye salmon in hatcheries either to 12 months of age or to 18 months and to compare the results of releases at different places. The results of these experiments are briefly summarized along with others in Table 1. In our text, the 10 experiments are arranged into five groups, Groups I through V, of two experiments each. Conditions were the same within each group for the Group I through IV experiments, except for the length of time that the fish were reared in the hatchery (i.e., in one experiment fish were reared for 12 months and in the other they were reared for 18 months) and the condition and number of released fingerlings. In the Group V experiments, all conditions were essentially the same except for the place of release.

Paired experiments of Group I are summarized below.

	<u>Experiment 2</u>	<u>Experiment 3</u>
Eggs from:	Native stock taken at Rock Island Dam	Same
Reared and marked at:	Leavenworth Hatchery	Same
Mark used:	Anal and left ventral	Anal and right ventral
Number released:	50,000	25,000
Release site and date:	Osoyoos Lake; 3 Nov. 1941	Osoyoos Lake; 8 May 1942
Age:	12 months	18 months
Brood:	1940	Same
Results:	Recovered, 859 fish; 1.72% recovered	Recovered, 24 fish; 0.10% recovered

In experiment 2, of the 859 adult fish recovered 846 or 98% were recovered from the commercial fisheries and 13 or 2% from the spawning area. In experiment 3, 20 were recovered in the commercial fisheries, and 4 were recovered in the spawning area (Okanogan River). The fingerlings in both experiments were in good condition when released. No data are available on their size, however.

In experiment 2, of the 13 adult fish recovered in spawning streams, 6 were recovered in Icicle Creek near Leavenworth National Fish Hatchery. As mentioned in the description of experiment 18, it is possible that a few marked fingerlings were accidentally released down the drain into Icicle Creek during marking at the hatchery, and we are not absolutely certain that

these six fish were strays. Two fish were recovered in the Similkameen River but we do not regard this as straying. The Similkameen flows into the Okanogan River 2 miles below Lake Osoyoos. Adult sockeye salmon are regularly seen in this tributary as far upstream as the impassable dam 6 miles above its mouth. It is believed that most of these fish inhabit the Similkameen only temporarily and then come back to the Okanogan and up into the streams above Lake Osoyoos to spawn. The temperature of the Similkameen is lower than that of the Okanogan and the fish probably seek its cooler water. Fish reenter the Okanogan when it cools.

In experiment 3, three marked adult fish were recovered at Zosel Dam just below Osoyoos Lake and another was recovered in the Similkameen River.

Paired experiments of Group II are summarized below.

	<u>Experiment 8</u>	<u>Experiment 9</u>
Eggs from:	Rock Isl. Dam	Rock Isl. Dam
Reared and marked at:	Leavenworth Hatchery	Leavenworth Hatchery
Mark used:	Anal and right ventral	Anal and left ventral
Number released:	31,264	33,864
Release site and date:	Osoyoos Lake; 21 March 1944	Osoyoos Lake; 1 Oct. 1943
Age:	18 months	12 months
Brood:	1942	1942
Results:	Recovered, 40 fish; 0.13% recovered	Recovered, 386 fish; 1.14% recovered

In experiment 8, no marked fish were recovered near the release site; but, in experiment 9, six fish were recovered in the Wenatchee River system. Here again these may not be strays because there is the possibility that some fingerlings were accidentally released into Icicle Creek, which is part of the Wenatchee River system, after being marked at Leavenworth National Fish Hatchery.

The fingerlings in experiment 9 were in poor to fair condition when released on 1 October 1943. There was a heavy planting loss but no accurate count was made of the size of this loss. The fish in experiment 8 were given therapeutic treatment before release. Their condition was believed to be fair when released.

Paired experiments of Group III are summarized below.

	<u>Experiment 10</u>	<u>Experiment 11</u>
Eggs from:	Native stock taken at Rock Isl. Dam	Same
Reared and marked at:	Leavenworth	Same
Mark used:	Adipose and left ventral	Adipose and right ventral
Number released:	35,022	30,186
Release site and date:	Lake Wenatchee; 1 Oct. 1943	Lake Wenatchee; 22 March 1944
Age:	12 months	18 months
Brood:	1942	Same
Results:	Recovered, 700 fish; 2.00% recovered	Recovered, 121 fish; 0.40% recovered

Condition and size of fingerlings at time of release were as follows: experiment 10 - fair condition, 117 fish per pound; experiment 11 - good condition, 80 fish per pound. In experiment 10, 11 adults homed to Icicle Creek and 13 came to the Little Wenatchee River hatchery racks; while in experiment 11, 3 homed to the Little Wenatchee River. No straying was found in these experiments, as Icicle Creek is the stream where the hatchery is located and the Little Wenatchee River is one of the spawning areas above Lake Wenatchee.

Paired experiments of Group IV are summarized below.

	<u>Experiment 13</u>	<u>Experiment 14</u>
Eggs from:	Little Wenatchee R.	Same
Reared and marked at:	Leavenworth	Same
Mark used:	Dorsal & right pectoral fin	Dorsal & left pectoral fin
Number released:	25,183	25,051
Release site and date:	Lake Wenatchee; 9 Oct. 1944	Lake Wenatchee; 23 March 1945
Age:	12 months	18 months
Brood:	1943	Same
Results:	Recovered, 159 fish; 0.63% recovered	Recovered, 286 fish; 1.14% recovered

No straying was discovered in these two experiments and few fish were recovered on the spawning grounds. In experiment 14, eight sockeye salmon returned to the spawning area as follows: 1 each to Lake Wenatchee and Icicle Creek, and 6 to Little Wenatchee River. The one fish from experiment 13 returned to

## Lake Wenatchee.

Juveniles in both experiments were in excellent condition when released. The fingerlings reared for 12 months numbered 106 fish per pound, while fingerlings reared 6 months longer reached a much larger size -- 34 fish per pound.

Paired experiments of Group V are summarized below.

	<u>Experiment 4</u>	<u>Experiment 5</u>
Eggs from:	Native stock taken at Rock Island Dam	Same
Reared and marked at:	Leavenworth Hatchery	Same
Mark used:	Dorsal & right ventral	Dorsal & left ventral
Number released:	25,000	25,000
Release site and date:	Lake Wenatchee; 9 May 1942	Icicle Creek; 9 May 1942
Age:	18 months	Same
Brood:	1940	Same
Results:	Recovered, 6 fish; 0.02% recovered	Recovered, 27 fish; 0.11% recovered

The purpose of this pair of experiments was to compare the results of releases at two places, Lake Wenatchee and Icicle Creek, and to determine if fish would home to Icicle Creek. Conditions were nearly identical for experiments 4 and 5 except that fingerlings of experiment 4 were released in Lake Wenatchee and fingerlings of experiment 5 were planted in Icicle Creek. In experiment 4, all the fish were recovered by the commercial fisheries, while in experiment 5, two were recovered at Icicle

Creek, one was recovered in the Little Wenatchee River, and 24 were recovered by the commercial fisheries. The Little Wenatchee River is one of the two main tributaries to Lake Wenatchee and is not far from the place of release. The usual migration of sockeye salmon in the Wenatchee system is to Lake Wenatchee and its tributaries, therefore the fish recovered in the Little Wenatchee is not regarded as a stray. The fish were believed to have been in good condition when released.

#### Kokanee

Three experiments were carried out to determine whether progeny of kokanee could be used to establish runs of sockeye salmon in streams of the upper Columbia River region below Grand Coulee Dam. Kokanee are O. nerka that do not go to sea but remain in fresh water throughout their lives. A large number of lakes in the Pacific Northwest have populations of kokanee, and, as far as is known, all lakes in the Columbia River drainage that produced sockeye salmon also had kokanee.

Lake Wenatchee was the source of eggs for two of the experiments and Lake Chelan was the source of eggs for the other. Lake Wenatchee has stocks of both sockeye salmon and kokanee. Lake Chelan, however, has no stock of sockeye salmon (anadromous fish cannot reach the lake from the sea because of high falls downstream that block their migration); kokanee there were introduced from Lake Whatcom in western Washington many years ago.

The experiment with Lake Chelan kokanee is summarized below.

Experiment 12

Eggs from: Lake Chelan

Reared and marked at: Entiat Hatchery

Mark used: Dorsal and left ventral fins

Number released: 22,341

Release site and date: Entiat River; 28 March 1944

Age: 18 months

Brood: 1942

Results: Recovered, 1 fish; 0.004% recovered

The Lake Chelan kokanee had a large mortality during their rearing in the hatchery, leaving only 22 thousand fish of the original 100 thousand put aside for the experiment. Those fish that survived the winter appeared to be in fair condition. At the time of release, they ranged in length from 2-1/2 to 8 inches and numbered 49 fish per pound. They were released in the early spring. Only one marked adult fish, a 5-year-old female, was recovered from this release; it was taken in the commercial fisheries and was a sockeye salmon (ie, a sea-run fish).

The experiments with Lake Wenatchee kokanee are summarized below.

	<u>Experiment 21</u>	<u>Experiment 22</u>
Eggs from:	Lake Wenatchee	Same
Reared and marked at:	Leavenworth Hatchery	Same
Mark used:	Dorsal & right ventral	Dorsal & left ventral
Number released:	29,189	60,128
Release site and date:	Icicle Creek; 12 March 1946	Lake Wenatchee; 9 Nov. 1945
Age:	18 months	12 months
Brood:	1944	Same
Results:	Recovered, 79 fish; 0.27% recovered	Recovered, 302 fish; 0.50% recovered

Kokanee eggs were taken at Lake Wenatchee on 13 and 14 September 1944. The adult kokanee that were captured for their spawn were distinguishable from the lake's sockeye salmon by their smaller size and different color. For example, the size range of mature Lake Wenatchee kokanee is from 6 to 9 inches while mature sockeye salmon vary from 14 to 23 inches. With rare exceptions, Lake Wenatchee kokanee are not as brightly colored during the spawning period as sockeye salmon.

The objectives of these two experiments were not only to determine whether kokanee could be used to start ocean runs of sockeye salmon but also to obtain information on the place (i.e., Lake Wenatchee in comparison to Icicle Creek), and time, of release. It was thought that if kokanee were released in Lake Wenatchee they might not go to sea, so one group (experiment 21)

was released in Icicle Creek after being held the period of time they normally remain in the lake; the other group (experiment 22) had been released in Lake Wenatchee the previous fall.

In experiment 21, 79 marked fish were recovered as adults in the Columbia River system, and all were sea-run fish. Forty-seven fish were taken in the commercial fisheries and 32 were taken in the home stream. The percentage return to the Columbia River system was 0.27% and to the home stream was 0.11%.

In experiment 22, 302 adult fish were recovered in the Columbia River system, and like experiment 21, all were sea-run fish. Two hundred sixty-eight fish were taken in the commercial fisheries and 34 were taken in the home stream. The percentage return to the river system was 0.50% and to the home stream was 0.06%.

#### Survival of Naturally Reared Fish

The experiment with wild fish from Lake Osoyoos is summarized below.

##### Experiment 1

Mark used: Adipose and anal

Number released: 15,932

Release site and date

of marking and release: Osoyoos Lake; 28 April to  
21 May 1941

Age: 19 months

Brood: 1939

Results: Recovered, 42 fish; 0.26% recovered

Downstream migrants were captured, marked, and released at the outlet of Osoyoos Lake during the spring of 1941. Forty-two of these marked fish were recovered as adults: 36 were recovered in the commercial fisheries and 6 at Rock Island Dam. The six fish recovered at Rock Island Dam were taken in 1943 when the upper Columbia River was still blocked to adult salmon. The percentage return was 0.26 which was well below the mean of 0.756 for all sockeye salmon experiments.

Weight and Length Data, Sex Ratios, and Age of Adult Fish

Weight and length data were obtained from about 55% of the recovered sockeye salmon. Frequency distributions of the weights and lengths of females and males are presented in Figures 2 and 3 respectively. The distributions show that females and males weighing 2.5 to 3.0 pounds and measuring 19.1 to 21.0 inches were the most numerous. Figure 4 presents the frequency distributions of the weights of the 3-, 4-, and 5-year-old fish.

Weight and length data have been summarized by experiments and are presented in Tables 2 to 7. The summary for 4-year-old fish is listed in Tables 2 to 4 and for 5-year fish in Tables 5 to 7. For all experiments, there is a difference of 0.7 pounds in average weight between 4- and 5-year females and a difference of 1.0 pound between 4- and 5-year males. In length between 4- and 5-year old fish, there is a difference of 1.6 inches for the females and 1.4 inches for the males.

