MIGRATION OF JUVENILE SALMON AND TROUT INTO BROWNLEE RESERVOIR, 1962–65

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ABSTRACT

Migrations of juvenile chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye and kokanee salmon (*O. nerka*), and rainbow trout (*Salmo gairdneri*) from the Snake and Weiser Rivers and from Eagle Creek were studied. Populations of fish were sampled with floating traps above the reservoir and a fixed louver trap in Eagle Creek near the lower end of Brownlee Reservoir. Age and length of fish, timing of migration, and numbers of fish of native or hatchery origin were determined. This information was needed to evaluate the effect of Brownlee Reservoir on migrations of anadromous fish.

Brownlee Reservoir was created when a high-head hydroelectric dam was built in 1958 at the upstream end of Hells Canyon on the Snake River. The 92-km. long reservoir forms part of the boundary between Idaho and Oregon. At full pool, it is 92 m. deep and less than 1 km. wide; the upper end (22 km.) is relatively shallow and essentially riverine.

BCF (Bureau of Commercial Fisheries) chose Brownlee Reservoir for an extensive research program to determine how a large impoundment affects the passage of salmon and trout. The research, begun in the spring of 1962, comprised 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 (this report), (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 (Sims, 1970).

Three major streams—the Snake, Burnt, and Powder Rivers—and more than a dozen minor streams, most of which have intermittent flows, are tributaries to Brownlee Reservoir. Previous investigations had shown that most of the streams supported local populations of rainbow trout (*Salmo gairdneri*), but chinook salmon and steelhead trout (the anadromous form of rainbow trout) spawned in only three of the streams. Spring- and fall-migrating steelhead trout and spring-migrating chinook salmon spawned in Eagle Creek, a tributary of the Powder River, and in the Weiser River, a tributary of the Snake River (fig. 1). Fall-migrating chinook salmon spawned in the Snake River about 257 km. above the dam.

Wild (native) salmon and trout fingerlings entered the reservoir during each year of study (1962–65). From 1963 on, most of the chinook salmon spawners were diverted to a hatchery. In 1964 and 1965, therefore, hatchery-reared progeny of fall chinook salmon from the lower Columbia River were released in the Snake River spawning area above the reservoir. We wished to study the effect of a large impoundment on other species of salmon, so yearling coho (*O. kisutch*) from the lower Columbia River and sockeye salmon (*O. nerka*) from the Skeena River were included in the hatchery releases in 1964 and 1965, respectively. In 1963, 1964, and 1965, migrations of wild kokanee (*O. nerka*) entered the reservoir from the Payette River system.

This report provides estimates of age and length of fish from each population at the time of entry into the reservoir, time and duration of downstream migrations, and numbers of fish of native and hatchery origin for 1962 through 1965.

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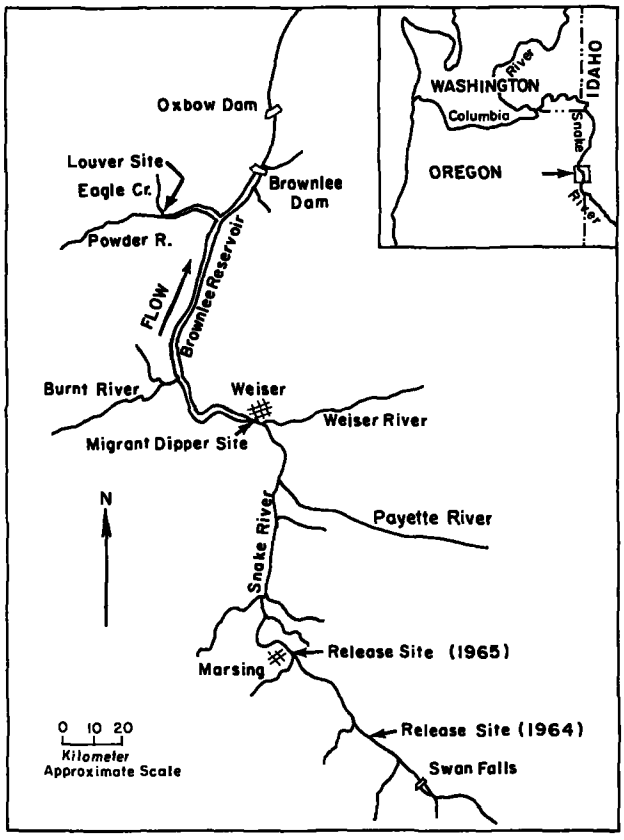

FIGURE 1.—Study area showing locations of sampling equipment used to assess migrations of juvenile salmon and rainbow trout to Brownlee Reservoir.

SAMPLING SITES, EQUIPMENT, AND PROCEDURES

The plan of study was to sample populations of migrating fish before they entered the reservoir, to determine their characteristics, and to estimate their abundance. This plan required the installation of floating fingerling traps in the Snake River above the reservoir and a fixed louver in Eagle Creek, a tributary of the Powder River near the lower end of Brownlee Reservoir (fig. 1).

Sample catches from the populations of juvenile chinook salmon in the Snake and Weiser Rivers early in the study established that juvenile fall chinook salmon migrated from the Snake River at age 0, whereas juvenile spring chinook salmon migrated from the Weiser River at age 1. Thus, it was possible to separate these two populations on the basis of age or size and to sample them from a single location below the confluence of the two rivers.

SNAKE RIVER

The sampling site for the Snake and Weiser Rivers was about 8 km. below their confluence and about 4 km. above the reservoir. Flows during the spring were 383 to 1,372 c.m.s. (cubic meters per second) and averaged 744 c.m.s. At average flow, the Snake River channel at this location was about 152 m. wide and had a maximum depth of 7.6 m.

The sampling device in the Snake River was a modified "migrant dipper" (Mason, 1966)—a self-cleaning, floating fingerling trap with louvered leads (fig. 2). The basic unit consisted of a trap section, 12.2 m. long by 7.6 m. wide by 1.8 m. deep, with fixed louver leads that extended 9.8 m. upstream at a 10° angle to the flow. A self-cleaning traveling screen formed the rear of the trap, and a metal screen floor extended upstream to the two fixed louver sections. The louvers guided the fish into the trap area where a continuously rotating scoop dipped the fish and deposited them into a trough. The fish were then flushed into a holding pen at the side of the trap.

