EMIGRATION OF JUVENILE SALMON AND TROUT FROM BROWNLEE RESERVOIR, 1963–65

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ABSTRACT

Floating scoop traps below Brownlee Dam captured samples of marked and unmarked salmon and trout that had left the impoundment from July 1963 through August 1965; estimates of emigration were based on these samples.

Success of passage varied among years and populations and was affected by the environment in the reservoir during outmigration. Downstream migrants that entered the reservoir early in the season were more successful than those that entered later. Emigration was also more successful when the reservoir level was low.

Brownlee Reservoir was chosen for an extensive research program by BCF (Bureau of Commercial Fisheries) to determine how a large impoundment affects the passage of salmon and trout. The research, begun in the spring of 1962, consisted of five studies: (1) limnology of the reservoir system (Ebel and Koski, 1968); (2) upstream migration of adult chinook salmon (*Oncorhynchus tshawytscha*) through the reservoir (Trefethen and Sutherland, 1968); (3) migration of juvenile salmon and trout into the reservoir (Krcma and Raleigh, 1970); (4) distribution and movement of juvenile salmon in the reservoir (Durkin, Park, and Raleigh, 1970); and (5) migration of juvenile salmon and trout from the reservoir (the present report).

Brownlee Reservoir, on the middle Snake River, lies at the southern end of Hells Canyon along the border between northeast Oregon and western Idaho. The reservoir is about 92 km. long and averages slightly less than 800 m. wide. Brownlee Dam (constructed by the Idaho Power Company) is a high-head structure, the primary function of which is hydroelectric power production. It is 396 m. wide on the top, has a single spillway and four Francis turbines with vertical shafts, and creates 83 m. of head at full pool. The dam discharges directly into Oxbow Reservoir, formed by Oxbow Dam about 19 km. downstream.

In an attempt to provide facilities for the passage of juvenile salmon and trout past Brownlee Dam, the Idaho Power Company installed a fingerling-collection system in 1959 in the forebay of the reservoir about 3 km. downstream from the dam (Soule, Heikes, Mitchell, and Schaufelberger, 1959). The system, consisting of a shore-to-shore barrier net and surface collection traps, proved only partly successful.[1] Many fingerlings passed under or through the barrier net and left the reservoir via the turbines or spillway. Idaho Power Company removed the system in February 1964, after which all fish that left the reservoir passed through the turbines or spillway.

Native populations of anadromous salmon and trout affected by Brownlee Reservoir include fall- and spring-run chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*). Before the construction of Brownlee Dam in 1958, the largest population was fall-run chinook salmon, which spawned in the Snake River upstream from what is now the upper end of Brownlee Reservoir. The Fish Commission of Oregon estimated annual fall chinook salmon spawning runs of as many as 20,000 fish in the late 1950's. By 1963 this population was greatly reduced. Before 1963, spring-run chinook salmon spawned in the Weiser River (a tributary of the Snake River above the head of the reservoir) and in Eagle Creek (a tributary of the Powder River, which enters near the lower end of the reservoir). Steelhead trout were native to Weiser River and Eagle Creek as well as several

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[1] Graben, James E. 1964. Evaluation of fish facilities, Brownlee and Oxbow Dams, Snake River. Idaho Department of Fish and Game, Boise, Idaho, 60 pp. (Processed.)

streams above Brownlee Dam. Several impoundments in the Snake River system above Brownlee Reservoir support populations of kokanee (*O. nerka*); these fish periodically move into the Brownlee area.

After the decline of the native runs, hatchery-reared chinook, coho (*O. kisutch*), and sockeye salmon were released in the Snake River above Brownlee Reservoir by the BCF in 1964 and 1965 to provide additional fish for study.

The study on the passage of juvenile salmon and trout from Brownlee Reservoir began in July 1963 and continued through the summer of 1965. I report here the number and size of emigrants and the time of emigration.

TECHNIQUES OF SAMPLING AND ANALYSIS

The sampling area (fig. 1) was immediately below Brownlee Dam. About 180 m. below the powerhouse the turbine tailrace channel enters the original river channel, which carries the intermittent discharges from the spillway of the dam. The Interstate Bridge crosses Oxbow Reservoir about 600 m. downstream from the dam. At that point, the reservoir is about 160 m. wide and 3.5 m. deep at midchannel when Oxbow Reservoir is at full pool.

The primary sampling site was in the turbine tailrace, about 150 m. below the powerhouse. The turbine tailrace is about 76 m. wide; the water is about 4 m. to 7 m. deep, depending on the level of Oxbow Reservoir and the discharge from Brownlee Dam. Because fish that passed over the spillway could not be sampled at the tailrace site, an additional sampling site was established downstream at the Interstate Bridge for use during periods of spillway operation.

The analyses of the data involved an evaluation of (1) equipment, (2) procedures, (3) tests of sampling efficiency, and (4) methods of computing emigration.

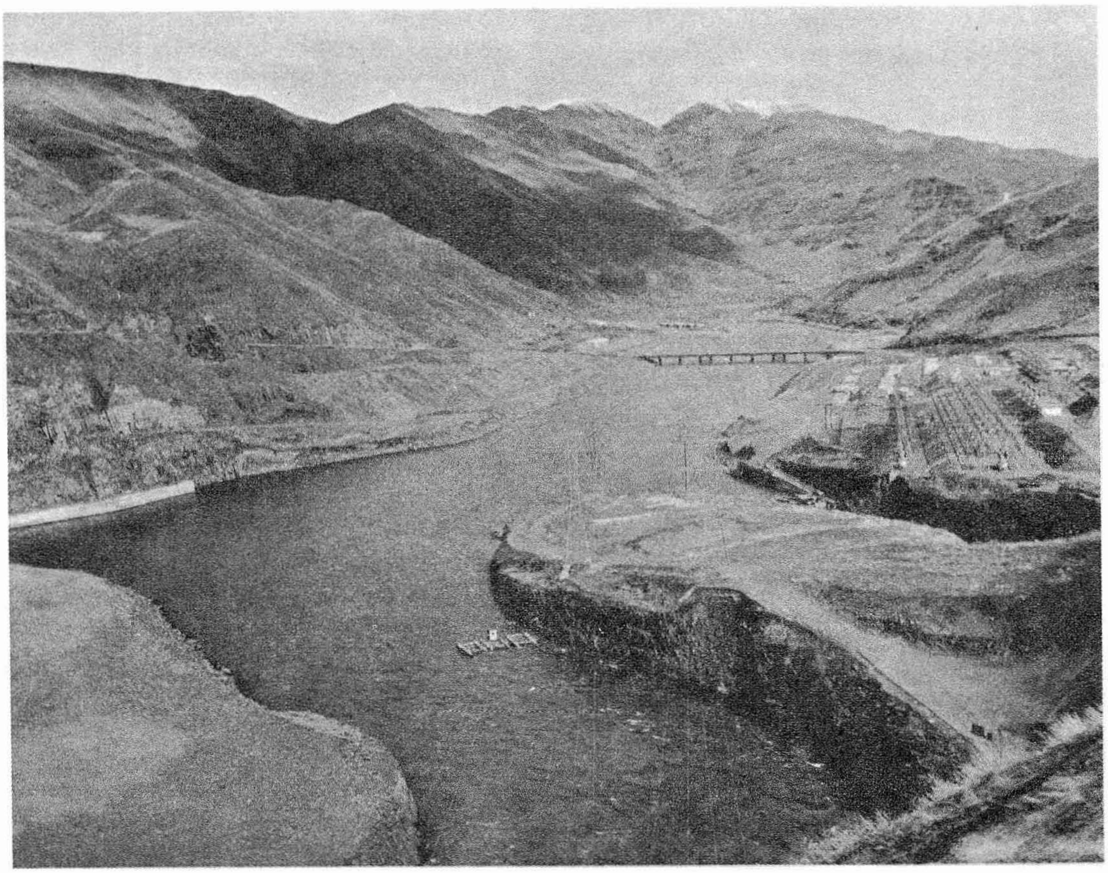

FIGURE 1.—Turbine tailrace (foreground) at Brownlee Dam with scoop traps in position below right bank. Spillway (not in operation in this photo) enters original river channel on extreme left.