Sex was determined for 81% of the recovered sockeye salmon. The number of fish of each sex and the number of fish of undetermined sex, as well as the percentage of each, is given in

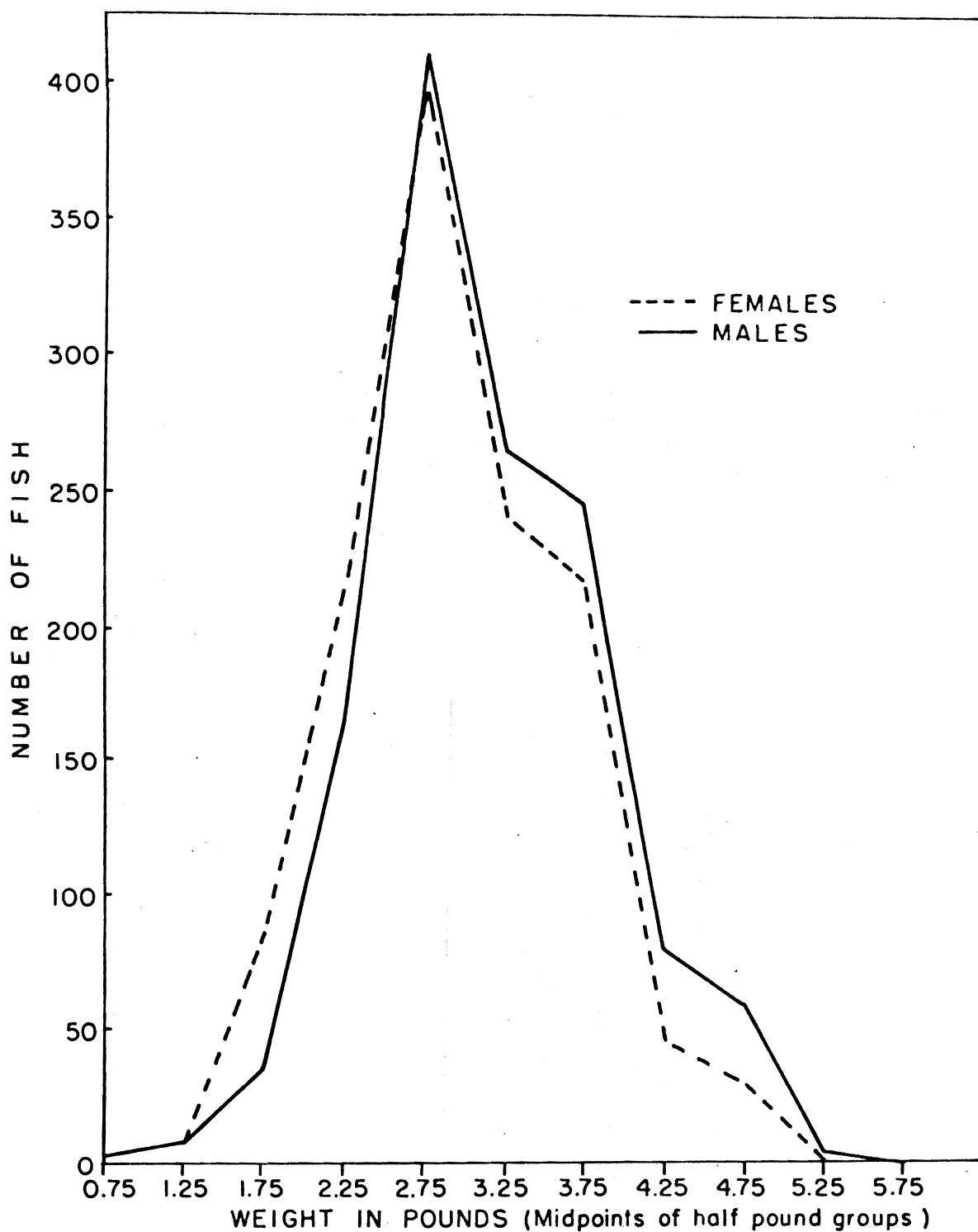


Figure 2.--Frequency distributions of the weights of marked female and male sockeye salmon.

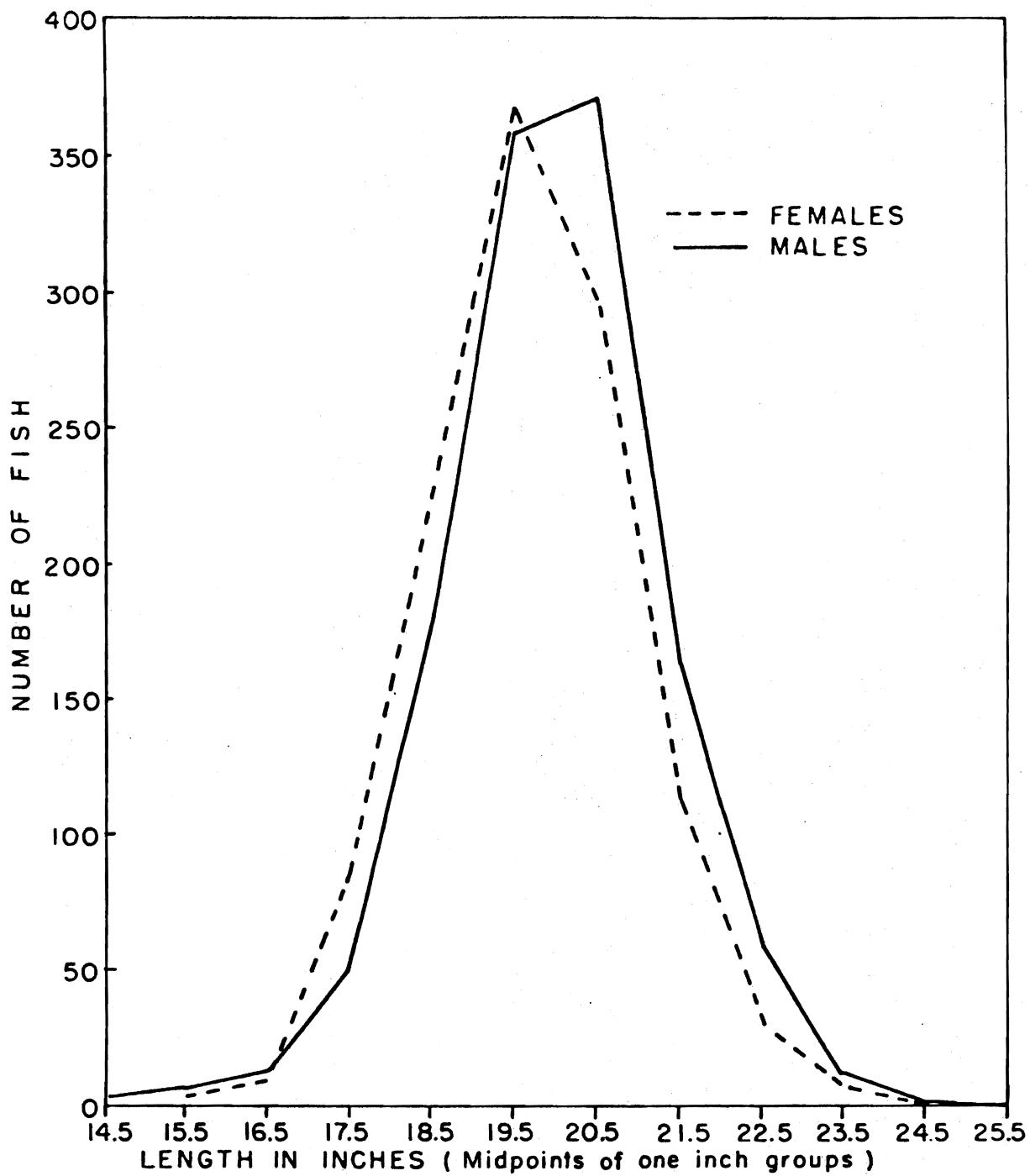


Figure 3.--Frequency distributions of the fork lengths of marked female and male sockeye salmon.

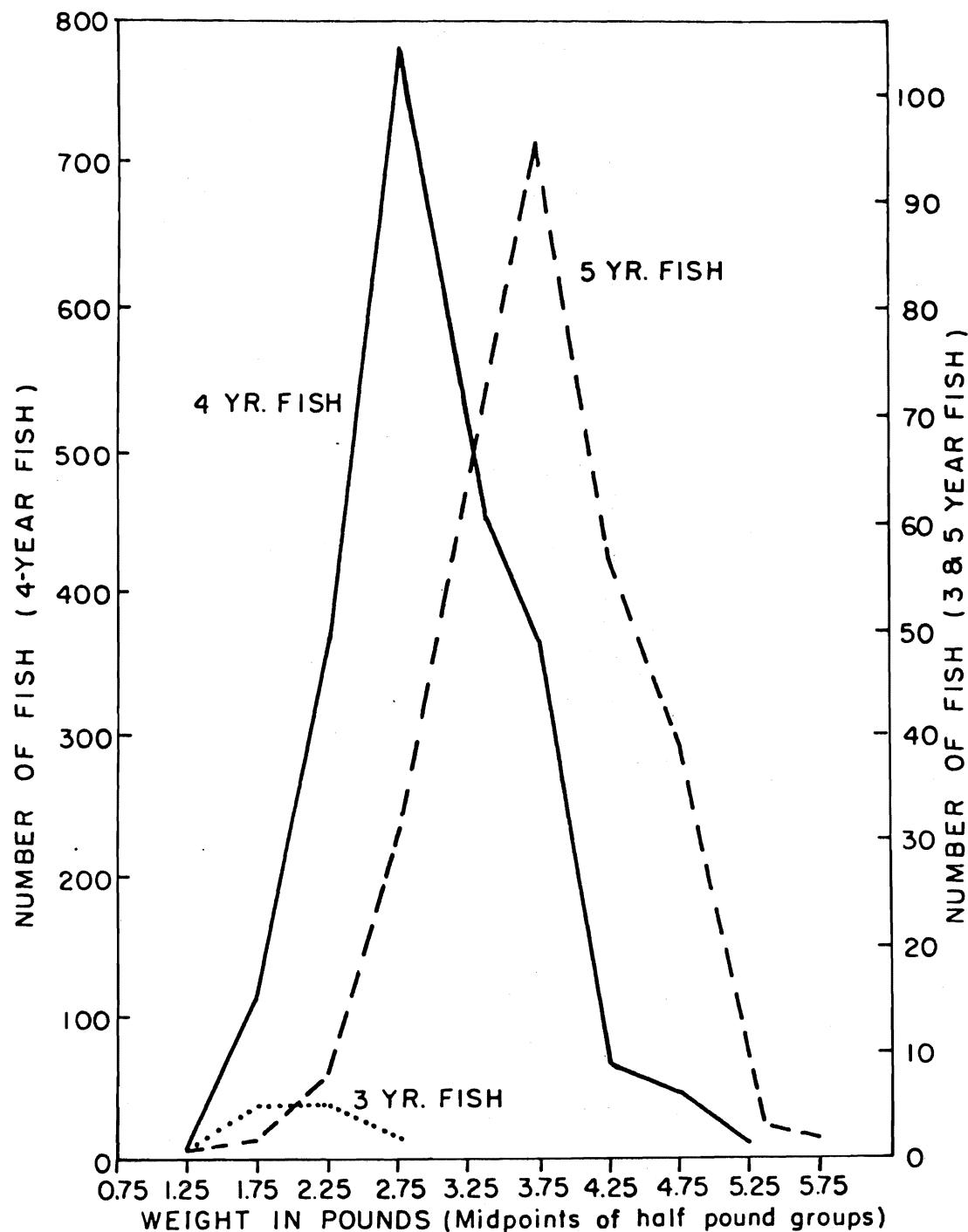


Figure 4.--Frequency distributions of the weights of marked  
3-, 4-, and 5-year old sockeye salmon.

Table 2.--Summary of weight and fork length data for marked 4-year old female sockeye salmon recovered in each experiment.

Experiment <sup>1/</sup>	Weight (pounds)			Length (in)		
	No.	Aver.	S.D.	No.	Aver.	S.D.
1	-	-	-	-	-	-
2	109	3.2	.55	36	18.9	1.13
3	1	3.0	-	-	-	-
4	2	2.8	-	2	18.8	-
5	3	2.5	-	-	-	-
6	208	3.6	.58	205	20.4	.95
7	1	2.5	-	1	11.0	-
8	1	3.0	-	1	20.0	-
9	126	3.2	.62	126	19.9	1.04
10	174	3.1	.58	174	19.5	.98
11	36	3.0	.46	34	19.6	.71
12	-	-	-	-	-	-
13	22	3.1	.60	22	20.2	.68
14	62	3.0	.68	62	20.0	1.03
15	2	4.0	-	2	21.5	-
16	3	4.2	-	3	21.7	-
17	94	3.2	.57	95	20.2	.92
18	11	3.3	-	11	20.5	-
19	14	2.9	-	14	19.8	-
20	96	2.7	.63	96	20.3	1.34
21	40	2.4	.50	39	19.0	.73
22	127	2.7	.51	126	19.1	.98
Total	1,132			1,049		
Average	3.1			19.8		

1/ Numbers designate experiments described in Table 1.

Table 3.--Summary of weight and fork length data for marked 4-year old male sockeye salmon recovered in each experiment.

Experiment <sup>1/</sup>	Weight (pounds)			Length (in)		
	No.	Aver.	S.D.	No.	Aver.	S.D.
1	-	-	-	-	-	-
2	92	3.1	.65	17	19.9	1.38
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	1	2.5	-	1	17.0	-
6	157	3.8	.76	157	20.8	.94
7	-	-	-	-	-	-
8	1	1.8	-	1	17.0	-
9	112	3.3	.58	113	20.2	1.03
10	215	3.2	.58	214	19.8	.90
11	42	3.1	.55	42	19.6	.93
12	-	-	-	-	-	-
13	25	3.2	.57	25	20.0	.97
14	53	3.2	.55	55	20.3	1.04
15	1	4.0	-	1	21.0	-
16	1	4.0	-	1	21.0	-
17	150	3.3	.56	157	20.4	.97
18	14	3.5	-	14	20.8	-
19	13	3.0	-	13	19.9	-
20	109	2.8	.47	109	20.2	1.12
21	19	2.6	.47	19	19.6	.84
22	84	2.8	.50	87	19.3	1.11
Total	1,089			1,026		
Average	3.2			20.2		

<sup>1/</sup> Numbers designate experiments described in Table 1.

Table 4.—Summary of weight and fork length data for  
4-year old marked sockeye salmon of  
undetermined sex recovered in each experiment.