Fish were captured in traps from 1962 through 1965. We carried out feasibility tests with one trap in 1962 and examined the horizontal distribution of downstream migrants at the same time. In the spring of 1963, two migrant dipper traps were attached to an overhead cable and positioned in the main current. Floating louver extensions were added to the fixed louver sections to increase the sampling capability. In attempts to increase the catch, the louver angle and lengths were altered each year (table 1). In 1962, the traps were operated continuously from mid-April until early July and then intermittently until December. On the basis of these early experiments, the operations in 1963–65 began in mid-March and ended in July.

TABLE 1.—*Traps used in the Snake River and configuration of attached louver arrays*

Year	Traps	Details of louver leads		
		Angle	Length	Width at mouth
	Number	*Degrees*	*M.*	*M.*
1962	1	10	9.7	13.7
1963	2	30	22.0	30.5
1964	2	15	22.0	21.4
1965	1	15	47.6	30.5

Fish captured in the traps and subsequent estimates of the magnitude of migration were classi-

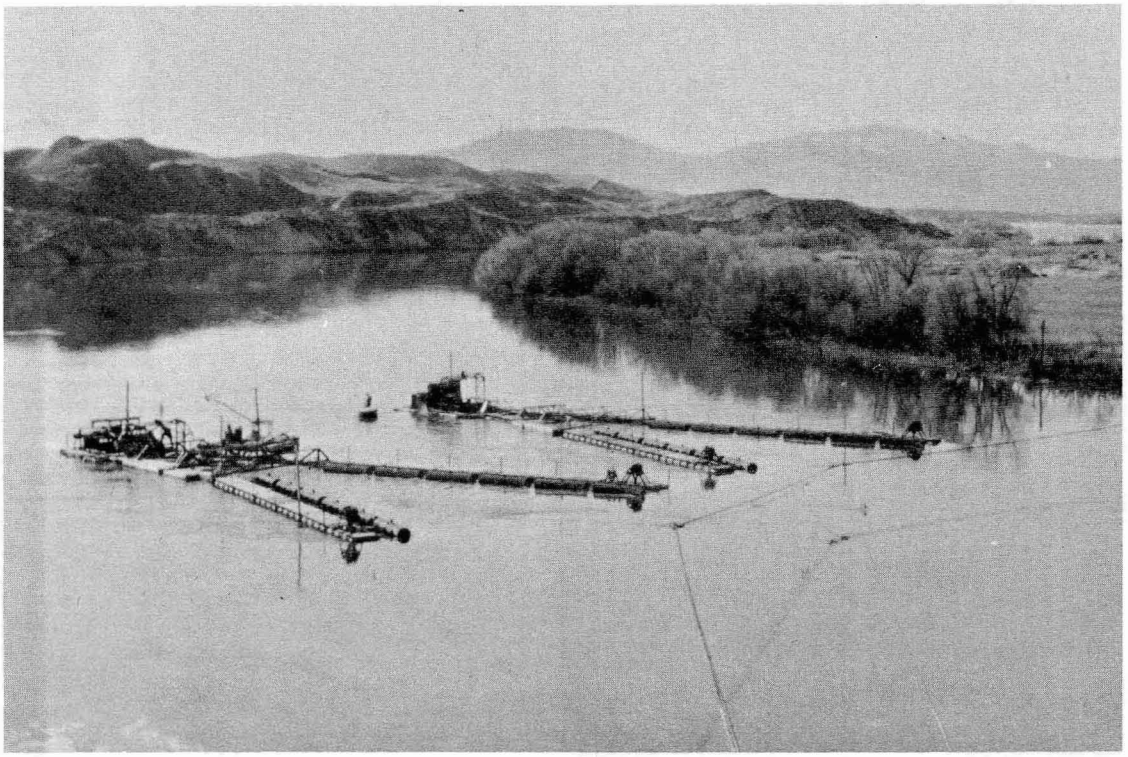

FIGURE 2.—Floating traps (migrant dippers) used to sample migrations of juvenile salmon and rainbow trout in the Snake River above Brownlee Reservoir.

fied by age group on the basis of lengths determined by daily sampling. The length-age relation was established by scale analysis. Fingerlings in their first year of life are termed age-group 0; these fish become age-group I on January 1 of the succeeding year.

Marked fish were used to estimate the proportion of the migration captured by the traps. The proportion varied with trap design and position, size and species of migrants, and flow and turbidity of the river. A portion of the daily catch of fish was marked, transported 3.2 km. upstream, and released for recapture. They were marked by age group and released at scheduled intervals during the day and night.

Fish marked to assess the migration from the Snake River were tattooed (Volz and Wheeler, 1966). This method provided many combinations of marks that were durable and could be easily detected. Juvenile salmon from each population were fin-clipped or jaw-tagged each year for subsequent identification as they moved through the reservoir.

EAGLE CREEK

The sampling site at Eagle Creek was 183 m. upstream from its confluence with the Powder River and about 460 m. from the reservoir (fig. 1). The stream at this point was 15 m. wide at normal flows. Except during maximum runoff in the spring, flows seldom exceeded 57 c.m.s.

Samples of downstream migrants were obtained with a stationary louver device (Bates and Vinsonhaler, 1957)—see figure 3. In 1962, the louver (18.3 m. long and 0.9 m. high) was positioned at a 30° angle to the stream bank. In 1963, to increase the catch and eliminate selectivity for larger fish, the angle was decreased to 15° and the length extended to 36.6 m. In 1964, the channel was altered above the louver to straighten the approach flow.

Fish from Eagle Creek were collected from three sources and marked in a variety of ways. Most fish were stained with Bismark Brown Y dye[1] (Deacon, 1961) and released above the sam-

[1] Trade names referred to in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