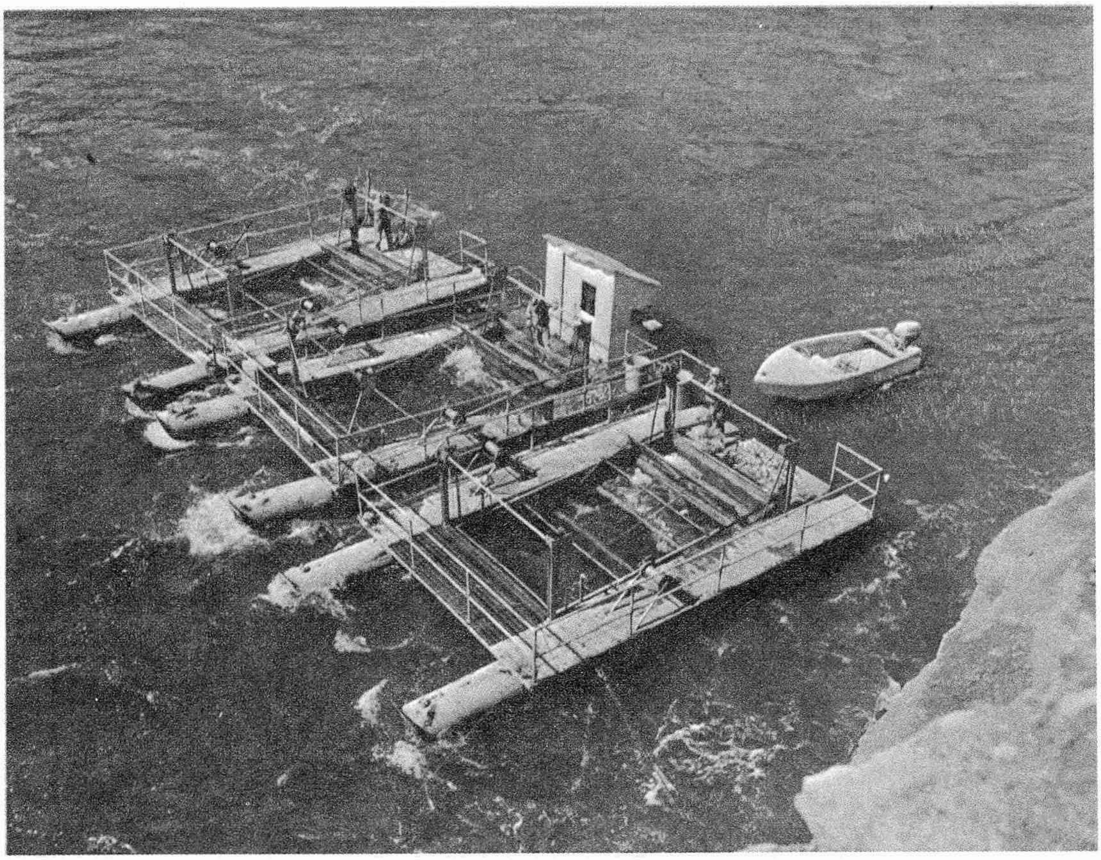

FIGURE 2.—Scoop traps in operation in the turbine tailrace.

EQUIPMENT

Three scoop traps (fig. 2) were used to collect juvenile migrants.[2] Each trap was 3.0 m. wide by 3.2 m. long and fished at a depth of 1.2 m. A pontoon-type barge, 5.5 m. by 7.5 m., supported the individual traps and winch equipment. In the turbine tailrace, the traps were close to the right (Idaho) bank. At the Interstate Bridge, one trap was in the center of the channel and the other two were about 30 m. from the right and left banks.

PROCEDURES

The traps were emptied of fish and cleared of debris at 8 a.m. and 4 p.m. Additional checks were made at noon and at midnight during peak outmigration and at any time that excessive debris accumulated. During special studies, the traps were emptied of fish and debris at intervals of 1, 4, and 6 hours.

[2] Bell, Robert. 1959. Time, size, and estimated numbers of seaward migrations of chinook salmon and steelhead trout in the Brownlee-Oxbow section of the middle Snake River. Idaho Department of Fish and Game, Boise, Idaho, 34 pp. (Processed.)

All salmon and trout were identified, examined for marks or tags, and measured for fork and standard length. All live salmon and trout were anesthetized before examination and then were released unless needed for special studies. Scale samples were taken from dead and injured fish when possible.

TESTS OF TRAP EFFICIENCIES

Fish marked by partial fin clip, tattoo, or thermal brand were used to evaluate the efficiency of the scoop traps at both sampling sites. Hatchery-reared juveniles were used for marking in all years, except in 1964 when a few tests were made with native age-group I spring and fall chinook salmon from scoop trap catches. Hatchery-reared age-group 0 chinook salmon were used in 1964 and 1965, age-group I coho salmon in 1964, and sockeye salmon in 1965.

Tests at the Interstate Bridge required that test fish be released into the spillway and into the turbine penstocks; tests at the turbine tailrace site required releases only into the penstocks. Penstock releases were made by pumping the test fish down the penstock air vent through a 76-mm. hose.

In 1964, about 1,570 hatchery-reared juvenile chinook salmon and an equal number of juvenile coho salmon were released into the spillway and turbine penstocks to determine efficiency of the traps at the Interstate Bridge (table 1). Fifteen chinook and 15 coho salmon were recaptured, (0.95-percent return for each species). Trapping efficiency for chinook salmon was slightly higher in 1965 when 1,171 hatchery-reared test fish were released and 15 fish (1.28 percent) were recaptured (table 2). Recovery efficiency of the traps for hatchery-reared sockeye salmon fingerlings released in 1965 was significantly higher than for chinook salmon; 2,670 test sockeye salmon were released and 71 (2.66 percent) were recaptured at the bridge site (table 3).

The scoop traps were more efficient in the turbine tailrace than at the Interstate Bridge. In 1964–65, 8,471 test fish (hatchery-reared juvenile chinook, coho, and sockeye salmon) were released into the various turbine penstocks for recovery in the turbine tailrace. Differences in average recovery between years and among species were so slight that the data were combined. Recoveries for daylight releases (8:00 a.m. to 4:00 p.m.) were 0.5 to 7.5 percent and averaged 4.1 percent (table 4). Recaptures of fish from night releases (4:00 p.m. through 8:00 a.m.) were 4.5 to 29.7 percent and averaged 11.3 percent (table 5).

METHODS OF COMPUTING EMIGRATION

Estimates of emigration were based on live and dead fish caught in the scoop traps. Identity of the various populations was determined from fish that had been marked in the tributary drainages and subsequently recovered in the scoop traps. Length-frequency data and scale samples were also used to determine the origin of different populations of fish emigrating at various times of the year.

Estimates of emigration during periods of sampling at the Interstate Bridge were computed with the general formula (Chapman, 1948):

$$N_1 = \frac{C(M+1)}{(R+1)} \qquad (1)$$

where

N=population estimate
C=sample size
M=number of marks
R=marked recaptures in C

TABLE 1.—*Numbers of marked juvenile chinook and coho salmon recovered in scoop traps at the Interstate Bridge after release in the spillway (S) or turbines (T) of Brownlee Dam, April 24 to June 30, 1964*

Date (1964)	Fish released	Release site	Average spill	Fish recovered	
	Number		*(M.³/sec.)*	*Number*	*Percent*
April:					
24	101	S	177	1	0.99
25	100	S	185	1	1.00
26	103	S	279	1	.97
27	95	S	405	0	.00
28	100	S	458	0	.00
29	100	S	452	1	1.00
May:					
7	106	S	548	4	3.77
7	89	T	548	4	4.49
8	100	S	642	0	.00
8	100	T	642	1	1.00
15	100	T	510	0	.00
16	100	T	510	2	2.00
20	102	S	579	1	.98
20	100	T	579	0	.00
21	116	T	551	2	1.72
27	106	T	0	1	.94
June:					
11	79	S	332	1	1.27
14	179	S	708	1	.56
15	189	S	737	2	1.06
16	200	S	795	2	1.00
16	200	T	795	1	.50
17	100	T	978	0	.00
18	100	T	1,100	1	1.00
19	100	T	1,136	1	1.00
23	100	S	1,189	0	.00
24	100	S	1,137	1	1.00
25	100	S	961	1	1.00
30	100	S	170	0	.00
Total	3,165			30	.95