Experiment <sup>1/</sup>	Weight (pounds)			Length (in)		
	No.	Aver.	S.D.	No.	Aver.	S.D.
1	-	-	-	-	-	-
2	41	3.6	.47	104	20.1	.96
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	2	4.0	-	-	-	-
6	1	3.5	-	8	18.2	-
7	-	-	-	-	-	-
8	-	-	-	1	17.0	-
9	6	3.4	-	6	20.2	-
10	7	3.0	-	5	20.1	-
11	1	3.4	-	1	22.0	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	1	5.0	-	3	21.2	-
15	-	-	-	-	-	-
16	-	-	-	-	-	-
17	4	3.6	-	4	20.6	-
18	-	-	-	-	-	-
19	1	3.0	-	1	20.0	-
20	-	-	-	-	-	-
21	1	4.0	-	1	21.0	-
22	1	4.0	-	1	21.0	-
Total	66			135		
		3.5		20.1		

<sup>1/</sup> Numbers designate experiments described in Table 1.

Table 5.--Summary of weight and fork length data for marked 5-year old female sockeye salmon recovered in each experiment.

Experi- ment <sup>1/</sup>	Weight (pounds)		Length (in)	
	No.	Aver.	No.	Aver.
1	2	3.2	2	19.5
2	33	4.2	41	21.7
3	5	3.0	4	21.9
4	2	4.2	2	21.4
5	1	4.0	2	21.5
6	24	3.9	23	21.5
7	-	-	-	-
8	5	3.6	4	20.5
9	6	3.8	7	21.6
10	7	3.7	7	21.8
11	-	-	-	-
12	-	-	-	-
13	4	3.5	5	20.1
14	5	3.8	5	21.3
15	-	-	-	-
16	-	-	-	-
17	11	3.4	11	21.4
18	1	3.8	1	20.0
19	-	-	-	-
20	-	-	-	-
21	-	-	-	-
22	-	-	-	-
Total	106		114	
	Average	3.8		21.4

1/ Numbers designate experiments described in Table 1.

Table 6.--Summary of weight and fork length data for marked 5-year old male sockeye salmon recovered in each experiment.

Experiment <sup>1/</sup>	Weight (pounds)		Length (in)	
	No.	Aver.	No.	Aver.
1	-	-	-	-
2	72	4.1	73	21.6
3	4	3.8	5	22.4
4	-	-	-	-
5	4	15.0	5	21.4
6	21	4.3	20	21.7
7	-	-	-	-
8	4	3.8	4	20.9
9	18	4.0	16	21.7
10	23	3.9	23	21.6
11	-	-	-	-
12	-	-	-	-
13	8	3.6	9	21.4
14	8	3.7	8	21.1
15	-	-	-	-
16	-	-	-	-
17	10	3.6	10	21.5
18	1	3.2	1	22.5
19	-	-	-	-
20	-	-	-	-
21	-	-	-	-
22	6	3.8	6	20.7
Total	179		180	
		Average 4.2		21.6

1/ Numbers designate experiments described in Table 1.

Table 7.--Summary of weight and fork length data for  
5-year old marked sockeye salmon of  
undetermined sex recovered in each experiment.

Experiment <sup>1/</sup>	Weight (pounds)		Length (in)	
	No.	Aver.	No.	Aver.
1	-	-	-	-
2	2	4.0	2	21.8
3	-	-	-	-
4	1	4.0	1	20.0
5	-	-	-	-
6	4	5.0	-	-
7	-	-	-	-
8	-	-	-	-
9	-	-	-	-
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-
13	-	-	-	-
14	1	4.0	1	21.0
15	-	-	-	-
16	-	-	-	-
17	1	4.0	1	21.0
18	-	-	-	-
19	-	-	-	-
20	-	-	-	-
21	-	-	-	-
22	-	-	-	-
	-	-	-	-
Total	9	5		
			Average	4.4
				21.1

1/ Numbers designate experiments described in Table 1.

Table 8. The number of males and females was 1,965 and 1,841 respectively or 41.9% males to 39.3% females, which is almost a 1 to 1 ratio.

The age of each recovered fish was known by virtue of its unique combination of fin clips. Approximately 87% were 4-years old, 10.0% were 5-years old, 2.9% were 3-years old, and 0.10% were 6-years old. The age of the recovered fish for each experiment is listed in Table 9.

#### Chinook Salmon

Twelve experiments involving 450,511 hatchery-reared chinook salmon fingerlings from brood years 1940-43 were carried out (Table 10). The experiments are grouped and presented according to their primary purpose -- 1) time of release, 2) transplantation, or 3) homing.

#### Time of Release

Eight experiments were conducted on tributaries of the upper Columbia River to determine whether a better return could be expected by 1) rearing chinook salmon in hatcheries to 1-year of age or 2) by rearing them to 1 1/2-years of age. Only upper river stock collected at Rock Island Dam was used for these studies. With the exception of experiment 25, the stock used for spawn was from the summer run; in experiment 25, a mixture of summer and late spring run fish was used.

At the time these experiments were conducted, Columbia River chinook salmon were categorized into three runs; spring, summer, and fall; depending on the season of the year that adult fish

Table 8.--Numbers of males, females, and fish of unidentified sex recovered in each sockeye salmon experiment.

Experiment <sup>1/</sup>	Male		Female		Unidentified		Total
	No.	%	No.	%	No.	%	
1	3	7.1	3	7.1	36	85.8	42
2	293	34.1	309	36.0	257	29.9	859
3	8	33.3	6	25.0	10	41.7	24
4	-	-	4	66.7	2	33.3	6
5	11	40.8	7	25.9	9	33.3	27
6	254	38.0	296	44.2	119	17.8	669
7	3	60.0	2	40.0	-	-	5
8	13	32.5	11	27.5	16	40.0	40
9	169	43.8	150	38.9	67	17.3	386
10	337	48.1	261	37.3	102	14.6	700
11	50	41.3	49	40.5	22	18.2	121
12	-	-	1	100.0	-	-	1
13	69	43.4	56	35.2	34	21.4	159
14	116	40.6	111	38.8	59	20.6	286
15	2	50.0	2	50.0	-	-	4
16	3	30.0	6	60.0	1	10.0	10
17	318	51.5	201	32.5	99	16.0	618
18	40	56.3	21	29.6	10	14.1	71
19	16	47.1	16	47.1	2	5.9	34
20	123	50.8	115	47.5	4	1.7	242
21	24	30.4	50	63.3	5	6.3	79
22	115	38.1	165	54.6	22	7.3	302
Total	1,965		1,841		881		4,685
Average	41.9		39.3		18.8		

<sup>1/</sup> Numbers designate experiments described in Table 1.

Table 9.—Age of marked sockeye salmon recovered in each experiment.

Experiment <sup>1/</sup>	Age (years)				Total
	3	4	5	6	
	No. of fish				
1	-	40	2	-	42
2	-	710	149	-	859
3	-	5	19	-	24
4	-	2	4	-	6
5	-	13	14	-	27
6	90	519	60	-	669
7	-	1	-	4	5
8	14	5	21	-	40
9	2	335	49	-	386
10	6	616	78	-	700
11	-	121	-	-	121
12	-	-	1	-	1
13	-	141	18	-	159
14	-	271	15	-	286
15	-	4	-	-	4
16	-	10	-	-	10
17	-	591	27	-	618
18	15	54	2	-	71
19	4	30	-	-	34
20	-	239	3	-	242
21	3	76	-	-	79
22	3	287	12	-	302
Total	137	4,070	474	4	4,685

Percentage  
of total 2.9 86.9 10.1 0.10 100.0

1/ Numbers designate experiments described in Table 1.

Table 10.—Summary of results of experiments with marked chinook salmon.

Type of experiment and no.	Brood year	Origin of stock <sup>1/</sup>	Release and marking info.			Recovery data				Percentage recovered
			Place of release	Mark <sup>2/</sup>	No. released	Commer. fish. <u>3/</u>	Home <u>3/</u>	Stray <u>4/</u>	Total	
<b>Time of release</b>										
23	1940	R.I.D., summer	Entiat R.	A-An	100,000	62	1	-	63	0.06
24	"	"	"	D-LV	50,008	84	5	-	89	0.18
25	"	R.I.D., summer and late spring	"	D-RV	24,982	397	27	-	424	1.70
26	"	"	"	D-BV	25,400	234	16	-	250	0.98
31	1942	R.I.D., summer	Methow R.	An-LV	40,015	133	38	-	171	0.43
32	"	"	"	An-RV	10,579	151	54	-	205	1.94
33	1943	"	Entiat R.	A-An	24,916	145	55	1	201	0.81
34	"	"	"	D-An	25,654	236	96	2	334	1.30
<b>Transplantation</b>										
29	1941	McKenzie R., spring	Icicle Cr.	An-BV	50,435	44	1	-	45	0.09
30	1942	B. White Salmon R., fall	"	A-BV	48,522	368	-	-	368	0.76
<b>Homing</b>										
27	1940	R.I.D., summer	Icicle Cr.	An-LP	25,000	26	-	-	26	0.10
28	"	"	Methow R.	An-RP	25,000	28	-	-	28	0.11
					450,511	1,908	293	3	2,204	(Aver.) 0.489

1/ Adult chinook salmon that migrated past Rock Island Dam (R.I.D.) on June 30, or before, were classified as spring run fish; and chinook salmon that passed the dam after June 30 were classified as summer run fish.

2/ Mark abbreviations are as follows: L, left; R, right; An, anal; A, adipose; D, dorsal; P, pectoral; V, ventral; and B, both fins.

3/ Home designates recoveries from the stream where fish were released.

4/ Stray designates recoveries from streams other than the stream where fish were released.

arrived in the river. The run of spring chinook salmon appeared at Rock Island Dam during the latter part of April, peaked near the end of May, and declined in early July. The run of summer chinook salmon overlapped the spring run and reached a peak early in August. The fall chinook salmon run appeared early in September and was similarly overlapped by the summer run. The three runs were quite distinct as to size of fish and time of spawning. The spring run fish were smaller than the summer run fish and spawned during late July to mid-September with the peak of spawning in August. The fall run fish were larger than the summer run fish. The summer run fish spawned mainly in October. The fall run spawned from October through mid-December.

Experiments with fish of the 1940 brood year are summarized below.

Experiment:	23	24	25	26
Eggs from:	Rock Is.	Same	Same	Same
	Dam, summer run			
Reared and marked at:	Leavenworth National Fish Hatchery	Same	Same	Same
Mark used:	Adipose & anal	Dorsal & left ventral	Dorsal & right ventral	Dorsal & both ventrals
Number released:	100,000	50,008	24,982	25,400
Release site and date:	Entiat R.; 31 July and 4 and 6	Same; 18 and 22 Oct. 1941	Same; 16 March 1942	Same; 11 May 1942
	August 1941			
Age:	11 months	13 months	17 months	19 months
Brood:	1940	Same	Same	Same
Results:	Recovered, 63 fish; 0.063%	Recovered, 89 fish; 0.178%	Recovered, 424 fish; 1.70%	Recovered, 250 fish; 0.984%
	recovered	recovered	recovered	recovered
Condition when released:	Poor	Good	Good	Poor

The fish were reared in Leavenworth National Fish Hatchery for about 1 year in experiments 23 and 24 and about 1-1/2 year in experiments 25 and 26, and were transferred to the Entiat National Fish Hatchery shortly before planting in the Entiat River. As can be seen in the text table, experiment 25 with 17 months of rearing yielded the largest returns. No straying of returning adults was observed in Icicle Creek or elsewhere.

No information is available on the size of the fish, but it was noted that considerable fungus infection was present among the fish released at 11 months of age (experiment 23). Contributory to this condition may have been the relatively high water temperature of 62°F. A therapeutic salt dip or bath was administered prior to release to arrest the fungus infection. The infection may not have been entirely arrested, and some fish may have died from this after they were released into the stream. Under these circumstances it is not surprising that few adult fish were recovered. Also the fish reared 19 months were apparently in poor condition (experiment 26). The loss during the hauling operation was high, and other fish may have died shortly after the planting operation.

Experiments with fish of the 1942 brood year are summarized below.

Experiment:	31	32
Eggs from:	Rock Is. Dam	Same
Reared and marked at:	Leavenworth and Winthrop National Fish Hatcheries	Same
Mark used:	Anal and left ventral	Anal and right ventral
Number released:	40,015	10,579
Release site and date:	Methow River; 19 Oct. 1943	Methow River; 13 April 1944
Age:	12 months	18 months
Brood:	1942	Same
Results:	Recovered, 171 fish; 0.427% recovered	Recovered, 205 fish; 1.938% recovered

The fingerlings were held at the Leavenworth National Fish Hatchery for a portion of their rearing and later were moved to the Winthrop National Fish Hatchery. The fish in both experiments were in poor condition when released. In experiment 32, mortality was high in the hatchery and increased during the winter prior to release, a condition which largely offsets the advantage of spring planting. Only 10,519 fingerlings, or 26% of the original 40,492 fish, survived to planting time; but, in spite of the poor condition of the fish when released, experiment 32 had the largest percentage recovery of the twelve chinook salmon experiments (the average percentage return for all chinook

salmon experiments was 0.489). However, if the percentage recovery is computed on the basis of the original number of fish held for the experiment, the percentage recovery decreases from 1.938 to 0.506. This is still a larger percentage than the return from experiment 31. In experiment 31, 38 fish, or 22% of the fish recovered, homed to the Methow River and in experiment 32, 54 fish or 26% homed to the Methow. No straying was observed.

Experiments with fish of the 1943 brood year are summarized below.