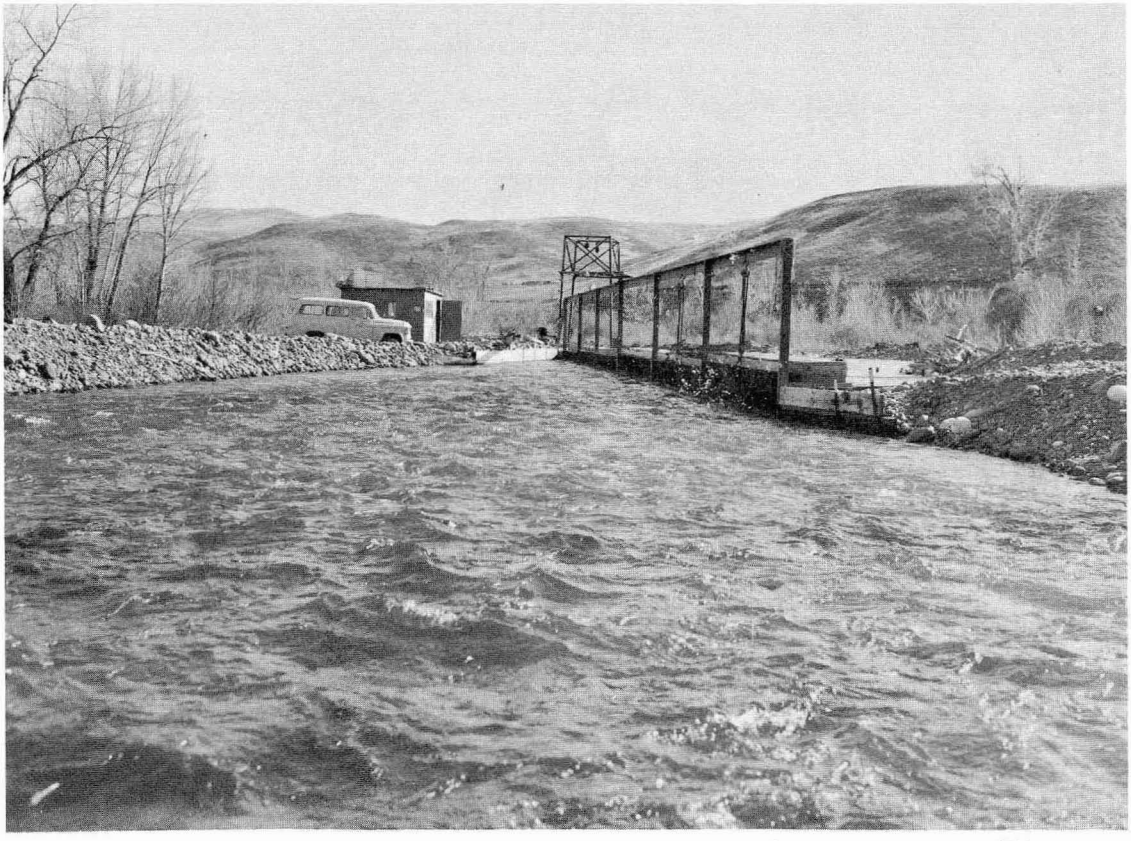

FIGURE 3.—Stationary louver used to estimate the number of juvenile salmon and rainbow trout migrating into Brownlee Reservoir from Eagle Creek.

pling site to determine trapping efficiencies of the louver. Fish to be stained could be held in the cooler waters of Eagle Creek with little difficulty, whereas they could not be kept alive for sufficient time to stain them in the warmer waters of the Snake River. We obtained test fish mainly from irrigation bypass traps and fyke nets located several kilometers upstream. When sufficient numbers of migrating fish were not available from these sources, we used fingerlings captured at the louver. Periodically, groups of migrants from Eagle Creek were marked by fin-clipping, jaw tags, or plastic thread tags [2] for identification in the reservoir.

DOWNSTREAM MOVEMENT, AGE, LENGTH, AND TIME OF ENTRY INTO THE RESERVOIR OF JUVENILE SALMON AND TROUT

The characteristics of the migrations into Brownlee Reservoir were determined from catches at the sampling sites. Timing and peaks of runs are expressed as weekly percentages of the estimated numbers of fish in the migrations. About 10 percent of each daily catch was examined for data on length and age.

[2] Developed by the Fish Commission of Oregon.

MIGRATIONS OF WILD SALMON AND TROUT

Migrations of wild chinook salmon and steelhead trout juveniles entered the reservoir from three tributaries. Fall chinook entered from the Snake River, whereas spring chinook and steelhead entered from Eagle Creek and Weiser River.

Fall Chinook Salmon

The movement of juvenile fall chinook salmon from the Snake River to Brownlee Reservoir began about mid-April and peaked in mid-May in 1962 and 1963 (fig. 4). About 75 percent of the migration took place during a 2-week period, and nearly all of the fish had migrated by mid-June. Principal movement was between sunrise and 10 a.m. and from 3 to 7 p.m.

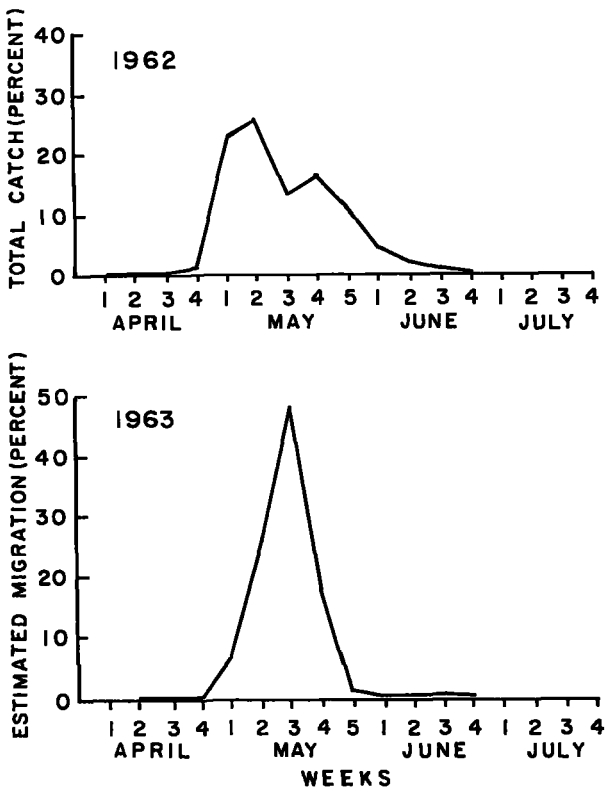

FIGURE 4.—Timing of migration of native juvenile fall chinook salmon (age-group 0) from the Snake River to Brownlee Reservoir by weekly periods, 1962–63.