TABLE 2.—*Numbers of marked juvenile chinook salmon recovered in scoop traps at the Interstate Bridge after release in the spillway (S) or turbines (T) of Brownlee Dam, April 9 to May 20, 1965*

Date (1965)	Fish released	Release site	Average spill	Fish recovered	
	Number		*(M.³/sec.)*	*Number*	*Percent*
April:					
9	160	S	409	1	0.6
13	102	T	566	2	2.0
13	121	S	566	0	.0
15	107	S	512	2	1.9
21	122	T	1,338	1	.8
25	154	T	1,557	2	1.3
May:					
14	101	S	958	1	1.0
14	106	T	958	2	1.9
20	101	S	622	3	3.0
20	97	T	622	1	1.0
Total	1,171			15	1.28

To compensate for the variation in efficiency of traps in the turbine tailrace, I computed emigration during periods of sampling at that site with an alternate method:

$$N_2 = \frac{\text{trap catch}}{\text{percentage of efficiency}} \qquad (2)$$

Upper and lower limits were computed for estimates of emigration at both sampling sites. For estimates based on sampling at the Interstate

TABLE 3.—*Numbers of marked juvenile sockeye salmon recovered in scoop traps at the Interstate Bridge after release in the spillway (S) or turbines (T) of Brownlee Dam, March 31 to May 15, 1965*

Date (1965)	Fish released	Release site	Average spill	Fish recovered	
	Number		*(M.³/sec.)*	*Number*	*Percent*
March:					
31	241	T	487	6	2.5
April:					
1	95	S	459	2	2.1
2	109	T	425	2	1.8
5	177	S	448	4	2.3
5	275	T	448	8	2.9
6	140	S	519	2	1.4
7	211	T	338	4	1.9
8	238	S	357	5	2.1
9	102	T	409	5	4.9
10	218	S	510	4	1.8
10	103	T	510	3	2.9
11	124	S	511	6	4.8
12	180	S	499	2	1.1
14	110	T	448	4	3.6
15	140	S	511	5	3.6
May:					
15	207	S	511	9	4.3
Total	2,670			71	2.66

TABLE 4.—*Numbers of marked juvenile salmon (chinook, coho, and sockeye) recovered in scoop traps in the Brownlee Dam tailrace between 8 a.m. and 4 p.m., 1964–65*

Date	Total fish released	Number released at turbine number				Turbine discharge	Fish recovered	
		1	2	3	4			
	Number	*Number of fish*				*(M.³/sec.)*	*Number*	*Percent*
1964:								
July 3	200	100			100	618	5	2.5
July 3	200	100			100	612	7	3.5
July 4	200	100			100	439	14	7.0
July 4	200	100			100	448	7	3.5
July 5	200	100			100	379	6	3.0
July 5	200	100			100	399	1	.5
July 5	200	100			100	375	3	1.5
July 7	200		100	100		387	15	7.5
July 7	200		100	100		443	10	5.0
July 7	200		100	100		417	10	5.0
July 8	200		100	100		536	9	4.5
1965:								
June 5	350	96	99	76	79	472	13	3.7
June 5	371	99	100	79	93	472	17	4.6
June 6	392	106	99	87	100	409	22	5.6
June 7	384	95	92	105	92	547	12	3.1
Total	3,697	1,096	790	747	1,064		151	4.11

Bridge, these limits represent the 95-percent confidence limits as computed by Chapman's formula:

$$\overline{m}, \underline{m} = R + \frac{1.96^2}{2} \pm 1.96\sqrt{R + \frac{1.96^2}{4}} \qquad (3)$$

where

$\overline{m}$ and $\underline{m}$ are the upper and lower values of R, respectively.

Upper and lower estimates at the turbine tailrace site were based on the 95-percent confidence interval of the means of the frequency distributions in the respective day-night tests of efficiency (Wilkes, 1948). These values were computed according to the formula:

$$u = \overline{X} \pm t_a \frac{s}{n}$$

where

u = population mean
$\overline{X}$ = sample mean
t_a = confidence coefficient
s = standard deviation
n = number of tests

TABLE 5.—*Numbers of marked juvenile salmon (chinook, coho, and sockeye) recovered in scoop traps in the Brownlee Dam tailrace between 4 p.m. and 8 a.m., 1964–65*

Date	Total fish released	Number released at turbine number				Turbine discharge	Fish recovered	
		1	2	3	4			
	Number	*Number of fish*				*(M.³/sec.)*	*Number*	*Percent*
1964:								
July 3	200	100			100	577	10	5.0
July 4	200	100			100	378	9	4.5
July 5	200	100			100	349	13	6.5
July 7	100			100		364	7	7.0
July 11	300	100	100	100		268	25	8.3
July 11	300	100		100	100	263	26	8.7
July 12	200	100		100		228	34	17.0
July 12	200		100	100		294	34	17.0
July 14	200	100		100		301	15	7.5
July 15	100	100				84	6	6.0
July 15	300	100		100	100	343	27	9.0
July 15	200			100	100	214	28	14.0
July 16	300		100	100	100	339	89	29.7
July 17	200	100		100		303	12	6.0
July 18	300		100	100	100	408	34	11.3
1965:								
June 5	409	110	100	99	100	553	36	8.8
June 5	364	61	99	99	105	168	54	14.8
June 6	381	94	96	101	90	159	52	13.6
June 7	320	98	98	59	65	358	30	9.4
Total	4,774	1,363	793	1,458	1,160		541	11.33

Estimates of annual emigration were based on scoop trap catches from May 1963 through August 1965 (table 6). No tests of efficiency of scoop traps were made in 1963; therefore, estimates of emigration for that year were based on efficiency tests in 1964. In the estimates of emigration, catches by the Idaho Power Company barrier net in 1964 were also included. Estimates of immigration used to compare with estimates of emigration were from Krcma and Raleigh (1970).

ESTIMATES OF EMIGRATION

EMIGRATION OF NATIVE SALMON

The migration of juvenile salmon and trout from Brownlee Reservoir included three native and three hatchery-reared salmon populations and a trout population of unknown origin. Estimates of emigration were made for each population.

Native juvenile salmon migrating through Brownlee Reservoir included fall chinook salmon and kokanee from the Snake River and spring chinook salmon from Eagle Creek and the Weiser River.

TABLE 6.—*Catches of juvenile salmon and rainbow-steelhead trout by scoop traps below Brownlee Dam, May 1, 1963 to August 31, 1965* [1]

Date (year and month)	Chinook salmon	Coho salmon	Sockeye salmon	Kokanee salmon	Rainbow-steelhead trout
1963:	*Number*	*Number*	*Number*	*Number*	*Number*
May	2				
June	194				
July	62				
August	82				13
September	16				1
October	8				1
November	49				1
December	101				
1964:					
January	247				14
February	273				11
March	370				28
April	885				114
May	505	256			79
June	621	262		2	76
July	56	124		11	51
August	114	84		90	32
September	25	3		2	3
October	7			1	4
November	8				4
December	2				3
1965:					
January	2				2
February	2				
March	14		2,214		9
April	2,198		8,162		338
May	900		8		392
June	1,802			80	142
July	111			193	34
August	208			3,077	128
Total	8,864	729	10,384	3,456	1,480

[1] Catches by scoop trap reported by Graben, 1964 (see text footnote 1).

Fall Chinook Salmon

An estimated 54,800 native fall chinook salmon from the Snake River left the reservoir in 1963 as age-group 0 and in 1964 as age-group I (table 7). Of these fish, 2,700 were captured by the Idaho Power Company barrier net in the forebay of the reservoir and transported below Oxbow Dam and released. Total emigration of the 1963 year class was about 15 percent of established immigration to the reservoir (table 7).