Experiment:	33	34
Eggs from:	Rock Island Dam, summer run	Same, taken at Leavenworth
Reared and marked at:	Leavenworth National Fish Hatchery	Leavenworth and Entiat National Fish Hatcheries
Mark used:	Adipose and anal	Dorsal and anal
Number released:	24,916	25,654
Release site and date:	Entiat R.; 28 Oct. to 6 Nov. 1944	Entiat R.; 28 March to 6 April 1945
Age:	12 months	18 months
Brood:	1943	Same
Results:	Recovered, 201 fish; 0.807% recovered	Recovered, 334 fish; 1.302% recovered

The fingerlings in experiment 33 were reared at the Leavenworth National Fish Hatchery and were large and apparently healthy when released in the Entiat River in October and

November. Fingerlings used in experiment 34 were reared at Leavenworth until fall and were then held over winter at the Entiat National Fish Hatchery. They sustained relatively large losses during the winter and were in poor condition when released in the spring. In spite of this handicap, they produced the third highest percentage return to the fishery.

One fish from experiment 33 was recovered in Herman Creek in the hatchery impoundment area near Cascade Locks, Oregon. This is a doubtful stray, as Columbia River water enters the Herman Creek impoundment and, if not prevented, the fish might have continued upstream to the Entiat River.

Experiment 34 produced two strays, one in the Wenatchee--the system in which the fish were reared before they were transferred to the Entiat Hatchery--and the other in the Methow River. Returns to the Entiat River included 55 from experiment 33 and 96 from experiment 34, or 27 and 28%, respectively, of the entire returns to the Columbia River.

#### Transplantation

Two experiments were performed to determine whether juvenile chinook salmon that had been reared in a hatchery, and then released in an area other than the native stream of their parents, would return to the area of release to spawn in numbers sufficient to maintain a run. In both experiments, progeny of adults from spawning areas of the lower Columbia River region were reared at Leavenworth National Fish Hatchery and then released into the upper Columbia region at Icicle Creek. The stock used for one experiment was from the McKenzie River, a

tributary of the Willamette River system in Oregon, and the stock used for the other was from the Big White Salmon River in Washington.

The Icicle Creek release of progeny from McKenzie River stock is summarized below.

Experiment: 29  
Eggs from: McKenzie River, spring run fish  
Reared and marked at: Leavenworth National Fish Hatchery  
Mark used: Anal and both ventrals  
Number released: 50,435  
Release site and date: Icicle Creek; 5 Oct. 1942  
Age: 12 months  
Brood: 1941  
Results: Recovered, 45 fish; 0.089% recovered

Spawn was taken from spring chinook salmon of the McKenzie River. The eggs were reared at Leavenworth National Fish Hatchery and the resultant fish released into Icicle Creek. The McKenzie River is 270 miles from the ocean, while Icicle Creek is about 500 miles away. Only one adult fish was recovered in Icicle Creek, the remaining 44 were recovered in the Columbia River commercial fisheries, some of them well above the mouth of the Willamette River, the spawning system of their parents. There was no indication of straying. The condition of the fingerlings at the time of release was judged as "good."

The Icicle Creek release of progeny from Big White Salmon River stock is summarized below.

Experiment: 30

Eggs from: Big White Salmon River

Reared and marked at: Leavenworth National Fish Hatchery

Mark used: Adipose and both ventrals

Number released: 48,522

Release site and date: Icicle Creek; 26 Oct. 1943

Age: 13 months

Brood: 1942

Results: Recovered, 368 fish; 0.758% recovered

Spawn was taken from fall chinook salmon returning to the Big White Salmon River rearing ponds. The eggs, after eyeing, were taken to the Leavenworth National Fish Hatchery and the resultant young were reared to 13 months of age before being marked and released. The condition of the fingerlings was believed to have been poor when they were released, based on the relatively large losses sustained in the hatchery during the winter. The poor condition of the fish may have been more apparent than real, however, because there was a better-than-average return of adult fish to the commercial fisheries. The mouth of the Big White Salmon River is 168 miles from the ocean while Icicle Creek is about 500 miles away. The adult fish were taken as far up the Columbia as Celilo Falls, which is 31 miles upstream of the mouth of the Big White Salmon River, the native stream of their parents. No adult fish were recovered in Icicle Creek.

Homing

Two experiments were conducted to study the homing, and the extent of straying, of hatchery reared chinook salmon of the upper Columbia River system. In both experiments, progeny of adults that had been collected at Rock Island Dam in 1940 were reared at Leavenworth National Fish Hatchery and then released at 18 months of age. In one experiment, the fish were released into Icicle Creek, and, in the other, they were released into the Methow River.

The Icicle Creek release is summarized below.

Experiment:	27
Eggs from:	Summer run fish at Rock Island Dam
Reared and marked at:	Leavenworth National Fish Hatchery
Mark used:	Anal and left pectoral
Number released:	25,000
Release site and date:	Icicle Creek; 14 May 1942
Age:	18 months
Brood:	1940
Results:	Recovered, 26 fish; 0.104% recovered

The marked fish in experiment 27 were from late summer stock obtained at Rock Island Dam during the migration in 1940. Fingerlings were in fair condition when released. There was no opportunity to evaluate homing and straying because all recoveries were in the commercial fisheries.

The Methow River release is summarized below.

Experiment: 28  
Eggs from: Summer run fish at Rock Island Dam  
Reared and marked at: Leavenworth National Fish Hatchery  
Mark used: Anal and right pectoral  
Number released: 25,000  
Release site and date: Methow River; 15 May 1942  
Age: 18 months  
Brood: 1940  
Results: Recovered, 28 fish; 0.112% recovered

The above marked fingerlings were in good condition when released. All of the recovered fish were taken by the commercial fisheries; no data, therefore was available to evaluate homing and straying.

Weight and Length Data, Sex Ratios, and Age of Adult Fish

Weight and length data were obtained from about 50% of the recovered chinook salmon (Table 11). The mean weight for 4-year old males was 14.2 pounds and of 4-year females 13.9 pounds. Five-year-old fish were several pounds heavier; the males averaged 22.1 and females 18.7 pounds.

In figures 5 and 6, mean lengths and weights are plotted for the different age groups of male and female chinook salmon recovered from all the experiments. In addition, in Figure 7 the weight-length relationship is presented graphically. Only the mean weights and mean lengths are plotted for each age group. The graphs show that the average length of 4-year-old females was slightly longer than the average length of 4-year-old males but

Table 11.—Summary of weight and fork length data, by age of fish, for marked male and female chinook salmon recovered in each experiment.

Age (years)	Weight data						Length data					
	Males			Females			Males			Females		
	No. fish	Aver. weight (pounds)	S.D.	No. fish	Aver. weight (pounds)	S.D.	No. fish	Aver. length (in)	S.D.	No. fish	Aver. length (in)	S.D.
3	198	3.9	1.53	-	-	-	206	20.2	2.24	-	-	-
4	332	14.2	4.33	228	13.9	4.25	316	29.8	3.50	228	30.2	3.88
5	102	22.1	6.55	232	18.7	4.56	90	34.2	4.01	245	33.2	2.67
6	-	-	-	-	-	-	16	33.0	-	23	34.8	-
Total	632			460			628			496		
Average	12.4			16.4			27.4			31.9		

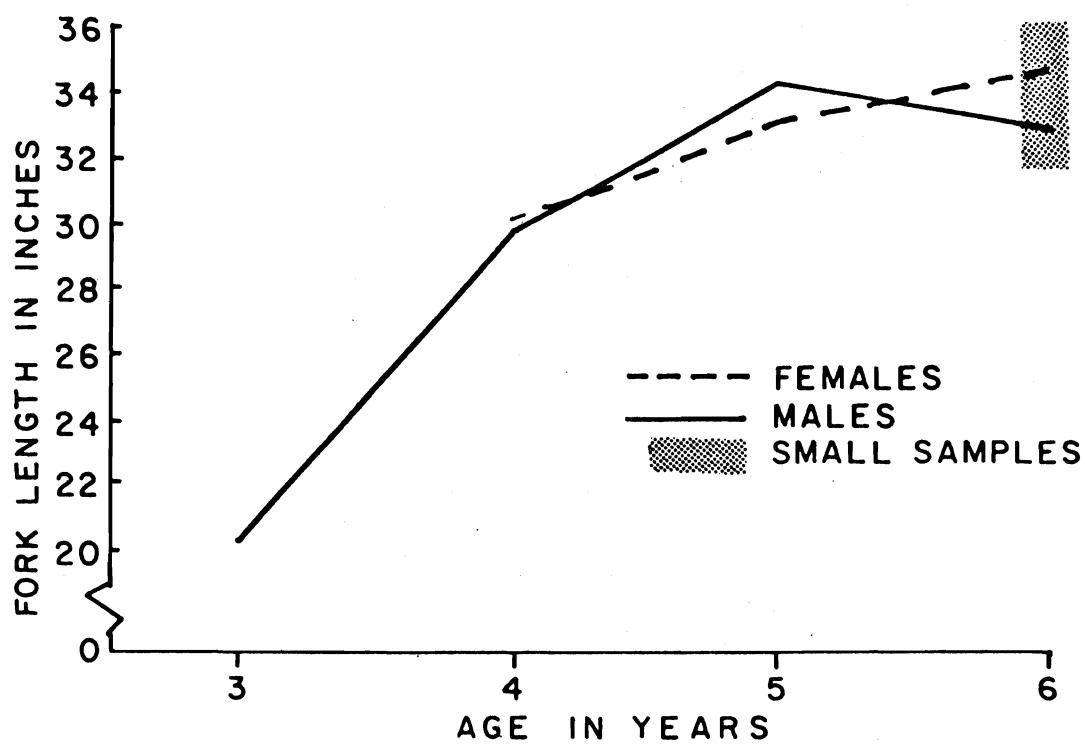


Figure 5.--Age-length relationship for marked male and female chinook salmon.

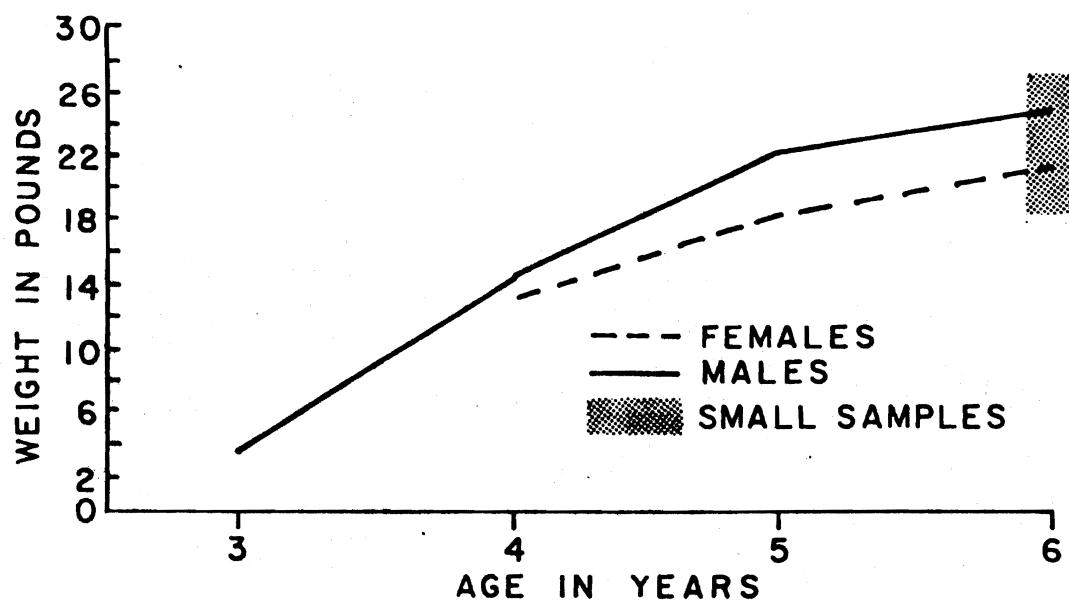


Figure 6.--Age-weight relationship for marked male and female chinook salmon.

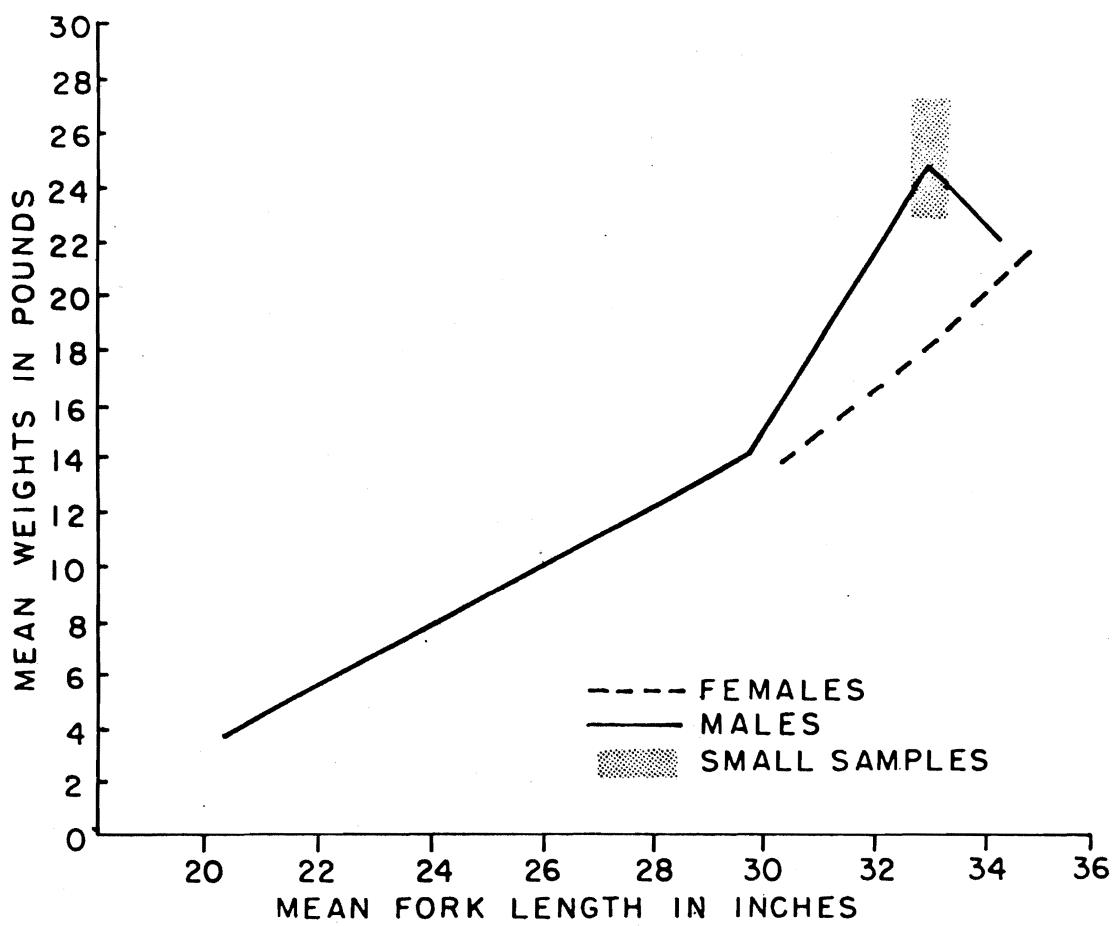


Figure 7.--Weight-length relationship for marked male and female chinook salmon.

females weighed slightly less.