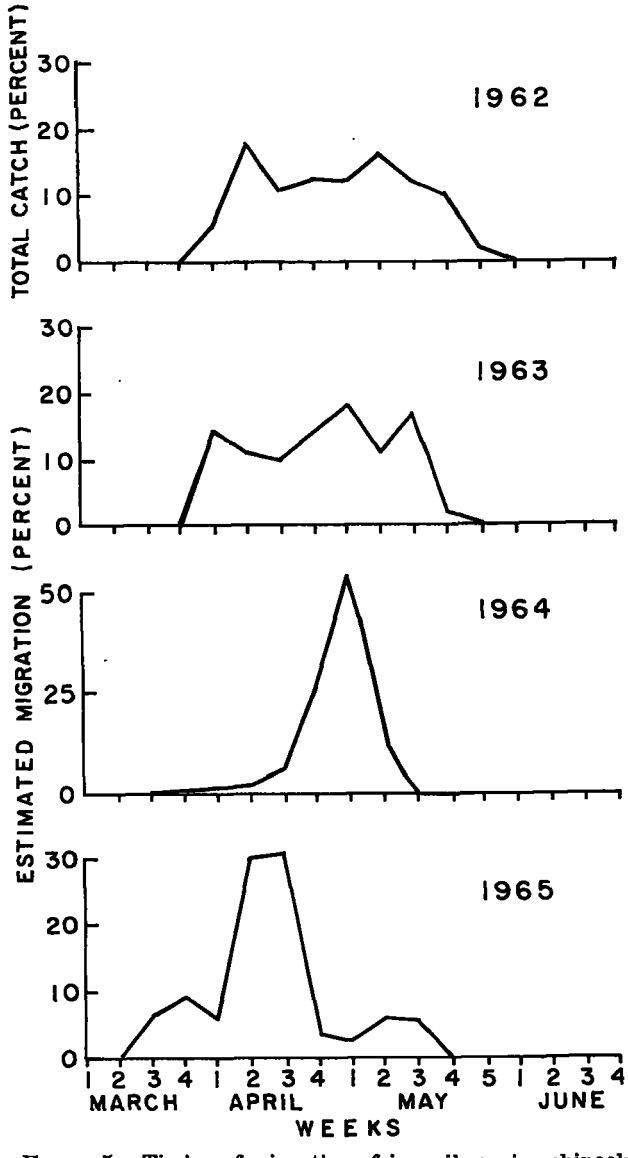

FIGURE 5.—Timing of migration of juvenile spring chinook salmon from the Weiser River to Brownlee Reservoir by weekly periods, 1962–65.

The size of native juvenile fall chinook salmon increased throughout the migration period (table 2). Early migrants in 1962 averaged 52 mm.; by the final week, average length had increased to 71 mm. The migrants averaged larger in 1963—73 mm. at the start and 81 mm. at the end of the migration period.

Spring Chinook Salmon

Spring chinook salmon enter Brownlee Reservoir from Weiser River and Eagle Creek; their season of spawning is similar, but the sizes and seasons of migration of the juveniles into the reservoir are substantially different.

Weiser River population.—Juvenile spring chinook salmon from the Weiser River first appeared at the Snake River trap in early April and peaked in late April or early May (fig. 5). The migration was nearly complete by late May in all years. Daily catches of spring chinook salmon were greatest between 7 and 11 a.m. and 3 and 7 p.m. except during the peak when diurnal highs were not clearly defined. Daily catches were lowest between 10 p.m. and 4 a.m.

The size of spring chinook salmon from the Weiser River differed from that of wild fall chinook salmon from the Snake River in 1962–63; spring fish were age-group I and distinctly larger than fall fish, which were age-group O. In 1964 and 1965, however, the difference between these wild spring chinook salmon and the hatchery-reared fall chinook salmon was less apparent by late April when the length ranges merged. In

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TABLE 2.—*Lengths of wild juvenile fall chinook salmon from the Snake River during migration past sampling site, 1962–64*

Year	Length of fish at stage of migration					
	Early [1]			Late [2]		
	Fish	Mean	Range	Fish	Mean	Range
	Number	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
1962	76	52	33–80	434	71	47–103
1963	97	73	48–99	133	81	67–98
1964	([3])			146	79	61–90

[1] Mid-April to mid-May.
[2] Mid-May to mid-June.
[3] No discernible fish of this group in sample.

1964 and 1965, the two populations were separated by the percentage of each age group in the daily sample as estimated from scale analysis.

The average length of spring chinook salmon varied from 106 mm. in 1962 to 149 mm. in 1964 (table 3). Each year the average size increased from the beginning to the end of the migration.

A few large individuals (215–260 mm.) were captured in 1963 and 1964, but the total constituted less than 1 percent of the catch. These fish (age-group III) appeared at the trap early in the season during extremely high flows from the Weiser River.

TABLE 3.—*Lengths of juvenile spring chinook salmon from the Weiser River during migration past sampling site in the Snake River, 1962–65*

Year	Length of fish at stage of migration					
	Early [1]			Late [2]		
	Fish	Mean	Range	Fish	Mean	Range
	Number	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
1962	8	106	95–117	104	134	125–151
1963	438	108	94–140	52	142	116–155
1964	249	112	100–145	81	149	126–165
1965	19	119	101–130	22	140	120–155

[1] April to peak of migration (late April or early May).
[2] From peak of migration through May.

Eagle Creek population.—Juvenile spring chinook salmon from Eagle Creek migrated downstream most of the year except during the summer when flows averaged less than 1 c.m.s. (fig. 6). The principal migration was in the fall when flows at the trapping site exceeded 1.5 c.m.s. As irrigation was reduced at this time, most of the flow remained in the stream channel, and water temperatures ranged from 0° to 13° C. Winter migrations were small and occurred only during short-term increases in water temperature and flow. A secondary migration took place in the spring as water temperature and flows again increased. The migration declined just before high flows from spring rain and melting snow (fig. 6). Periodic sampling during the high flows suggested that few chinook salmon were migrating. As water levels receded, however, fish were taken in limited numbers until the upstream diversion of water for irrigation greatly reduced the flows at the louver. Water temperatures increased in the spring from near freezing to about 8° C.

Chinook salmon of age-group O dominated the migration in the fall. These fish emerged from the gravel in the spring and were the offspring of adults that had spawned in late summer and early fall of the previous year. The size of the O-group fish varied slightly from year to year and throughout the migration period (table 4).

Juvenile chinook salmon that moved downstream from January into late spring were primarily age-group I fish. A small number of age-group 0 (average, 60 mm.; range, 41–80 mm.) was sampled from April through June 1963. Some age-group II fish—less than 3 percent of the total

TABLE 4.—*Lengths of juvenile spring chinook salmon at beginning and end of spring and fall migrations at Eagle Creek, 1962–65*

Year	Spring migration								Fall migration							
	Age-group 0				Age-group I				Age-group 0				Age-group I			
	Beginning		End		Beginning		End		Beginning		End		Beginning		End	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1962	([1])	([1])	([1])	([1])	([1])	([1])	([1])	([1])	78	53–109	84	60–111	119	112–120	132	[2]115–168
1963	([3])	([3])	61	45–80	86	65–105	93	71–98	87	64–118	89	60–116	144	130–152	([3])	([3])
1964	([3])	([3])	66	58–78	90	72–108	94	72–130	102	76–121	103	78–125	158	—158	([3])	([3])
1965	([3])	([3])	([2])	([2])	100	86–118	111	83–119	108	83–119	([1])	([1])	([1])	([1])	([1])	([1])

[1] Not in operation.
[2] Few fish sampled.
[3] Not in catches.