Age-group-0 fish from the 1963 year class first appeared in the scoop traps below the dam in May 1963 (fig. 3); peak migration was in June. Except for one period in 1963 (late September to early October), some fish moved past the dam throughout the summer and fall. About 75 percent of age-group I fish in 1964 (1963 year class) left the reservoir in late January; a second peak appeared in early April.

Spring Chinook Salmon

Emigration of juvenile spring chinook salmon of the 1963 year class was 5,900 fish or about 16 percent of the estimated immigration from the Weiser River and Eagle Creek to the reservoir (table 8). A small number from Eagle Creek began

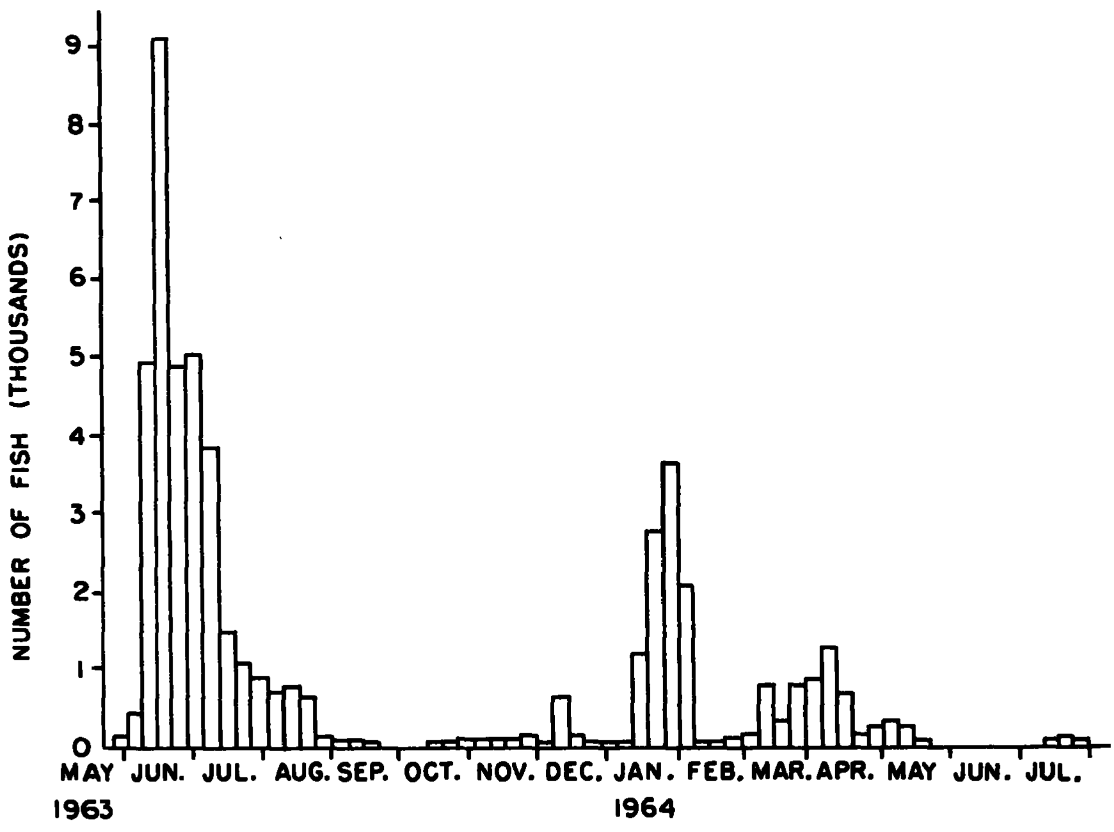

FIGURE 3.—Estimated emigration from Brownlee Reservoir of juvenile native fall chinook salmon (1963 year class), from the Snake River, May 1963 to August 1964.

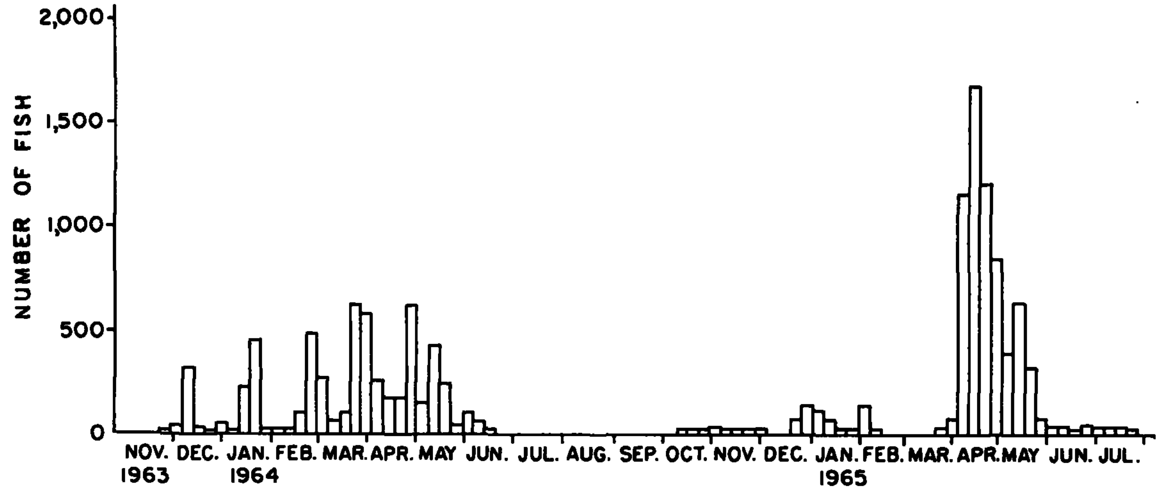

FIGURE 4.—Estimated emigration from Brownlee Reservoir of juvenile native spring chinook salmon from Eagle Creek and Weiser River, November 1963 to July 1965.

TABLE 7.—*Estimated immigration of juvenile native fall chinook salmon into Brownlee Reservoir from the Snake River and estimated emigration from the Reservoir, May 1, 1963 to August 1964 (all fish of 1963 year class)*

Estimated immigration	Years of emigration	Estimated emigration		Range of estimated emigration	
				Low	High
Number		*Number*	*Percent*	*Number*	*Number*
374,000	1963-64	[1] 54,800	15	39,600	72,500

[1] Includes 2,700 fish captured at the Idaho Power Company barrier net.

to leave the reservoir as age-group 0 fish in November 1963, and the emigration continued through June 1964 (fig. 4). Distinction between fish from the Weiser River and those from Eagle Creek was not always possible, but knowledge of the age of fish at the time of downstream migration to the reservoir provided a basis for their identification at certain times of the year. Krcma and Raleigh (1970) have shown that fish from the Weiser River do not enter the reservoir until spring 1 year after hatching, whereas fish from Eagle Creek enter at age 0 in the fall and again as age-group I in the spring. Spring chinook salmon that left the reservoir in the fall, winter, and early spring, therefore, were probably from Eagle Creek; fish leaving later in the spring and in early summer could be from either the Weiser River or Eagle Creek.

The emigration of the 1964 year class of spring chinook salmon was estimated at 14,000 fish, 51 percent of estimated immigration. Most of these fish were from Eagle Creek. Additional catches of juvenile migrants from Eagle Creek were made in the stream, transported downstream below Oxbow Dam, and released (Krcma and Raleigh, 1970). Juvenile spring chinook salmon that entered the reservoir in late March and early April 1964 migrated rapidly through the impoundment. Peak emigration was in mid-April, and the migration ended in late July (fig. 4).

Kokanee

The origin of, or reasons for, some migrations of juvenile kokanee into Brownlee Reservoir are not completely understood, but most fish observed during the present study were probably from the Payette River system (Payette Lakes and Cascade and Deadwood Reservoirs). Kokanee periodically migrate however, and rather large numbers of fingerlings entered Brownlee Reservoir in 1964

TABLE 8.—*Estimated immigration of juvenile native spring chinook salmon into Brownlee Reservoir from Eagle Creek and the Weiser River and estimated emigration from the Reservoir, November 1, 1963 to August 1965*

Year class	Estimated immigration			Years of emigration	Estimated emigration		Range of estimated emigration	
	Weiser River	Eagle Creek	Total				Low	High
	Number	*Number*	*Number*		*Number*	*Percent*	*Number*	*Number*
1963	15,000	22,300	37,300	1963-64	5,900	16	4,700	8,500
1964	6,800	7,200	14,000	1964-65	7,200	51	4,500	11,300

and 1965. In 1964, 2,100 kokanee fingerlings (1963 year class) were estimated to have left the reservoir, representing about 38 percent of the estimated recruitment to the reservoir (table 9). The outmigration started during the latter part of June 1964, reached a peak in early August, and ended by the first week in September.