The sex ratio of recovered adults varied with age of fish as follows:

Age of fish	3	4	5	6	Total
Number of males	334	586	284	29	1,233
Number of females	8	406	467	39	920
Percentage of males	97.6	58.1	37.8	42.8	

The older age groups contained a larger percentage of females than males; the younger age groups had more males than females. Of the 2,153 chinook salmon examined for sex, 57.3% were males and 42.7% were females, which is a 1 to 0.75 ratio.

Four year old adult fish were the most numerous (Table 12). About 46% of the recovered fish were 4-years old, 34% 5-years old, 17% 3-years old, and 3% 6-years old.

Rich and Holmes (1928), in experiments with chinook salmon of the lower Columbia River system, reported the following age composition: 49% 5-years old, 33% 4-years old, 9% 3-years old, 9% 6-years old, and less than 1% 2-years old. Five year old fish were the most numerous in Rich and Holmes' experiments, whereas 4-year olds were the most numerous in ours. Rich and Holmes also reported more 6-year old fish and much fewer 3-year old fish than in our experiments. As in our experiments, their fish were reared in the hatchery before being released to migrate to the ocean.

Table 12.--Age of marked chinook salmon recovered in each experiment.

Experiment <sup>1/</sup>	Age (years)						Total
	2	3	4	5	6	7	
No. of fish							
23	-	2	15	34	12	-	63
24	-	5	37	40	7	-	89
25	-	53	217	144	10	-	424
26	-	40	123	82	4	1	250
27	-	-	4	14	8	-	26
28	-	-	3	15	10	-	28
29	-	-	15	30	-	-	45
30	-	18	207	140	3	-	368
31	-	41	76	48	6	-	171
32	-	62	82	52	9	-	205
33	-	45	103	53	-	-	201
34	1	104	125	104	-	-	334
Total	1	370	1,007	756	69	1	2,204
Percentage of total		0.04	16.79	45.69	34.30	3.13	0.04

1/ Numbers designate experiments described in Table 10.

### Coho Salmon

Four experiments were carried out with coho salmon (Table 13). A total of 113,479 marked fingerlings were released: 61,784 fish were of the 1942 brood and 51,695 fish were of the 1943 brood. Eyed eggs were obtained from the Lewis River Hatchery of the Washington Department of Fisheries for all four of the experiments. The fish were reared and released at the Leavenworth National Fish Hatchery. The purposes of the coho salmon experiments were to determine if stock from the lower Columbia River region could be successfully transplanted to the Wenatchee River system and to determine the best age of fish and time of year to release the fish from the hatchery.

### Transplantation

Four experiments were conducted to determine whether the progeny of the Lewis River stock that had been reared and released at Leavenworth National Hatchery would return to the hatchery stream, Icicle Creek, in numbers sufficient to maintain a run. Fish of the 1942 brood were used for two experiments, and fish of the 1943 brood were used for the other two experiments.

Table 13.--Summary of results of experiments with marked coho salmon.

Experi- ment	Brood year	Origin of stock	Release and marking info.			Recovery data				Percentage recovered	
			Place of release	Mark <sup>1/</sup>	No. released	No. recovered					
						Commer. fish.	Home <u>2/</u>	Stray <u>3/</u>	Total		
35	1942	Lewis R.	Icicle Cr.	An-LV	32,562	131	0	0	131	0.402	
36	"	"	"	An-RV	29,222	188	0	0	188	0.643	
37	1943	"	"	A-BV	25,217	-	-	-	87	0.345	
38	"	"	"	D-BV	26,478	-	-	-	277	1.046	
					113,479	319	0	0	683	(Aver.) 0.602	

1/ Mark abbreviations are as follows: L, left; R, right; An, anal; A, adipose; D, dorsal; V, ventral; and B, both fins.

2/ Home designates recoveries from the stream where fish were released.

3/ Stray designates recoveries from streams other than the stream where fish were released.

Experiments with coho salmon of the 1942 brood are summarized below.

Experiment:	35	36
Eggs from:	Lewis River	Same
Reared and marked at:	Leavenworth National Fish Hatchery	Same
Mark used:	Anal and left ventral	Anal and right ventral
Number released:	32,562	29,222
Release site and date:	Icicle Creek; 26 Oct. 1943	Icicle Creek; 30 March 1944
Age:	12 months	17 months
Brood:	1942	Same
Results:	Recovered, 131 fish; $0.402\%$ recovered	Recovered, 188 fish; $0.643\%$ recovered

The fish used in experiment 35 were in poor condition during part of their hatchery rearing and had a relatively high loss in the hatchery of about 1,500 fish. Their size at time of release was 79 fish per pound. The fish in experiment 36 were also in poor condition and even greater losses (about 7,500 fish) occurred in the hatchery. Their size at time of release was 56 fish per pound.

Experiments with coho salmon of the 1943 brood are summarized below.

Experiment:	37	38
Eggs from:	Lewis River	Same
Reared and marked at:	Leavenworth National Fish Hatchery	Same
Mark used:	Adipose and both ventral fins	Dorsal and both ventral fins
Number released:	25,217	26,478
Release site and date:	Icicle Creek; 7 Oct. 1944	Icicle Creek; 24 March 1945
Age:	12 months	17 months
Brood:	1943	Same
Results:	Recovered, 87 fish; 0.345% recovered	Recovered, 277 fish; 1.046% recovered

Fingerlings in experiments 37 and 38 were in better condition at time of release than the fish in the 1942 brood experiments. The 12-month old fish in experiment 37 attained the comparatively large size of 54 fish per pound (compared to 79 fish per pound for the 12-month old fish in experiment 35) while fish in experiment 38 at 17 months of age, had attained a size of 25 fish per pound. Although a few fish were small and in poor condition at the time of release, the majority were in good condition.

None of the adult coho salmon were discovered straying and all of the recoveries were from the Columbia River system, with the exception of two fish taken in the ocean. A considerable number of coho salmon were recovered at the Celilo Falls Indian

fishery, which is about 295 miles downstream of their release site in Icicle Creek and more than 120 miles upstream from the spawning area of their parents in the Lewis River; these fish may have been on their way to their release site. However, none were recovered at Rock Island Dam or in the tributaries above the dam.

Time of Release

The four coho salmon experiments reported above were also performed to determine whether a better return could be expected by 1) rearing fish in the hatchery to 12 months of age and releasing them in the fall or 2) by rearing them for 17 months and releasing them in the spring. The fish of the 1942 and 1943 broods that were described above in the descriptions of experiments 35, 36, 37, and 38 were also used in these experiments. The percentage return of adults of the 1942 brood was 0.40% for the fish that had been reared for 12 months and released in the fall and was 0.64% for the fish that had been reared for 17 months and released in the spring (Table 13). The percentage return of adults of the 1943 brood was 0.34% for the fish that had been reared for 12 months and released in the fall and was 1.05% for the fish that had been reared for 17 months and released in the spring. The percentage recovery was higher for the fish that had been reared in the hatchery to 17 months of age and released in the spring for both the 1942 and 1943 broods.

Weight and Length Data and Age of Adult Fish

Weight and length data for only experiments 35 and 36 are available. The average weight for females of the total of both

experiments was 9.6 pounds with a standard deviation of slightly more than 2 pounds (Table 14). The average weight for males was 9.3 pounds, with a much higher standard deviation -- 4.1, and 2.9 pounds for experiments 35 and 36, respectively. The average fork length of female coho salmon was 27.0 inches with a standard deviation of about 2 inches for both experiments. The average fork length of males was 26.3 inches; as expected from the weight data, there was a wider standard deviation for the males -- 3.4 and 2.7 for experiments 35 and 36, respectively. All but 2 of the 683 marked coho salmon recovered in the four experiments reported above were 3-year old fish. The two exceptions were 2-year old males that were caught in the ocean by the commercial troll fishery.

#### Steelhead Trout

Three experiments were conducted on steelhead trout (Table 15). A total of 75,000 marked fingerlings were released, and all were of the 1941 brood and were progeny of adult fish from the upper Columbia River region that had been collected at Rock Island Dam and then hauled to Leavenworth National Fish Hatchery for their spawn. Experiments are presented according to their purpose, as follows: 1) time of recovery in fresh water and 2) homing.

#### Time of Recovery in Fresh Water

One experiment was conducted with progeny of spring run fish, and two experiments were conducted with progeny of fall run fish. Like chinook salmon, steelhead trout are divided into runs

Table 14.--Summary of weight and length data for male and female marked coho salmon, 1942 brood.

Sex of fish and experiment no. <sup>1/</sup>	Number of fish	Weight data		Length data	
		Mean weight (pounds)	Standard deviation	Mean fork length (inches)	Standard deviation
<b>Female</b>					
Experiment 35	43	9.4	2.2	26.9	2.1
Experiment 36	46	9.7	2.3	27.1	2.0
		Average 9.6		Average 27.0	
<b>Male</b>					
Experiment 35	46	10.0	4.1	26.8	3.4
Experiment 36	75	8.8	2.9	25.9	2.7
		Average 9.3		Average 26.3	

<sup>1/</sup> Numbers designate experiments described in Table 13.

Table 15.—Summary of results of experiments with marked steelhead trout, 1941 brood.

Experi- ment	Origin of stock <sup>1/</sup>	Release and marking info.			Recovery data				Percentage recovered
		Place of release	Mark <sup>2/</sup>	No. released	Commer. fish.	Home <u>3/</u>	Stray <u>4/</u>	Total	
39	R.I.D., spring	Icicle Cr.	A-An	25,000	28	0	0	28	0.112
40	R.I.D., fall	"	D-RV	25,000	70	1	0	71	0.284
41	"	Methow R.	A-LV	25,000	38	0	0	38	0.152
				75,000	136	1	0	137	(Aver.) 0.182

1/ Adult steelhead trout that migrated past Rock Island Dam (R.I.D.) on July 9, or before, were classified as spring run fish; and steelhead trout that passed the dam after July 9 were classified as fall run fish.

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2/ Mark abbreviations are as follows: L, left; R, right; An, anal; A, adipose; D, dorsal; and V, ventral fin.

3/ Home designates recoveries from the stream where fish were released.

4/ Stray designates recoveries from streams other than the stream where fish were released.

on the basis of the season of the year that adult fish arrive in the river. Adult steelhead trout migrate past Rock Island Dam from the latter part of March to the last of November, reaching two peaks -- one peak in the spring in early May and the other in the fall in late September or early October.

The objective of these experiments was to determine the time of the year that the hatchery reared progeny of the spring and fall run fish returned to the river as adults. In one experiment, progeny of spring run fish were released into Icicle Creek, and in another experiment progeny of fall run fish were released into Icicle Creek. In the third and last experiment, progeny of fall run fish were released into the Methow River.

The Icicle Creek release of spring run stock is summarized below.

#### Experiment 39

Eggs from: Rock Island Dam, spring run

Reared and marked at: Leavenworth National Fish Hatchery

Mark used: Adipose and anal

Number released: 25,000

Release site and date: Icicle Creek; 4 June 1942

Age: 12 months

Brood: 1941

Results: Recovered, 28 fish; 0.112% recovered

Of the three steelhead trout experiments, experiment 39 had the lowest percentage of return of adult fish to the Columbia River system. One reason for the low return may have been the poor condition of the fish at time of release. This poor condition

was related to fin rot which occurred in the hatchery during the winter. The juvenile fish were treated with a salt water dip to control the fungus, but their poor condition persisted through the spring.

Twenty-eight fish were recovered as adults, and all were taken in the Columbia River by commercial fisheries. The areas of capture varied widely and extended from close to the mouth of the river upstream to Rock Island Dam. The time of capture extended from 16 July to 3 September, with a peak in the catch on 20 August.

The Icicle Creek release of fall run stock is summarized below.

#### Experiment 40

Eggs from: Rock Island Dam, fall run

Reared and marked at: Leavenworth National Fish Hatchery

Mark used: Dorsal and right ventral

Number released: 25,000

Release site and date: Icicle Creek; 4 June 1942

Age: 8 months

Brood: 1941

Results: Recovered, 71 fish; 0.284% recovered

Experiment 40 had the highest percentage of return of adult steelhead trout to the Columbia River system, and at the time of their release as juveniles they were in better condition than the fish used in the other two experiments.