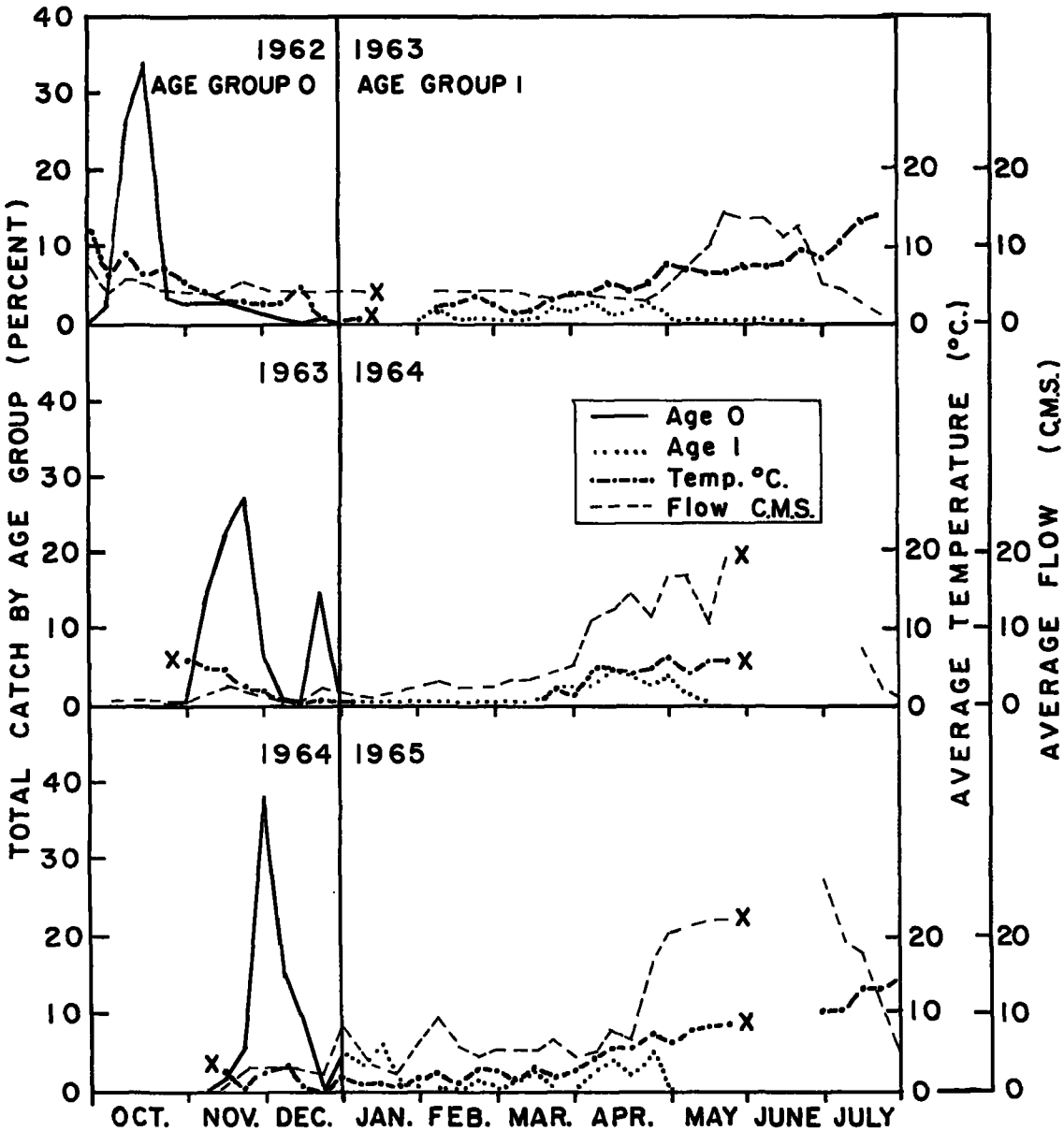

FIGURE 6.—Timing of migration of spring chinook salmon (age-groups 0 and I) from Eagle Creek to Brownlee Reservoir in relation to water temperature and flow, 1962–65 (x indicates periods of no data).

catch—were taken each spring. These fish averaged 140 mm. (126–180 mm.) and were scattered throughout the migration.

Most fish moved downstream past the louver at night—between 6 and 12 p.m. Few fish were caught through the rest of the 24-hour period except during high flows and turbid water; at these times fish moved downstream throughout the day and night.

Kokanee

Kokanee salmon from the Payette River system appeared at the Snake River sampling site in mid-June in 1963–65. The migration was evident for 3 or 4 weeks, but most of the fish moved downstream during a 1-week period (fig. 7). Kokanee averaged 118 to 120 mm. long through the 1964 migration and 93 to 108 mm. through the 1965 season (table 5).