TABLE 9.—*Estimated immigration of juvenile kokanee into Brownlee Reservoir from the Snake River system and estimated emigration from the Reservoir, May 1964 and 1965*

Year class	Estimated immigration	Year of emigration	Estimated emigration		Range of estimated emigration	
					Low	High
	Number		*Number*	*Percent*	*Number*	*Number*
1963........	5,500	1964	2,100	38	1,700	2,900
1964........	506,800	1965	52,100	10	4,200	73,200

An estimated half million age-group I kokanee entered Brownlee Reservoir in 1965, but only 10 percent (52,100 fish) are estimated to have left the reservoir. According to Durkin et al. (1970), the poor success of the migration of kokanee can be attributed to the high reservoir level and its attendant lack of downstream-orienting currents. These fish did not enter the reservoir until June and did not begin to leave until late June. The outmigration was greatest in late August and was completed by early September (fig. 5). Fish remaining in the reservoir in late July, August, and September were subjected to high temperatures in the epilimnion (above 21° C.) and oxygen-deficient water in the hypolimnion. These factors forced fish into unfavorable habitats where survival was poor (Durkin et al., 1970).

EMIGRATION OF JUVENILE HATCHERY-REARED SALMON

About 250,000 age-group 0 juvenile fall chinook salmon and 375,000 age I juvenile coho salmon were released in the Snake River above Brownlee Reservoir in late winter and early spring of 1964. Additional releases of 592,000 age-group 0 fall chinook salmon and 473,000 age-group I juvenile sockeye salmon were made in the spring of 1965. Chinook and coho salmon fingerlings were from hatcheries on the lower Columbia River; sockeye salmon fingerlings were from the Leavenworth National Fish Hatchery, where they had been reared from eggs obtained from Babine Lake in British Columbia.

Fall Chinook Salmon

About 85 percent (94,500) of the estimated 111,500 hatchery-reared juvenile fall chinook salmon that entered the reservoir in 1964 passed

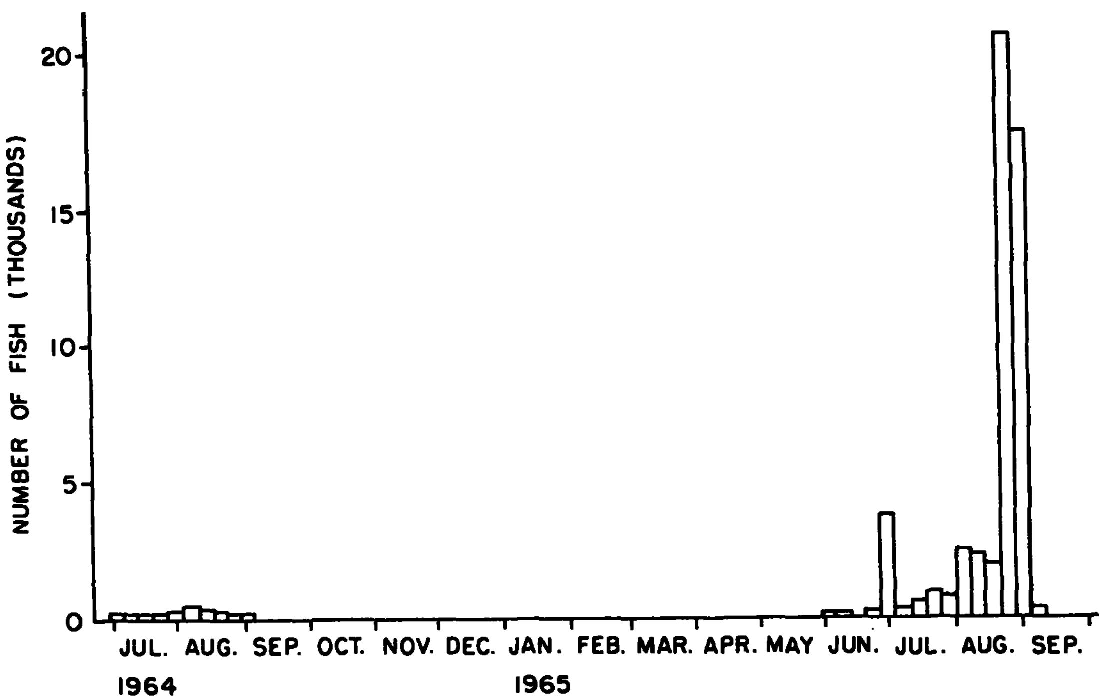

FIGURE 5.—Estimated emigration from Brownlee Reservoir of juvenile native kokanee from the Snake River system, 1964–65.

Brownlee Dam in 1964 (table 10). These fish first appeared at the traps below the dam in early April (9 days after release in the Snake River above the reservoir) and their numbers peaked in the second week of May. Small numbers of fish moved out of the reservoir through the summer until the emigration of the 1964 year class was completed on September 1 (fig. 6).

An estimated 275,200 hatchery-reared fall chinook salmon (1965 year class) left the impoundment in 1965—more than were estimated to have entered the reservoir. The discrepancy between the two estimates is probably due to different sampling methods. Nevertheless, such a comparison is useful when one recognizes that the low range emigration estimate (175,000 fish) is within the 95-percent statistical confidence range of the immigration estimate. Fish of the 1965 year class were first taken in the scoop traps below the dam in late March (fig. 6), 12 days after release in the Snake River above the reservoir. Peak migration was in mid-April, and a few fish were still leaving the reservoir when the experiment terminated at the end of August.

Coho Salmon

Emigration of juvenile hatchery-reared coho salmon (1963 year class) in 1964 was estimated at 51,600 fish or about 75 percent of immigration to the reservoir (table 11). The emigration of coho salmon began on May 16, 1964, about 6 weeks

TABLE 10.—*Estimated immigration of juvenile hatchery-reared fall chinook salmon into Brownlee Reservoir from the Snake River and estimated emigration from the Reservoir, 1964–65*

Year class	Estimated immigration	Year of emigration	Estimated emigration		Range of estimated emigration	
					Low	High
	Number		*Number*	*Percent*	*Number*	*Number*
1964	111,500	1964	94,500	85	68,600	133,400
1965	162,800	1965	[1] 275,000	[1] >100+	175,000	432,000

[1] Discrepancy between estimates of immigration and emigration probably due to differences in sampling techniques in the Snake River and below Brownlee Reservoir.

after their release in the Snake River above the reservoir. The run reached a peak 1 week later and continued until the end of August (fig. 7).

Sockeye Salmon

Juvenile hatchery-reared sockeye salmon (1964 year class) released in 1965 had little difficulty in passing through the reservoir. Emigration in 1965 was estimated at 408,000 fish, more than 100 percent of the estimated immigration (table 11). The range of the two estimates overlap, however. The first sockeye salmon appeared in the scoop traps 6 days after the first releases on March 15, 1965. The emigration was relatively short, beginning on March 21 and ending by the second week of May (fig. 8). Peak was during the week of April 4 to 10, when 175,000 fish are estimated to have left the reservoir.