Seventy-one fish were recovered as adults, and all were taken in the Columbia River system--seventy by the commercial

fisheries in the Columbia River and one in the Wenatchee River by a sport fisherman. With regard to the commercial catch, the areas of capture extended from the mouth of the Columbia River upstream to Rock Island Dam, and the time of capture extended from 18 June to 20 August, with peak catches on 16 and 30 July.

The Methow River release of fall run stock is summarized below.

#### Experiment 41

Eggs from: Rock Island Dam, fall run

Reared and marked at: Leavenworth National Fish Hatchery

Mark used: Anal and left ventral

Number released: 25,000

Release site and date: Methow River; 5 June 1942

Age: 12 months

Brood: 1941

Results: Recovered, 38 fish; 0.152% recovered

Experiment 41 had the second highest percentage of return of adult steelhead trout to the Columbia River system. At the time of their release as juveniles, they, like the fish in experiment 39, were in poor condition because of fin rot.

Thirty-eight fish were recovered as adults, and all were taken in the Columbia River by commercial fisheries. The areas of capture extended from close to the mouth of the river upstream to Rock Island Dam. The time of capture extended over a longer period of time than in experiments 39 and 40; fish were taken from 25 June to 15 September, with a peak in the catch on 30 July.

Homing

The main purpose of experiments 39, 40, and 41 was to determine whether the adult steelhead trout would return to spawn to the stream where they had been released as juveniles. However, as reported above in the description of experiment 40, only one adult fish was recovered near a spawning area; it was taken in the Wenatchee River. This fish was not classified as a stray because it returned to the correct river system, the Wenatchee, and may have been on its way to the place of release, Icicle Creek.

Weight and Length Data and Age of Adult Fish

Weight and length data were collected from 53% of the steelhead trout that were recovered. The data collected is summarized in Table 16. Three-year-old males and females had an average weight of 8.8 pounds. The average weight of 4-year-old females was 9.6 pounds; 4-year-old males were heavier, averaging 10.4 pounds.

The steelhead trout that were recovered ranged in age from 3-7 years (Table 17); but, like the marked adults of the chinook and sockeye salmon experiments, 4-year-old fish were the most numerous. Of the 137 recoveries, 48.9% of the fish were 4-years old, and 43.8% were 3-years old.

Table 16.—Summary of weight and fork length data, by age of fish, for marked male and female steelhead trout.

Age (years)	Sex	No. fish	Aver. weight (pounds)	Aver. length (in)
3	Male	19	8.8	23.5
	Female	6	8.8	23.2
4	Male	15	10.4	30.5
	Female	33	9.6	21.6

Table 17.--Age of marked steelhead trout recovered in each experiment.

Experiment <sup>1/</sup>	Age (years)					Total
	3	4	5	6	7	
No. of fish						
39	4	19	0	1	4	28
40	36	30	0	0	5	71
41	20	18	-	-	-	38
Total	60	67	0	1	9	137
Percentage of total	43.8	48.9	0	0.7	6.6	

1/ Numbers designate experiments described in Table 15.

## DISCUSSION

## Sockeye Salmon

Transplantation

A total of eight experiments were carried out to determine whether sockeye salmon that had been reared in a hatchery and then released in an area other than the native stream of their parents would return to the area of release to spawn in numbers sufficient to maintain a run. In these experiments, 186,354 marked fingerlings were released into the Columbia River system and 1,653 were recovered in the system as adults; this was a percentage recovery of 0.89, which was above the average of 0.76% for all sockeye salmon experiments.

Two experiments using progeny of adults from Lake Quinault in western Washington were not successful in establishing runs to the upper Columbia River system, although a good return to the commercial fisheries was obtained in one of the experiments. In the first experiment, fingerlings were reared in the hatchery for 17 months and then released in the spring in the Entiat River. In the second experiment, fingerlings were reared in the hatchery for 24 months and then released in the fall in Icicle Creek. The results of these two experiments cannot be closely compared because nearly all of the fish that were being used for the second experiment died during their last 7 months of rearing in the hatchery, and those that did survive were in poor condition at the time of release. The return of adults from the 1,945 young that were released was 0.26%, which was far below the

average of 0.76% for all sockeye salmon experiments. In contrast, the fish of the first experiment returned at a rate of 1.11%.

Two experiments using progeny of adults taken at Bonneville Dam were not successful in establishing runs to Spirit Lake in the lower Columbia River region. Only 14 adults were recovered in the Columbia River system from a total release of 43,326 young, a percentage recovery of 0.03; and no adults were recovered or observed in Spirit Lake or its outlet, the Toutle River. In one experiment, fingerlings were reared in the hatchery for 14 months and then released in the lake in the fall, and, in the other experiment, fingerlings were reared in the hatchery for 18 months and then released in the lake in the spring. In addition to determining whether sockeye salmon runs could be established in Spirit Lake, the experiments were designed to evaluate the two different lengths of time that the fish were reared in the hatchery, 14 months in one experiment and 18 months in the other.

Three experiments using progeny of adults taken at Bonneville Dam were somewhat successful in establishing runs in the Little White Salmon River in the lower Columbia River region. In the first and third experiments, fingerlings were reared in the hatchery for 18 months and then released in the spring. In the second experiment, fingerlings were reared in the hatchery for 12 months and then released in the fall. A total of 70,618 young salmon were released into the river, and 894 returned as adults to the Columbia River system for a percentage return of

1.27%. The initial return to the Columbia River commercial fisheries was above average and fair numbers (148 out of 894, or 17%) returned to the Little White Salmon River. A relatively large number of returning adults were classified as strays. For example, 83 fish were recovered in the upper Columbia River, which is all but 4 of the total number of strays for all sockeye salmon experiments. In subsequent years, this run of sockeye salmon has all but disappeared from the Little White Salmon River, and we conclude that this area lacks suitable environment for the species.

In the eighth and final experiment, progeny of adults taken at Bonneville Dam were released below the outlet of Suttle Lake into Lake Creek, a tributary of the Metolius River in the Deschutes River system of Oregon. The return of adults to the Columbia River system was average, and 21% of the recovered fish were sexually precocious 3 year olds. Since only one fish returned to the Metolius River, this experiment was unsuccessful in establishing a run in the river.

#### Time and Place of Release

Ten experiments were conducted 1) to determine whether a better return could be expected by rearing sockeye salmon in hatcheries to 12 months of age and releasing them in the fall or by rearing them for 18 months and releasing them in the spring and 2) to compare the results of releases at different places. A total of 305,570 fingerlings were released into the Columbia River system and 2,608 were recovered in the system as adults, for a percentage return of 0.85 (Table 1). Of the 2,608 marked

fish that were recovered, 2,546, or 97.6%, were recovered by the commercial fisheries, and 62, or 2.4%, were recovered on the spawning grounds.

Results of the time of release part of these experiments are shown in Figure 8. The fall releases of Groups I, II, and III were more successful than the spring releases. However, the spring releases of Group IV and the lower river group were more successful than the fall releases--particularly for the lower river group. In summary, the best returns were usually obtained when the juveniles were released in the fall rather than in the following spring. In addition, diseases were a greater problem in the hatchery for the spring release fish than for the fall release fish; losses were often large during the 6 months of extra rearing.

Results of the place of release part of these experiments for Groups I, II, III, and IV indicated that the progeny of the adults that had been collected at Rock Island Dam could adjust to the environment at Lake Wenatchee and Lake Osoyoos and that these lakes have suitable habitat for the rearing of the young. The parents of some of these fish were part of runs that migrated to the Arrow Lakes, which are upstream of Grand Coulee Dam. Of the two lakes, a larger percentage of fish returned to Lake Wenatchee. There is a significant difference, based on a Chi-square test, favoring Lake Wenatchee over Lake Osoyoos. The data on the recoveries are summarized as follows:

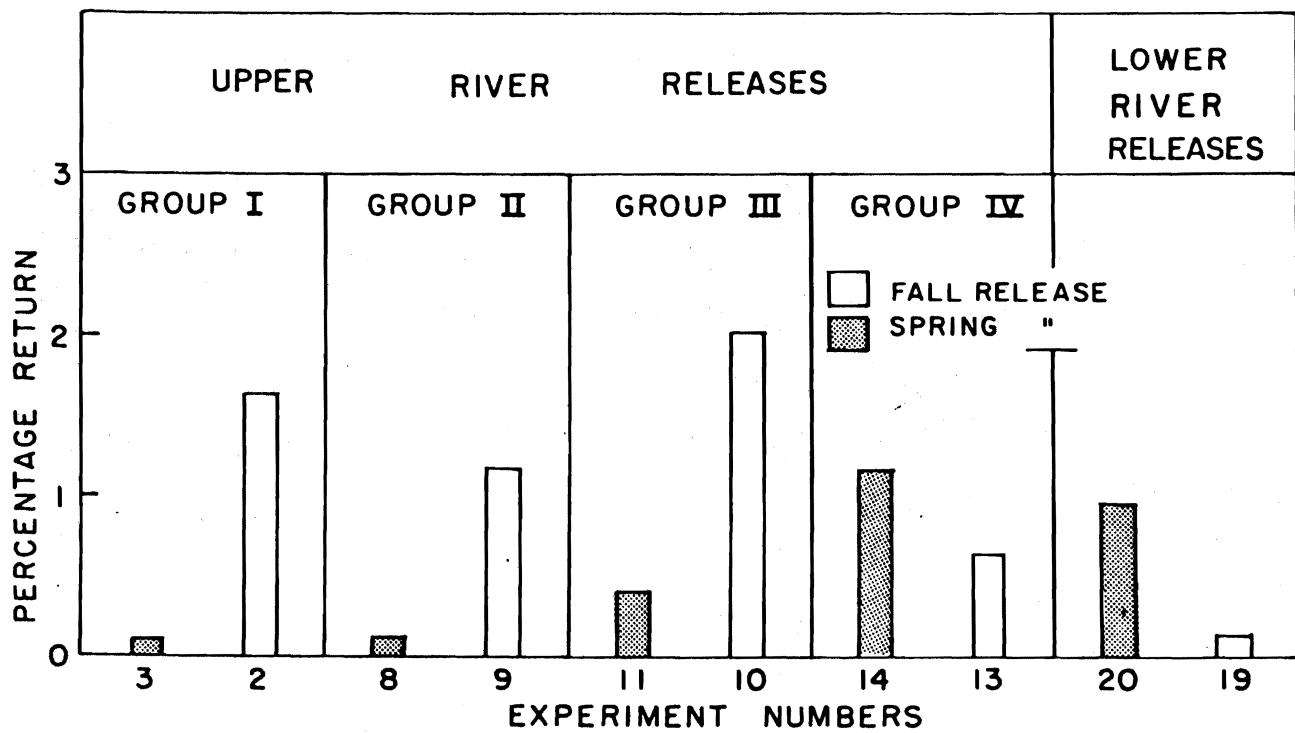


Figure 8.--Percentage of return to the Columbia River system of marked sockeye salmon that were released in the fall at an age of 12 months and in the spring at an age of 18 months.

Place	Number released	Number recovered	Percentage recovered	Number returned to rearing area
Osoyoos L.	140,168	1,309	0.93	23
Wenatchee L.	115,442	1,266	1.10	36

The releases made into Lake Wenatchee and Icicle Creek, experiments 4 and 5 (i.e., Group V), yielded few returns--6 adult fish in experiment 4 and 27 in experiment 5. The fish were reared for 18 months rather than for 12 months to compensate for the length of time that the fish of experiment 5 would have lived in a lake--lake habitat was not available for the fish released into Icicle Creek. Tested by Chi-square, there was a significant difference favoring the Icicle Creek release.

#### Kokanee

Three experiments were carried out to determine whether progeny of kokanee could be used to establish runs of sockeye salmon in the upper Columbia River region. In the first experiment, progeny of Lake Chelan kokanee were reared in the hatchery for 18 months and then released into the Entiat River. In the second experiment, progeny of Lake Wenatchee kokanee were reared in the hatchery for 18 months and then released into Icicle Creek; and, in the third experiment, progeny of Lake Wenatchee kokanee were reared in the hatchery for 12 months and then released into Lake Wenatchee.

The first experiment was not successful in establishing a

run in the Entiat River, only one fish returned as an adult sockeye salmon to the Columbia River system. However, perhaps it is possible to establish a run of sockeye salmon using progeny of Lake Chelan kokanee by modifying the experiment -- either by rearing them for a different length of time or by planting them in a different area.

The return of adult sockeye salmon from the second and third experiments was large enough to conclude that progeny of Lake Wenatchee kokanee could be used to establish a run. This was particularly true for the fish of the third experiment which had a percentage of return to the Columbia River system of 0.50%.

A question was raised on whether the Lake Wenatchee kokanee that were used in the second and third experiments were from a stock of residual sockeye salmon rather than a stock of kokanee. "Residuals" are defined as nonmigratory offspring of anadromous parents, while kokanee are offspring from nonmigratory parents. At any rate, there was a question as to whether the fish were far enough removed from seaward migratory behavior to be classified as kokanee. There is probably no way of determining the type of fish that were used in the second and third experiments.

Foerster (1947) reported that in the Fraser River system progeny of kokanee migrate from Cultus Lake and return from the ocean as adult sockeye salmon, and we believe that this type of migratory behavior may also be true for kokanee of the Columbia River system. For example, adult sockeye salmon are reported below Chief Joseph Dam on the Columbia River during the fall of some years. These fish are either strays from the Okanogan River

runs or are kokanee, which are known to descend the spill at Grand Coulee Dam, that migrated to the ocean and returned as sockeye salmon. Another observation favoring the theory that progeny of Columbia River kokanee migrate to the ocean and return as adult sockeye salmon is the report of adults in the Chelan River downstream of Lake Chelan. Adult sockeye salmon were observed below Chelan Dam by the powerhouse operators during the fall of some years. Of course, there is always the possibility of straying, but enough fish have been seen at different times to strongly support the belief that the adult sockeye salmon observed in the Chelan River below Chelan Dam and in the Columbia River below Chief Joseph Dam were progeny of kokanee.