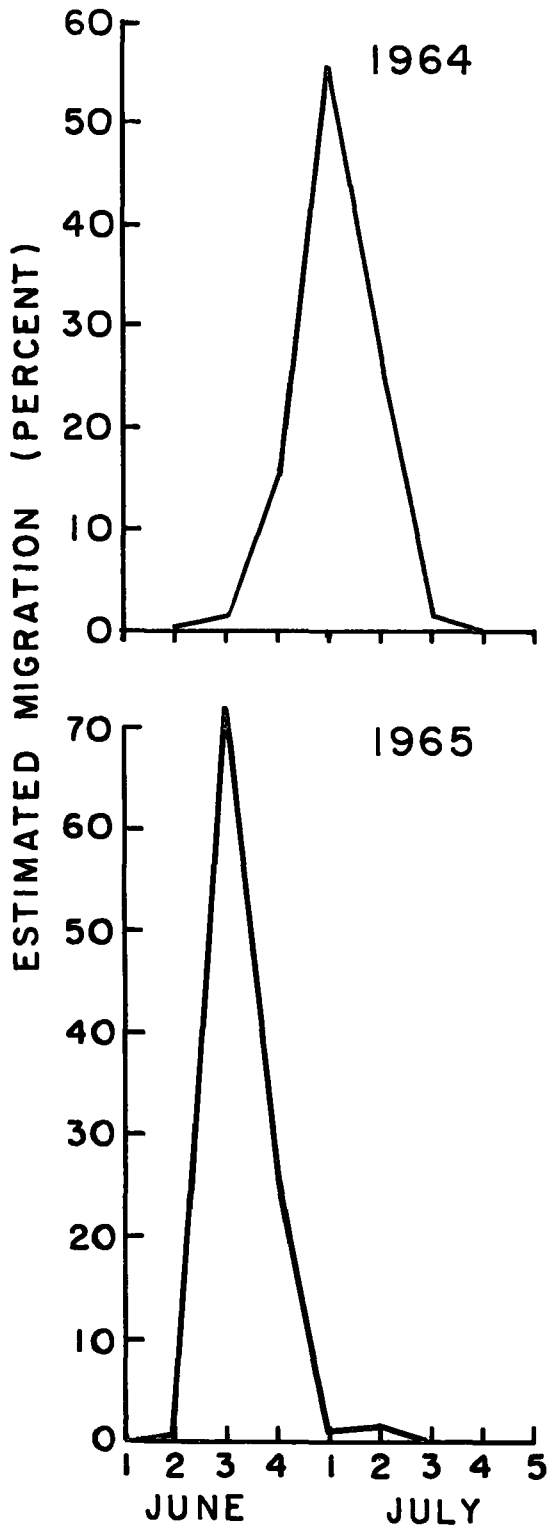

FIGURE 7.—Timing of migration of kokanee salmon from the Snake River to Brownlee Reservoir, 1964–65.

Rainbow Trout

Anadromous rainbow trout spawned in the same tributaries as spring chinook salmon. Offspring of the anadromous form could not be separated from resident native and planted rainbow trout that complete their life cycle in fresh water. Studies on the entry of trout into the reservoir included young from all three groups.

TABLE 5.—*Lengths of juvenile kokanee salmon during migration past sampling site in Snake River, 1963–65*

Year	Length of fish at stage of migration					
	Early [1]			Late [2]		
	Fish	Mean	Range	Fish	Mean	Range
	Number	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
1963	7	[3]	100–110	3	[3]	128–142
1964	279	118	88–140	107	120	104–146
1965	166	93	80–110	151	108	70–155

[1] First week.
[2] Last week.
[3] Insufficient sample.

Trout migrated from the Snake River in the spring (fig. 8) at the same time as the chinook salmon populations. Time of peak migration varied but was in late April or May 1962–65. Age groups were from O to IV, but most were age-group I and II. Size overlap was considerable among age-groups I and II. Table 6 shows the age groups and length-frequency ranges for 1963.

The movement of rainbow trout from Eagle Creek (fig. 9) also took place primarily in the spring; about 75 percent of the fish migrated in late spring, at a time of high flows. A smaller run peaked in the fall. Fish of age-groups I and II dominated the run in the spring. Age-groups O and I were dominant in the fall; however, all age-groups O through IV were represented. Table 7 shows the size ranges.

MIGRATIONS OF HATCHERY-REARED SALMON

Most of the chinook salmon spawners were diverted to hatcheries from 1963 through 1965. In 1964 and 1965, hatchery-reared fingerling salmon were released at the Snake River spawning area, 88 to 120 km. above the reservoir. Chinook salmon fingerlings from fall migrating adults were released in 1964 and 1965. Coho salmon fingerlings were released in 1964 and sockeye salmon fingerlings in 1965.

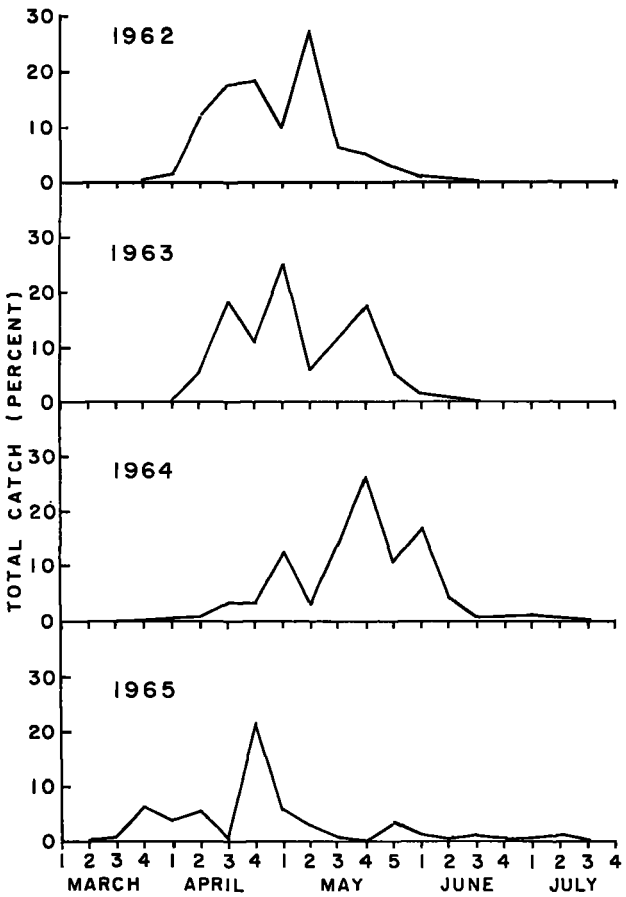

FIGURE 8.—Timing of migration of juvenile rainbow trout to Brownlee Reservoir from the Snake River, 1962–65.

TABLE 6.—*Age groups and lengths of juvenile rainbow trout captured in the migrant dipper traps in the Snake River above Brownlee Reservoir in 1963*

Age group	Fish	Mean length	Range
	Number	*Mm.*	*Mm.*
0	2	(1)	95–100
I	502	177.1	125–210
II	276	239.8	190–285
III	34	294.1	275–340
IV	1	(1)	382

[1] Insufficient sample.

TABLE 7.—*Age groups and lengths of juvenile rainbow trout from Eagle Creek during migration past sampling site in fall 1962*

Age group	Fish	Mean length	Range
	Number	*Mm.*	*Mm.*
0	119	78.0	53–109
I	228	141.7	90–183
II	16	200.0	180–265
III	3	(1)	225–270
IV	1	(1)	285

[1] Insufficient sample.

Fall Chinook Salmon

Hatchery-reared juveniles of fall chinook salmon were released in the Snake River above the reservoir in 1964 and 1965 to supplement the dwindling smolt migrations of wild fall chinook salmon. About 250,000 fall chinook salmon were released 120 km. above the reservoir from March 30 to April 3, 1964, when water temperatures averaged 9.5° C. In 1965, 592,000 juvenile fish were released 88 km. upstream from the reservoir from March 15 to 25, when the water temperature averaged 9.8° C. A tank truck transported the fish from hatcheries on the lower Columbia River. The fish were released during daylight.