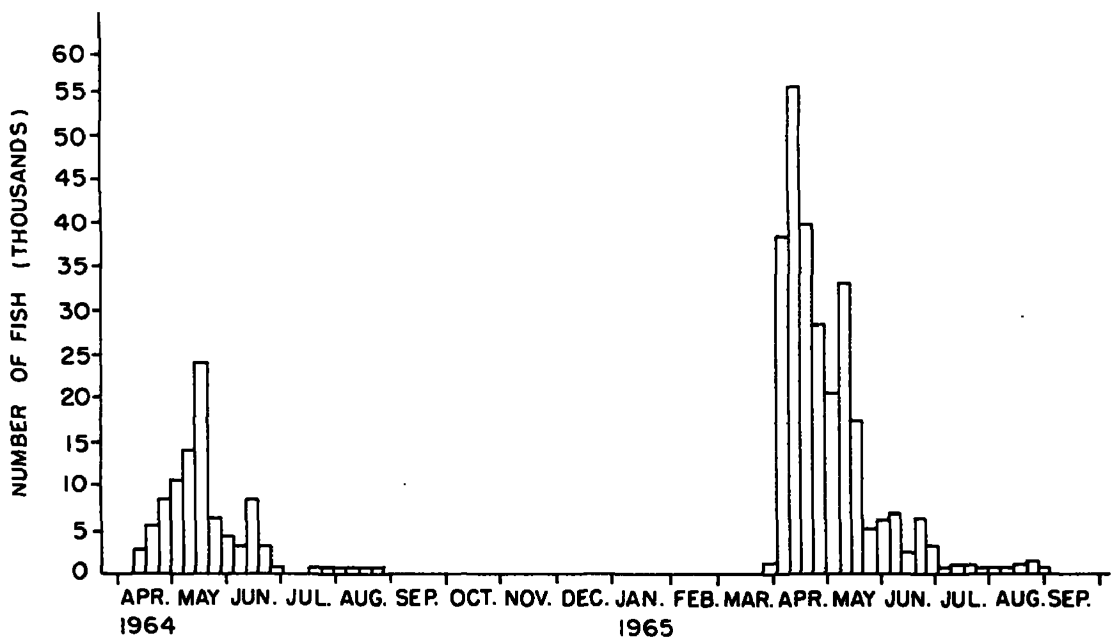

FIGURE 6.—Estimated emigration from Brownlee Reservoir of juvenile hatchery-reared fall chinook salmon from the Snake River, April 1964 to September 1965.

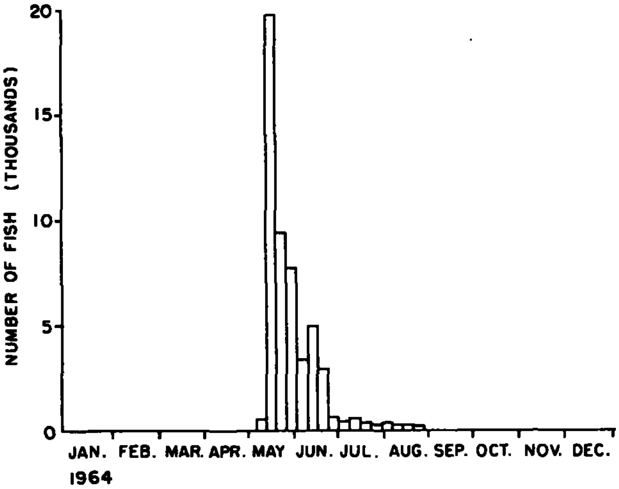

FIGURE 7.—Estimated emigration from Brownlee Reservoir of juvenile hatchery-reared coho salmon from the Snake River, 1964.

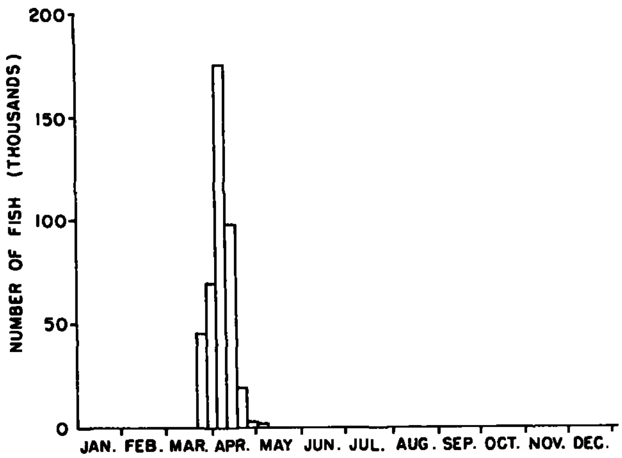

FIGURE 8.—Estimated emigration from Brownlee Reservoir of juvenile hatchery-reared sockeye salmon from the Snake River, 1965.

TABLE 11.—*Estimated immigration of juvenile hatchery-reared coho and sockeye salmon into Brownlee Reservoir from the Snake River and estimated emigration from the Reservoir, May 1, 1963 to August 31, 1965*

Year class	Species	Estimated immigration	Year of emigration	Estimated emigration		Range of estimated emigration	
						Low	High
		Number		*Number*	*Percent*	*Number*	*Number*
1963	Coho	69,000	1964	51,600	75	37,900	72,600
1964	Sockeye	360,000	1965	[1] 408,000	[1] >100+	324,000	513,500

[1] Discrepancy between estimates of immigration and emigration probably due to differences in sampling techniques in Snake River and below Brownlee Reservoir.

EMIGRATION OF JUVENILE TROUT OF UNKNOWN ORIGIN

Because anadromous rainbow trout (steelhead) could not be separated from native and hatchery-reared resident rainbow trout, the data on emigration include all populations of rainbow trout. For the same reason, Krcma and Raleigh (1970) did not attempt to estimate immigrations of rainbow steelhead trout. Comparisons of emigration and immigration, therefore, were not possible. Juvenile rainbow trout emigrated from Brownlee Reservoir each year during this study. An estimated 24,800 rainbow-steelhead trout (table 12) left the reservoir from August 1963 through December 1964. The major emigrations were in May and June. In 1965, emigration was estimated at 73,600 fish, and the major outmigrations were in April and May.

TABLE 12.—*Estimates of emigration of juvenile native and hatchery-reared resident rainbow trout and anadromous rainbow (steelhead) trout from Brownlee Reservoir, May 1, 1963, to August 31, 1965*

Year of emigration	Estimated emigration	Range of estimate	
		Low	High
	Number	*Number*	*Number*
1963–64	24,800	17,900	35,000
1965	73,600	46,600	116,000

LENGTHS OF EMIGRANTS

The sizes of the juvenile fish in various stocks that emigrated from Brownlee Reservoir generally increased as the season progressed. The fork length of fall chinook salmon caught below the dam from August 1963 through December 1964 was 45 to 240 mm. (table 13). Two distinct length groups were evident from November 1963 through June 1964. The larger fish (age-group I) were from the 1963 year class of fall chinook salmon from the Snake River; these fish dominated the catch through March 1964. Beginning in April 1964, the smaller native spring chinook salmon of the 1963 year class and the hatchery releases of fall chinook salmon of the 1964 year class dominated. Holdover of fish was slight in 1965; the entire emigration was of native kokanee and spring chinook salmon (age-group I) of the 1964 year classes and hatchery releases of sockeye salmon (age-group I) and fall chinook salmon (age-group 0) of the 1964 and 1965 year classes.

Hatchery-reared coho salmon increased from an average length of 125 mm. (90–155 mm.) in May 1964 to 200 mm. (155–245 mm.) in August 1964 (fig. 9).