It was previously mentioned that fork lengths of mature Lake Wenatchee kokanee range from 6 to 9 inches while fork lengths of mature sockeye salmon range from 14 to 23 inches. Would the average size of adult sockeye salmon from kokanee parents be smaller than the average size of adult sockeye salmon from anadromous parents? This question is probably answered by the data presented in Table 18; this table lists the average weights of adult fish recovered in the home stream and commercial fisheries for the two kokanee experiments and the two sockeye salmon experiments that had the greatest number of home stream recoveries with accompanying weight data. The average home stream weights of progeny of kokanee parents were 0.2 and 0.3 pounds less than the average home stream weights of the progeny of sockeye salmon, and the average commercial fishery weights of the progeny of kokanee parents were each 0.4 pounds less than the

Table 18.--Average weight of marked sockeye salmon, taken in home streams and in commercial fisheries, that had kokanee and sockeye parents.

Experiment <sup>1/</sup>	Parents	Home stream		Commercial fisheries	
		No. of fish	Aver. wt. (pounds)	No. of fish	Aver. wt. (pounds)
10	Sockeye	22	2.5	367	3.2
20	Sockeye	134	2.5	71	3.2
21	Kokanee	32	2.2	27	2.8
22	Kokanee	27	2.3	184	2.8

1/ Numbers designate experiments described in Table 1.

average commercial fishery weights of the progeny of sockeye salmon. In addition, most adult sockeye salmon that were recovered were 4-years old, and the average weights of the 4-year old males and females from kokanee parents were from 0.4 to 0.7 pounds less than the average weights of 4-year old males and females from sockeye parents (Tables 3 and 4). It is concluded from the experiments that adult sockeye salmon that had kokanee parents were slightly smaller than adult sockeye salmon that had anadromous parents.

#### Survival of Naturally Reared Sockeye Salmon

In the fall of 1939, adult sockeye salmon were hauled from the collection facility at Rock Island Dam and released into Lake Osoyoos. None were taken to hatcheries for their spawn because they were not sexually mature at the time of capture. These fish were probably a mixture of stocks from Lake Osoyoos, Lake Wenatchee, and the Arrow Lakes; and the downstream outlet of the lake was blocked with a rack to prevent the Lake Wenatchee and Arrow Lakes fish from leaving the system. The fish spawned in the tributaries of the lake and a few spawned in the lake itself. After hatching, their progeny fed in the lake until their seaward migration in the spring of 1941.

The original purpose of this experiment was to obtain information on the homing of the progeny of the mixture of stocks that had been released into the lake in 1939. However, we were not able to obtain information on the homing of these fish to the lake in the following years because nearly all of the recoveries returned as adults in 1943 when the Columbia River was still

blocked to adult salmon downstream at Rock Island Dam.

Results of the experiment, however, do provide information on the survival to adulthood of naturally reared sockeye salmon after their capture and marking as juveniles. Since the percentage of return of adults was 0.26%, which is well below the average return of 0.756%, it was concluded that the capture and marking operations led to considerable mortality. During capture and marking the water temperature was relatively high for juvenile sockeye salmon and probably stressful to the fish causing some mortality. In addition, the scales were easily dislodged while the fish were being captured in a beach seine and then handled during their marking, which may have injured the fish or led to some type of infectious disease.

#### Chinook Salmon

##### Time of Release

A total of eight experiments were conducted to determine whether a better return could be expected by 1) rearing chinook salmon in hatcheries to 1 year of age and releasing them in the fall or 2) by rearing them for 1-1/2 years and releasing them in the spring. In these experiments, a total of 301,554 fingerlings were released into either the Entiat or Methow Rivers of the upper Columbia River region, and 1,737 were recovered as adults in the Columbia River system--a return of 0.58% (Table 10). All of the fingerlings were progeny of adult fish from the upper Columbia River region that had been collected at Rock Island Dam and then hauled to hatcheries for their spawn. The parents of

the fingerlings in six of the eight experiments were summer run fish; the parents in the other two experiments were a mixture from summer and late spring runs.

Figure 9 shows the percentage recovery of adult chinook salmon for each experiment. The recovery for experiments with fish that were released in the fall at one year of age ranged from 0.06 to 0.81%, and the recovery for experiments with fish that were released in the spring at 1-1/2 years of age ranged from 0.98 to 1.95%. The fish released in the spring at 1-1/2 years of age yielded significantly better returns to the Columbia River system than the fish released in the fall at one year of age; and it was therefore concluded that spring was the preferable time of release for the chinook salmon of the Entiat and Methow Rivers.

#### Transplantation

Two experiments were performed to determine whether fingerling chinook salmon that had been reared in a hatchery and then released in an area other than the native stream of their parents would return to the area of release to spawn in numbers sufficient to maintain a run. Here, progeny of adults from two spawning areas, the McKenzie River and the Big White Salmon River, of the lower Columbia River region were reared at Leavenworth National Fish Hatchery on the upper Columbia and then released at one year of age into the hatchery's stream, Icicle Creek. The parents from the McKenzie River were spring run fish, and the parents from the Big White Salmon River were fall run fish. A total of 98,957 fingerlings were released into Icicle

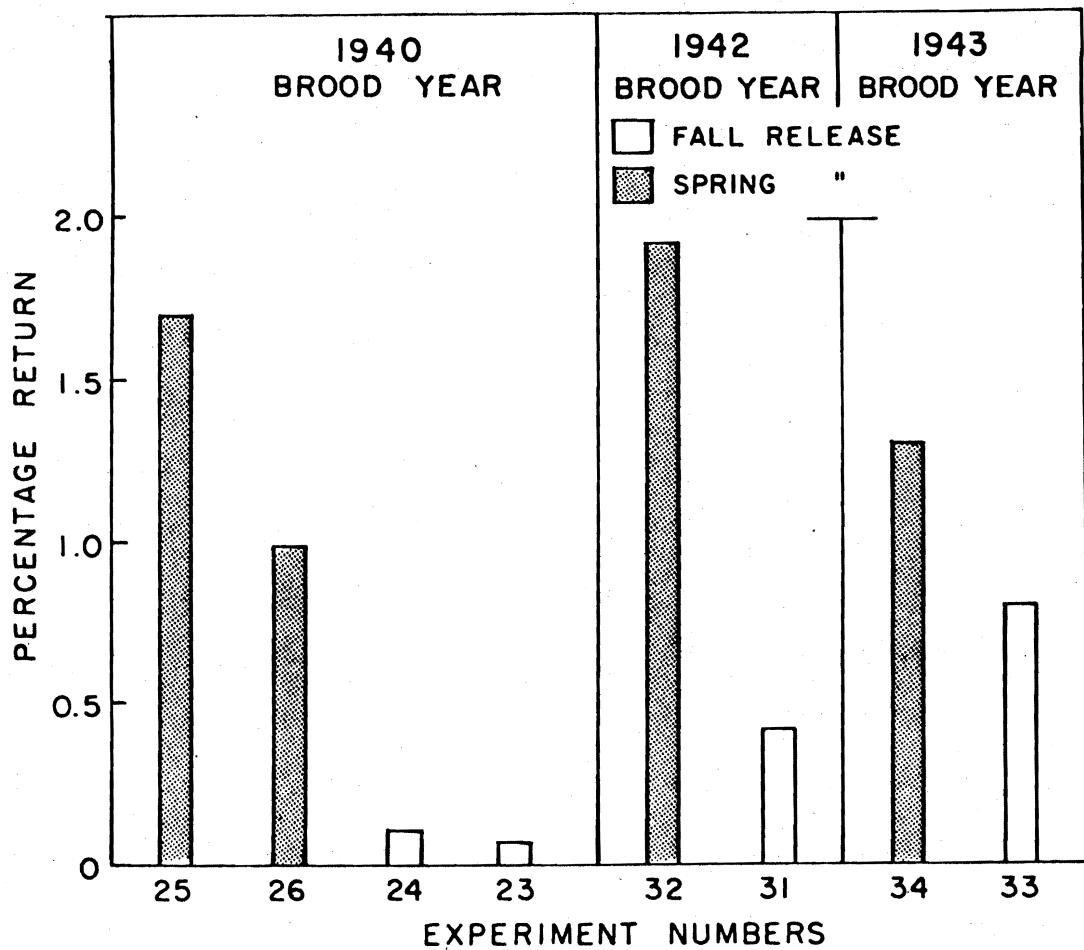


Figure 9.--Percentage of return to the Columbia River system of marked chinook salmon that were released in the fall at an age of 1 year and in the spring at age 1-1/2 years.

Creek, and 413 were recovered as adults in the Columbia River system, for a percentage recovery of 0.42 (Table 10).

The experiment with progeny of spring run adults from the McKenzie River was not successful in establishing a run in Icicle Creek. Only one adult fish was recovered in the creek, and the total return of adults to the Columbia River system from the 50,435 fingerlings that were released was only 45 fish, which was 0.09% of the number released--a percentage far below the average of 0.49% for the 12 chinook salmon experiments (Table 10).

The experiment with progeny of fall run adults from the Big White Salmon River was also not successful in establishing a run in Icicle Creek; no adult fish were recovered in the creek. The results of this experiment, however, differed considerably from the results of the previous experiment in that there was a good return of adult fish to the Columbia River commercial fisheries. For example, 48,522 fingerlings were released into Icicle Creek and 368 were recovered as adults by the commercial fisheries; this was a percentage recovery of 0.76. The relatively large catch by the commercial fisheries raises an important question on whether it is reasonable to assume that Icicle Creek was the destination of the intercepted fish. If Icicle Creek was indeed the destination of these fish, they probably would have returned to the creek in numbers sufficient to establish a run. In this particular experiment, it was not possible to answer the question on the destination of the fish because they were all caught in the lower reaches of the Columbia River far from Icicle Creek and the upper Columbia.

Homing

Two experiments were carried out to study the homing, and the extent of straying, of hatchery reared chinook salmon of the upper Columbia River region. In both experiments progeny of summer run adults that had been collected at Rock Island Dam were reared at Leavenworth National Fish Hatchery and then released at 18 months of age. In one experiment, 25,000 fingerlings were released into Icicle Creek, and, in the other, 25,000 were released into the Methow River.

Insufficient returns were obtained from these two experiments to draw any conclusions regarding homing, except to state that no marked adults were found straying. A total of 54 fish were recovered as adults, and they all were taken by the Columbia River commercial fisheries.

Information on homing can also be derived from the other marking experiments. Table 10, for example, shows that of the 2,204 adult fish recovered from all the chinook salmon marking experiments a total of 293 fish, or 13.3%, returned to the stream where they were released as young fish. Three, or 0.1%, strayed to tributaries other than their home streams; and the remaining 1,908 fish, or 86.6%, were recovered in the commercial fisheries. From these results, it was concluded that the marked chinook salmon exhibited a strong homing tendency to the stream in which they were released.

## Coho Salmon

Transplantation

Four experiments were conducted with coho salmon to determine whether stock from the lower Columbia River could be successfully transplanted to the Wenatchee River system. A total of 113,479 marked fingerlings were released into the Wenatchee River system, and 683 were recovered as adults in the Columbia River system, for a return to the Columbia of 0.60% (Table 13). The fingerlings were progeny of adult fish from the Lewis River, and they were reared at the Leavenworth National Fish Hatchery and then released into Icicle Creek, which is part of the Wenatchee River system.

The experiments were not successful in establishing a run in the Wenatchee River system; no marked fish were recovered as adults near the release site in Icicle Creek or in other parts of the Wenatchee River system. The return of adult fish to the Columbia River system, however, was good. For example, a total of 683 fish were taken by the commercial fisheries, mainly in the lower reaches of the river. The percentage recovery of the individual experiments ranged from 0.34 to 1.05%. Some of the recovered fish were taken upstream of the Lewis River, the spawning area of their parents; and, they like others intercepted by the commercial fisheries, may have been on their way to their release site.

Time of Release

The four coho salmon experiments discussed above were also carried out to determine whether a better return could be expected by 1) rearing fish in the hatchery to 12 months of age and releasing them in the fall or 2) by rearing them for 17 months and releasing them in the spring. The recovery of marked adults by the commercial fisheries demonstrated that greater returns were obtained by rearing fish in the hatchery to 17 months of age and releasing them in the spring than by rearing them for 12 months and releasing them in the fall. The percentage of recovery for the two experiments with 17 month old fish that were released in the spring was 0.64 and 1.05%, and the percentage of recovery for the two experiments with 12 month old fish that were released in the fall was 0.40 and 0.34%. Chi-square tests of data from these experiments show that there was a significant difference in the returns, favoring the 17 month old fish that were released in the spring.

## Steelhead Trout

Time of Recovery in Fresh Water

Three experiments were performed with steelhead trout to obtain information on the time of the year that the hatchery reared progeny of spring and fall run fish returned to the river as adults. A total of 75,000 marked fingerlings were released into either Icicle Creek or the Wenatchee River system or the Methow River, and 137 were recovered as adults in the Columbia River system--a return of 0.18%. All of the fingerlings were

progeny of adult fish from the upper Columbia River region that had been collected at Rock Island Dam in 1941 and then hauled to Leavenworth National Fish Hatchery for their spawn.

With the exception of one fish, all recoveries of marked adults from these three experiments were from commercial fisheries in the Columbia River below Rock Island Dam. Figure 10 shows the periods during which they were recovered by the commercial fisheries. Progeny of the fall run fish were recovered over a relatively long period, from 18 June to 17 September, but most of them were caught from early July to early August. Most of the progeny of the spring run fish were recovered during August.