The migrations of hatchery chinook salmon overlapped with migrations of wild spring chinook (age-group I) from the Weiser River. In 1964, juvenile chinook salmon from hatchery releases were recovered at the Snake River sampling site within 3 days after the first release. Downstream migration continued until late June, but catches were highest in mid-May (fig. 10). The migration in 1965 was longer and the peak less well defined.

The lengths of hatchery-reared chinook salmon increased as the season progressed and by late April were the same size as those of the age-group I wild chinook salmon from Weiser River. The hatchery fish captured at the migrant dipper in 1964 averaged 74 mm. (56–100 mm.) early in the season and 112 mm. (91–135 mm.) near the end of the migration (table 8). In 1965, the hatchery fish averaged 69 mm. (46–90 mm.) at the start of migration and 112 mm. (96–125 mm.) at the end.

TABLE 8.—*Lengths of hatchery-reared juvenile chinook salmon during migration past sampling site in Snake River, 1964–65*

Year	Length of fish at stage of migration					
	Early [1]			Late [2]		
	Fish	Mean	Range	Fish	Mean	Range
	Number	*Mm.*	*Mm.*	*Number*	*Mm.*	*Mm.*
1964	264	74.5	56–100	220	112	91–135
1965	125	69.3	46–90	124	112	96–125

[1] March through mid-May.
[2] Mid-May through June.

Coho Salmon

The introduction of 375,000 juvenile coho salmon into the Snake River in 1964 provided an

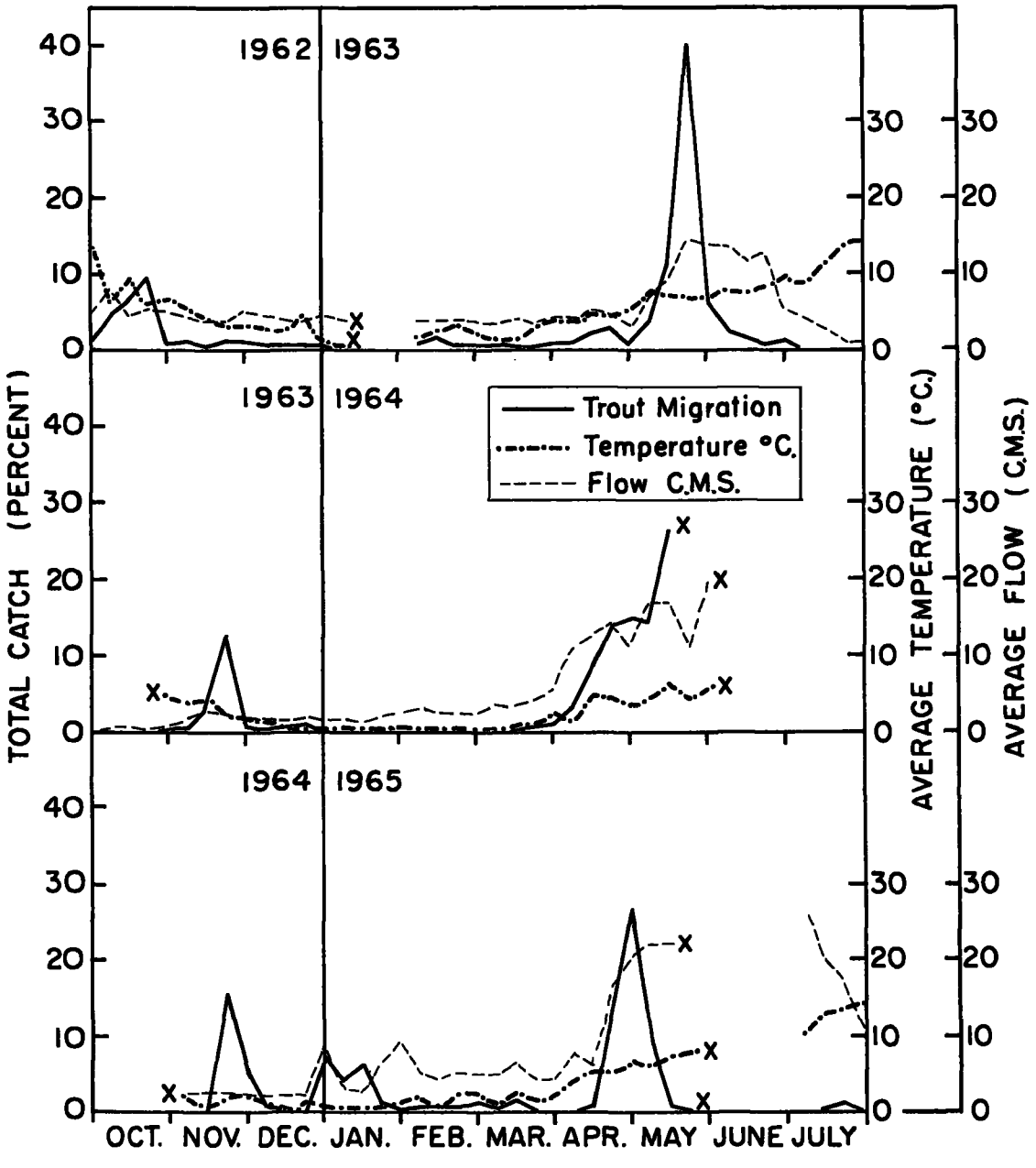

FIGURE 9.—Timing of migration of juvenile rainbow trout to Brownlee Reservoir from Eagle Creek in relation to water temperature and flow, 1962–65 (x indicates period of no data).

opportunity to study the migration of a nonindigenous species. These fish were obtained from a hatchery in the lower Columbia River, transported 120 km. above the reservoir, and released from March 15 to 30 in water that averaged 9.4° C. They did not appear in the Snake River trap until mid-April (fig. 11). The run peaked in mid-May and ended in early June.

The mean lengths of trap samples of coho salmon increased throughout the migration. Migrants averaged 112 mm. (71–140 mm.) early in the season; by the end of the migration period they averaged 131 mm. (110–166 mm.).