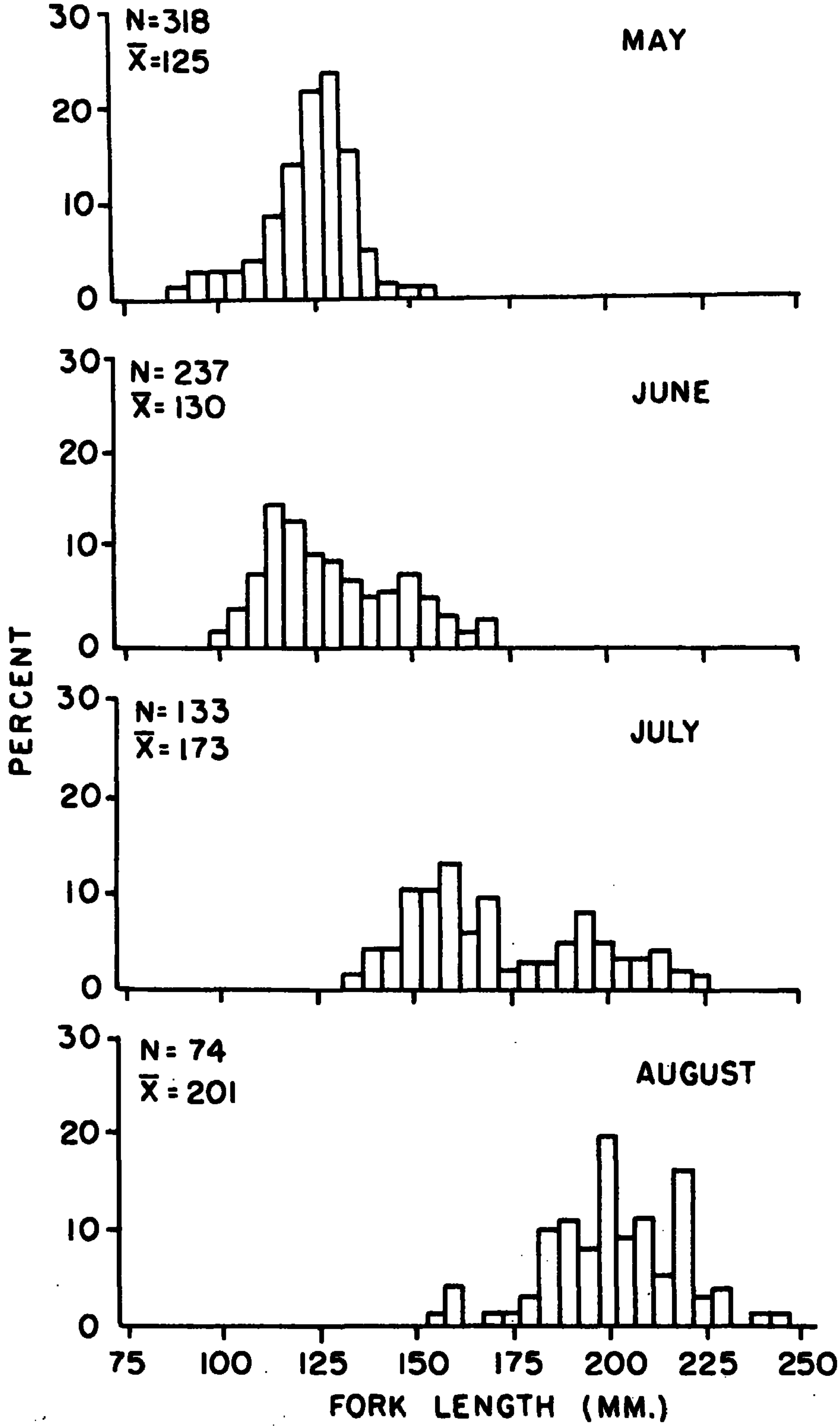

FIGURE 9.—Length-frequency distribution of 762 juvenile hatchery-reared coho salmon from the Snake River collected below Brownlee Dam, May 16 to August 31, 1964. (N=number of fish; X̄ indicates average length.)

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TABLE 13.—*Length-frequency distribution of 5,697 juvenile fall chinook salmon from the Snake River collected below Brownlee Dam, August 1, 1963 to August 31, 1965*

Fork length	Number of fish by year and month											
	1963					1964						
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Mm.												
240												
235												
230								1				
225								3	4			
220							2	13	6	1		2
215						7	8	29	16	2		3
210					1	13	25	49	25			3
205					1	41	47	45	24			2
200					7	48	55	34	10	1		1
195			1	2	13	43	26	17	9	2		
190				12	14	23	21	15	6	2		1
185				21	22	12	4	7	7	1		2
180			1	13	7	5	6	4	6	1		4
175			1	13	2	2		4	3			3
170	1	1		2	1	3	4	3				8
165	3	2	3	3	1	1	3	2				3
160	8	3	1	2			1	3				6
155	13	4	2									7
150	36	8								2	1	2
145	42	2								4	2	2
140	15								1	14	4	2
135	4							1	4	37	1	
130	1				1		1	4	11	86	16	
125	1				8	3	4	7	7	89	52	
120					2	3	6	10	12	66	111	
115					14	5	9	13	28	58	158	
110					7	3	12	15	50	65	131	
105					4	6	8	32	45	62	58	
100					2	1	10	29	51	76	20	
95				1	5		2	15	55	55	12	
90					1		4	6	56	43	1	
85							2		68	44	1	
80							2		74	32		
75									104	21		
70				1					102	8		
65									98	1		
60									31			
55									19			
50									1			
45									1			
Total	124	20	9	70	108	219	262	361	934	773	568	51

The average lengths of kokanee differed little in the early and late runs in 1964 (about 5 mm.), but in 1965 the average increased from 105 to 138 mm. during a 90-day period in June, July, and August (fig. 10).

Hatchery-reared sockeye salmon migrated through the reservoir during such a short period in 1965 that size of the fish changed little. The lengths of these fish were 75 to 170 mm. (fig. 11).

Length-frequency distributions for juvenile rainbow-steelhead trout are given in table 14. Lengths of trout below the dam were 65 to 368 mm. The larger fish probably were native rainbow trout rather than the offspring of anadromous steelhead trout.

EFFECT OF ENVIRONMENT ON EMIGRATION

The environment significantly affected the passage of juvenile salmon and trout through Brownlee Reservoir. In 1963, emigration from the reservoir was low when (1) reservoir drawdown in the spring was small, (2) the reservoir was filled early, and (3) maximum discharge was late.

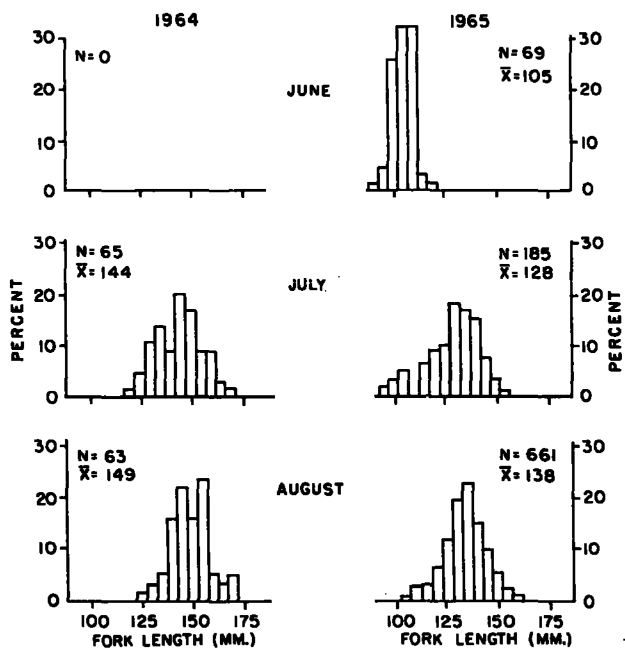

FIGURE 10.—Length-frequency distribution of 1,043 juvenile native kokanee from the Snake River collected below Brownlee Dam, 1964 and 1965. (N=number of fish; X̄ indicates average length.)