The recovery data and information inferred from the degree of sexual maturity of steelhead trout at Rock Island Dam indicate that spring run fish enter the mouth of the Columbia River from the ocean during the summer and remain in the river below the dam until the following spring, at which time they migrate past the dam and proceed to the spawning grounds. The fall run fish also enter the Columbia River during the summer, but they migrate past the dam in the fall--rather than in the spring--and spend the winter in the river above the dam before proceeding to the spawning grounds in the spring.

#### Homing

The main purpose of the steelhead trout experiments was to determine whether the adult fish would return to spawn to the stream where they had been released as juveniles. It was impossible, however, to arrive at any conclusions regarding their

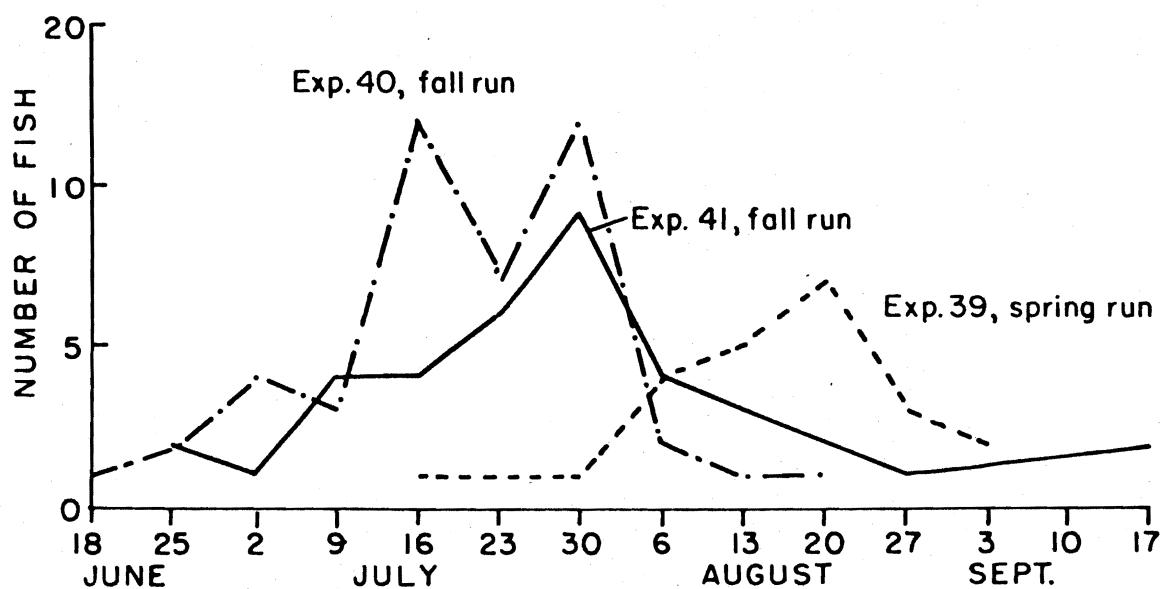


Figure 10.--Dates that marked steelhead trout were recovered in the Columbia River below Rock Island Dam.

homing because of the lack of recoveries from either the areas of release (i.e., Icicle Creek of the Wenatchee River system and the Methow River) or from other spawning areas to which the marked fish may have strayed. Only one adult fish was recovered near a spawning area; this fish was probably not a stray because it had been released as a fingerling in Icicle Creek and was recovered in the Wenatchee River. The other adult fish that were recovered were intercepted by commercial fisheries in the Columbia River below Rock Island Dam.

Loss of Marked Adult Fish in Spawning Areas and  
at Hatcheries

In experiments with marked fish, there are assumptions concerning the collection of data that are of great importance in the interpretation of results. The most important assumption is probably that all marked fish within the sampling area will be recovered. We know, however, that in this study there were circumstances that cast doubt on whether this assumption is totally reasonable. For example, personnel were not available to thoroughly search for marked adult fish in the vast spawning areas of the Columbia River system, as had been planned prior to World War II. In addition, James W. Mullan (Project Leader, Fisheries Assistance Office, U.S. Fish and Wildlife Service, Leavenworth, WA 98826. Pers. commun., March 1981) believes that it was possible in the years prior to 1953 for small marked sockeye salmon to pass through the bars of the rack at Entiat National Fish Hatchery and to continue to migrate, undetected, to

spawning areas upstream of the hatchery.

#### SUMMARY AND CONCLUSIONS

Construction of Grand Coulee Dam made extensive spawning grounds in the upper Columbia River inaccessible to valuable runs of salmon and steelhead trout. These runs were completely blocked by the dam in 1939 and it became necessary to transfer them to tributaries that entered the river downstream. During the years that the runs were being transplanted, experiments were performed to evaluate the success of these transfers and other transfers within the Columbia River system. Fish and Hanavan (1948) reported the results of some of these experiments, and we are reporting the results of others.

The major objective of this study was to obtain information of the survival and homing of fish that had been reared and released in areas other than the native stream of their parents. This information was obtained by clipping the fins of the juveniles for identification prior to their seaward migration and then recovering them as adults during their spawning migration in the Columbia River system. Forty-one experiments were carried out: 22 on sockeye salmon, 12 on chinook salmon, 4 on coho salmon, and 3 on steelhead trout. With the exception of one experiment on sockeye salmon, all of the juvenile fish were reared in hatcheries. A related objective of the study was to obtain information on the practice of artificial propagation to enhance the natural production of salmon and steelhead trout.

A total of 619,514 marked juvenile sockeye salmon were released and 4,685 adults were recovered for a percentage recovery of 0.76; 92% of the adults were taken by commercial fisheries, 6% were collected from the areas of their release, and 2% were taken from spawning areas other than the areas of release. The major findings of the sockeye salmon experiments were as follows.

1) Progeny of adults from Lake Quinault in western Washington were not successful in establishing runs to the Entiat River or Icicle Creek in the upper Columbia River region, although a very good recovery (1.11%) was obtained by the commercial fisheries from the release in the Entiat River.

2) Progeny of adults taken at Bonneville Dam were not successful in establishing runs to Spirit Lake in the lower Columbia River region.

3) Progeny of adults taken at Bonneville Dam were somewhat successful in establishing runs in the Little White Salmon River in the lower Columbia River region; however, an excellent recovery (2.94%) was made by the commercial fisheries in one of the experiments.

4) Progeny of adults taken at Bonneville Dam were not successful in establishing runs to Lake Creek, a tributary of the Metolius River in the Deschutes River system of Oregon, although a good recovery (0.52%) was obtained by the commercial fisheries.

5) Evidently progeny of adults taken at Rock Island Dam successfully adjusted to the environments of Lakes Wenatchee and Osoyoos in the upper Columbia River region because good

recoveries, mainly by the commercial fisheries, were obtained (1.10 and 0.93%, respectively).

6) The largest recoveries usually occurred when the juveniles were released from the hatchery in the fall at an age of 12 months rather than in the spring at an age of 18 months. In addition, diseases were a greater problem in the hatchery for the spring release fish than for the fall release fish; losses were often large during the 6 months of extra rearing. These results were particularly true for juveniles released in the upper Columbia River region. However, a spring release of juveniles in the Little White Salmon River of the lower Columbia River region was more successful than a fall release.

7) Progeny of kokanee from Lake Wenatchee that were released in Lake Wenatchee and Icicle Creek returned as adult sockeye salmon to the Columbia River.

8) In one experiment, wild juvenile fish (ie., fish that had not been reared in a hatchery) were captured with a beach seine at the outlet of Lake Osoyoos during their seaward migration. They were marked and released immediately after capture, and it was concluded that this type of capture and marking operation led to considerable mortality.

9) The ages of all recovered fish were known; 2.9% were 3-years old, 87% were 4-years old, 10% were 5-years old, and 0.10% were 6-years old.

10) Weight and length data were obtained from about 55% of the recovered fish. The average weight for 4-year old fish, which made up 87% of the recoveries, was 3.2 pounds for males and

3.1 for females; the average length of 4-year old fish was 20.2 inches for males and 19.8 inches for females.

11) Data on sex of fish were obtained from 81% of the recoveries; the sex ratio was 1 male to 1 female.

A total of 450,511 marked juvenile chinook salmon were released and 2,204 were recovered as adults for a percentage recovery of 0.49. Eighty-seven percent of these adults were taken by commercial fisheries and 13% were collected from the areas of their release. Only three adults were taken from spawning areas other than the areas of release. The major findings of the chinook salmon experiments were as follows.

1) Progeny of spring run adults from the McKenzie River and fall run adults from the Big White Salmon River (both rivers are in the lower Columbia River region) were not successful in establishing runs to Icicle Creek, although a very good recovery (0.76%) was made by the commercial fisheries from the release of progeny of Big White Salmon River adults which were also unsuccessful in establishing runs to Icicle Creek.

2) The largest recoveries occurred when juveniles, mainly progeny of summer run adults taken at Rock Island Dam, were released from the hatchery (ie., into the Entiat and Methow Rivers) in the spring at 1-1/2 years of age rather than in the fall at one year of age.

3) Fish, mainly progeny of summer run adults taken at Rock Island Dam, exhibited a strong homing tendency to the stream in the upper Columbia River region into which they were released.

4) The ages of all recovered fish were known: 17% were

3-years old, 46% were 4-years old, 34% were 5-years old, and 3% were 6-years old. One 2-year old fish and one 7-year old fish were also found.

5) Weight and length data were obtained from about 50% of the recovered fish. The average weight for 4-year old males was 14.2 pounds and of 4-year old females was 13.9 pounds; the average for 5-year old males was 22.1 pounds and of 5-year old females was 18.7 pounds. The average length for 4-year old males was 29.8 inches and of 4-year old females was 30.2 inches; the average for 5-year old males was 34.2 inches and of 5-year old females was 33.2 inches.

6) Data on sex of fish were obtained from 98% of the recoveries; the sex ratio was 1 male to 0.7 females. The younger age groups (ages 3 and 4) had more males than females; the older age groups (ages 5 and 6) had more females than males.

A total of 113,479 marked juvenile coho salmon were released and 683 were recovered as adults for a percentage recovery of 0.60. Detailed recovery data was only available for 319 of the 683 adult fish; all of the 319 fish were taken by commercial fisheries. The major findings of the coho salmon experiments were as follows.

1) Progeny of adults from the Lewis River in the lower Columbia River region were not successful in establishing runs to Icicle Creek, although good recoveries (1.05 and 0.64%) were obtained by the commercial fisheries in two of the four experiments.

2) The largest recoveries occurred when the juveniles were

released from the hatchery in the spring at an age of 17 months rather than in the fall at an age of 12 months.

3) The ages of all recovered fish were known. All but 2 of the 683 marked coho salmon were 3-year old fish; the two exceptions were 2-year olds that were caught in the ocean.

4) Weight and length data were obtained from 31% of the recovered fish. The average weight for the 3-year old fish was 9.3 pounds for males and 9.6 pounds for females. The average length of the 3-year old fish was 26.3 inches for males and 27.0 inches for females.

5) Data on sex of fish were also obtained from 31% of the recovered fish; the sex ratio was 1 male to 0.7 females.

Of 75,000 marked juvenile steelhead trout released, 137 adults were recovered for a percentage recovery of 0.18. With the exception of one fish, which was collected near the area of release, all of the recovered adults were taken by commercial fisheries. The major findings of the steelhead trout experiments were as follows.

1) Progeny of summer and fall run adults taken at Rock Island Dam were not successful in establishing runs to Icicle Creek, although a good recovery (0.28%) was obtained by the commercial fisheries from the release of progeny of fall run fish.

2) Progeny of fall run adults taken at Rock Island Dam were not successful in establishing runs to the Methow River in the upper Columbia River region.

3) Progeny of the spring run fish migrated as adults from

the ocean into the Columbia River from the middle of July to early September, and they remained in the lower Columbia River below Rock Island Dam until early spring before proceeding to their spawning grounds. On the other hand, progeny of fall run fish started to leave the ocean in the middle of June, proceeding up the Columbia River and passing over Rock Island Dam from early July through September. They remained in the main Columbia River until spring, when they proceeded into the tributaries to spawn. The fall run fish were not sexually mature when they reached Rock Island Dam in contrast to the almost-mature spring run fish.

4) The ages of all recovered fish were known; 43.8% were 3-years old, 48.9% were 4-years old, and 6.6% were 7-years old. One 6-year old fish was also found.

5) Weight and length data were obtained from 53% of the recovered steelhead trout (ie., only 73 fish). The average weight for 3-year old males and females was 8.8 pounds. The average weight for 4-year old females was 9.6 pounds and for 4-year old males was 10.4 pounds. The average length for 3-year old males was 23.5 inches and for 3-year old females 23.2 inches; the average length for 4-year old males was 30.5 inches and for 4-year old females was 21.6 inches.

6) Data on sex of fish were also obtained from 53% of the recovered fish; the sex ratio was 1 male to 1.2 females.

It is possible that some marked salmon and steelhead trout were not recovered in the spawning areas and at the Entiat National Fish Hatchery. We cannot accurately assess this loss of marked fish; but, in the case of the Entiat National Fish

Hatchery, the loss of small marked sockeye salmon may have been considerable.

#### ACKNOWLEDGMENTS

We wish to acknowledge the assistance given during the marking experiments by employees of the U.S. Fish and Wildlife Service, the Fish Commission of Oregon, and the Washington Department of Fisheries. We are grateful for the help that personnel of the Columbia River salmon canneries gave in recovery of marked fish and collection of scales and data. The senior author also wishes to thank Mitchell G. Hanavan for his leadership during the experiments.

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