TABLE 14.—*Length-frequency distribution of 1,381 juvenile rainbow-steelhead trout collected below Brownlee Dam, August 1, 1963 to August 31, 1965*

Length (mm.)	Number of fish by year and month											
	1963					1964						
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
350-359												
340-349											1	
330-339						2			1	1	2	1
320-329						2		1	3	1		
310-319						2		4	2	4	1	
300-309						4	5	8	14	5	1	
290-299	1			1		1	5	6	2	3		
280-289						1		1	1	2	2	
270-279								3				1
260-269	2								1		1	1
250-259			1							4		6
240-249	2	1							1	1		11
230-239	4							1	1	11		9
220-229	1							1	1	3	5	8
210-219								1	5	9	7	4
200-209								1	2	12	21	6
190-199								1	6	13	13	
180-189								1	2	19	15	1
170-179				1					9	29	7	
160-169							1	1	13	22	1	
150-159						1			14	15	1	
140-149									11	14		
130-139									9	8		
120-129									3	1		
110-119						1			3		1	
100-109									2	1		
90-99												
80-89									2		1	
70-79									2			
60-69												
Total	10	1	1	2	0	14	11	30	110	178	80	48

TABLE 14.—*Length-frequency distribution of 1,381 juvenile rainbow-steelhead trout collected below Brownlee Dam, August 1, 1963 to August 31, 1965*—Continued

Length (mm.)	Number of fish by year and month												
	1964					1965							
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
360-369									1		1		
350-359	1								1				
340-349								1	1	1			
330-339	2								2				
320-329			1							2	2	1	1
310-319								1	3	1	1		1
300-309								2	1				3
290-299	1							1	3	2			12
280-289	2							1	1	4	1		10
270-279	4								3	9	2		13
260-269	6							1	8	7	3	5	24
250-259	12							1	18	12	2	8	17
240-249	11								24	16	3	5	16
230-239	3	2						1	32	20	1	5	8
220-229	4								24	18	5	3	
210-219	1								34	17	7		2
200-209		1							19	18	5		
190-199									22	30	12	1	
180-189	1		1						32	25	15	2	
170-179				1					43	26	16		
160-169								1	27	22	11		
150-159									13	14	5		
140-149				1				1	9	4	1		
130-139					1				3	4	1		
120-129						1			1		3		
110-119										1	2		
100-109				1		1							
90-99			1						1			1	3
80-89			1							1			3
70-79													
60-69								1					
Total	48	3	4	3	1	2	0	12	326	254	99	31	113

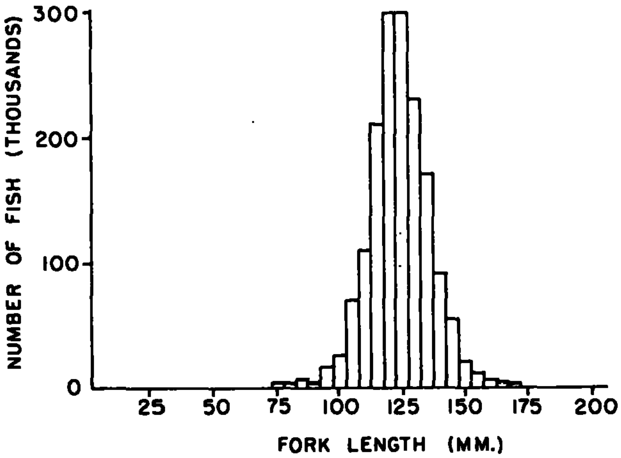

FIGURE 11.—Length-frequency distribution of 1,626 juvenile hatchery-reared sockeye salmon from the Snake River collected below Brownlee Dam, March 21 to May 13, 1965.

Emigration was notably more successful in 1964 and 1965 when the reservoir level was low through most of the downstream migration, and discharges were high during early and midspring.

Fish that entered the reservoir after the middle of June, as kokanee did in 1964 and 1965 (fig. 5), had poor success of passage. In both years, emigration of kokanee was less successful than that of other species of fish migrating earlier in the season. Kokanee did not enter the reservoir until late June when the reservoir was full and currents were weak and not clearly oriented in any direction. Those fish remaining in the reservoir through the summer encountered low oxygen concentrations (0–3 p.p.m.) below the thermocline and high water temperatures (24° C. or above) near the surface (Ebel and Koski, 1968). Few kokanee survived the harsh summer.

MORTALITY RELATED TO TURBINES

Because many fish were found dead in the scoop traps, the mortality attributable to the traps and the turbines was examined. A detailed investigation was beyond the scope of this study, but mortality was assessed at the turbine tailrace site in June 1965. During a 6-day period (June 1–6), all scoop traps were emptied twice daily—at 8:00 a.m. and 4:00 p.m. In a second 6-day period (June 7–12), all fish were removed as soon as they entered the traps (table 15). All fish caught during both periods were hatchery-reared chinook salmon of the 1965 year class.

Mortality during the two periods was as indicated in table 15: 88 percent of the fish were dead in the traps in the first period, and 16 percent were dead when they entered the traps in the second period. Because the fish were removed immediately in the second period, they died of causes other than trapping or handling.

To assess delayed mortality, samples of live fish taken from the traps during the second period were held in a holding tank in circulated water for an additional 24-hour period. Hatchery-reared chinook fingerlings collected in the reservoir above the dam were held with these fish to serve as a control (table 16). At the end of 24 hours, 67.5 percent of the fish taken from the traps and 17.5 percent of the control fish were dead. Thus, the delayed mortality of fish passing through the turbines was 50 percent.

Thus, on the average under test conditions, 16 of every 100 fish passing the sampling site were already dead. Of the 84 survivors, 42 died within 24 hours, which indicated a total turbine-related mortality of 58 percent.

TABLE 15.—*Mortality of juvenile hatchery-reared chinook salmon taken by scoop traps at the turbine tailrace sampling site, June 1–12, 1965*

Date	Turbine discharge	Water temperature	Fish in total catch	Mortality	
	M.³/sec.	*°C.*	*Number*	*Number*	*Percent*
Period A:[1]					
June 1	451	13	105	66	62
June 2	484	13	83	77	93
June 3	478	15	167	160	96
June 4	470	15	230	216	94
June 5	472	14	160	146	91
June 6	410	15	323	274	85
Totals			1,068	939	88
Period B:[2]					
June 7	547	15	148	26	18
June 8	523	15	65	12	19
June 9	440	15	23	1	4
June 10	433	15	18	1	5
June 11	423	16	4	1	25
June 12	334	17	15	2	13
Totals			273	43	16

[1] Normal operating conditions. Trap emptied at 8:00 a.m. and 4:00 p.m. daily.
[2] Fish removed from trap immediately upon entry.

TABLE 16.—*Delayed mortality of juvenile hatchery-reared chinook salmon taken from the tailrace scoop traps, June 7–12, 1965*

Group	Fish in trap	Mortality at the end of 24 hours	
	Number	*Number*	*Percent*
Experimental	83	56	67.5
Control	103	18	17.5

SUMMARY AND CONCLUSIONS

Estimates of emigration of juvenile salmon and trout from Brownlee Reservoir from July 1963 through August 1965 were based on catches in floating scoop traps below Brownlee Dam and on estimates of efficiency of the traps.

Emigration of native fall chinook salmon of the Snake River was estimated at 15 percent of immigration into the Reservoir in 1963 (1963 year class). Hatchery-reared fall chinook salmon (age-group 0) were planted in the Snake River in 1964 and 1965. Estimates of emigration were 85 percent of immigration in 1964 and 100 percent in 1965.

Emigration of native spring chinook salmon (Eagle Creek and the Weiser River) was estimated at 16 percent of immigration in 1964 and at 51 percent in 1965.

Emigration of native kokanee of the Snake River system was estimated at 38 percent of immigration in 1964 and at 10 percent in 1965.

Hatchery-reared coho and sockeye salmon were planted in the Snake River in 1964 and 1965, respectively. An estimated 75 percent of the coho salmon (1963 year class) that entered the reservoir in 1964 passed through. Emigration of sockeye salmon (1964 year class) in 1965 was estimated at 100 percent of immigration.

Because anadromous rainbow trout (steelhead) could not be separated from populations of native and hatchery-reared resident rainbow trout, I did not compare emigrations and immigrations. About 24,800 rainbow trout left the reservoir from August 1963 through December 1964. Emigration was estimated at 73,600 fish in 1965.

The environment in the reservoir during the time of outmigration clearly affected success of passage. In general, fish that entered the reservoir early in the spring, when the reservoir was drawn down and water temperature and oxygen concentrations were favorable, passed through more successfully than did those that entered during the summer, when water temperatures were high, currents were weak, and concentrations of oxygen were low.

The fish of the various stocks that emigrated from Brownlee Reservoir showed a general increase in length as the season progressed.

The following general conclusions were reached:

1. Downstream migrants that entered the reservoir early in the season passed through more successfully than those that entered later.
2. Emigration was more successful when the reservoir level was low during the time of migration than when the reservoir was filled before completion of the migration.
3. Because of time of emigration, size of the fish at time of entry into the reservoir, and the shorter distance traveled by the fish, one would expect what happened: Progeny of native spring chinook salmon migrated through the reservoir more successfully than native fall chinook salmon.

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