Sockeye Salmon

About 473,000 sockeye salmon fingerlings were released in 1965 in the Snake River 88 km. above

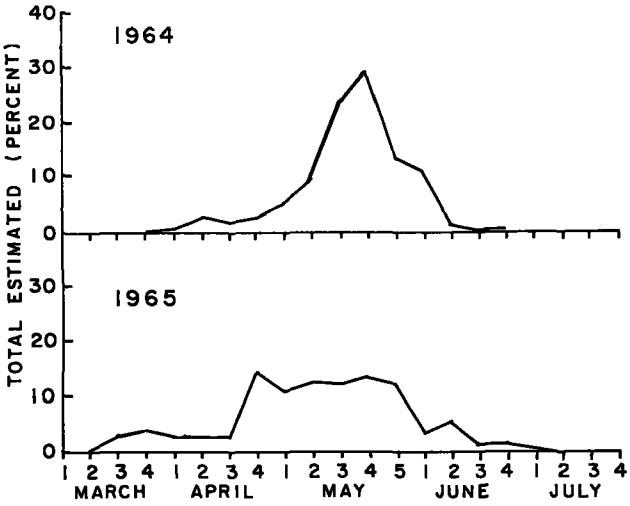

FIGURE 10.—Timing of migration of juvenile hatchery-reared fall chinook salmon (age-group 0) to Brownlee Reservoir from the Snake River, 1964–65.

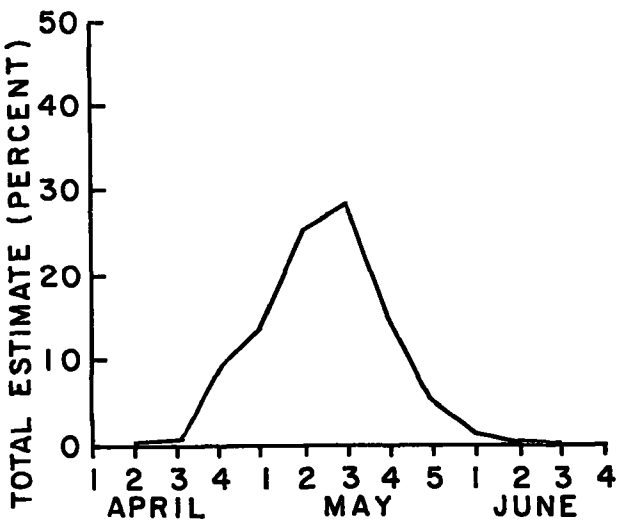

FIGURE 11.—Timing of migration of juvenile hatchery-reared coho salmon from the Snake River to Brownlee Reservoir, 1964.

the reservoir. These fish were reared from eggs obtained in the fall of 1963 from Babine Lake, British Columbia. The eggs were eyed at a hatchery at Maurice Lake, British Columbia, and transported to Leavenworth National Fish Hatchery in Washington, where they were reared until their release in 1965. Releases of 20,000 to 30,000 fish were made 5 days each week from March 15 to April 8, 1965; river water temperatures averaged 9.8° C. The sockeye salmon moved rapidly downstream; the first migrants were recovered within 2 days after the initial release. Peak migration was during the first week of April (fig. 12); by mid-April the migration was nearly complete. Sockeye salmon migrants averaged 121 mm. long (86–175 mm.).

UPSTREAM MOVEMENTS OF JUVENILE CHINOOK SALMON

A late group of chinook salmon fingerlings appeared at the Snake River trap near the end of June or in early July of each year. Because the migrations of fall- and spring-run chinook salmon were essentially completed by this time, the origin of these fish was of interest. Their length was similar to that of age-group I fish from the Weiser River, but examination of their scales revealed that they were fingerlings of age-groups O and I. Growth patterns on their scales showed an area of rapid growth at the margin typical of fish from the reservoir. This scale structure indicated they had moved upstream from the reservoir. This movement was confirmed in 1963 when 12 fin-clipped individuals were caught that had been marked as emigrants from Eagle Creek in the fall of 1962. In 1964, 2.7 percent of the fish captured from this July migration were fall chinook salmon that had been previously tagged and released in the upper reservoir.

According to Durkin et al. (1970), this upstream movement of fish into the Snake River may be related to the environment of the reservoir. The reservoir was rapidly filled early in the 1963 season, and, except for a minor drawdown of 3 m. in May, it was at full pool. Some Eagle Creek fish moved up the reservoir in 1963, possibly because surface currents frequently moved toward the upstream end of the reservoir. Late arrivals may have been attracted upriver by the relatively cooler, oxygenated water as the smolting phenomenon (Hoar, 1963; Conte, Wagner, Fessler, and Gnose, 1966) attenuated and reservoir temperature and oxygen conditions deteriorated (Ebel and Koski, 1968). As the river temperature increased to 20° C., the fish returned to the reservoir. In 1964, when the surface level of the reservoir was lower, Eagle Creek fish were not captured in the Snake River; however, recovery of fall chinook salmon that had been marked and released in the upper reservoir again suggested an upstream response to cooler water.

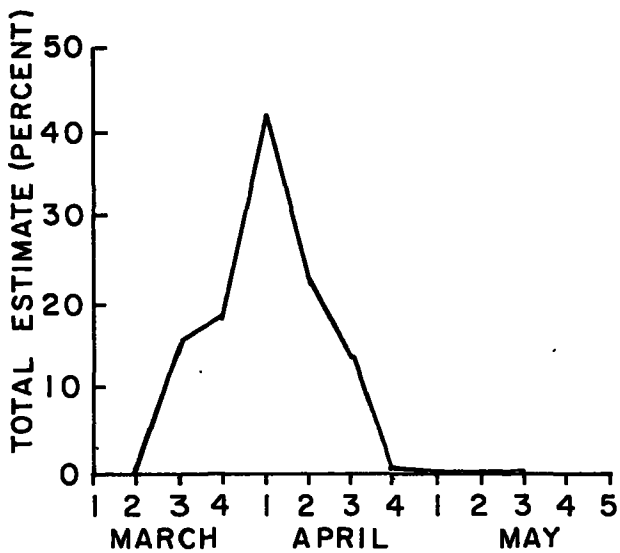

FIGURE 12.—Timing of migration of juvenile hatchery-reared sockeye salmon from the Snake River to Brownlee Reservoir, 1965.

ESTIMATES OF IMMIGRATION

Recruitments by age-group and population were estimated each year from data on release and recapture of marked fish. Estimated recruitment (N) was obtained by dividing the recaptures of marked fish (R) into the number of marked fish released (M) and multiplying by the catch (C).

In 1962, personnel of the Idaho Department of Fish and Game working upstream from the Bureau's migrant-dipper trap marked fall chinook juveniles and released them in the Snake River. These marked fish were used for the 1962 estimate. The marked fish group far exceeded the total catch of the migrant dipper. As a result, a single estimate was made for the Snake River population over the entire season. The 1962 estimate of recruitment for Weiser River chinook salmon was based upon the total catch by the scoop traps of the Idaho Department of Fish and Game and the estimated efficiency of these traps.

In 1963–65, the Snake and Weiser River fish that passed our trap were estimated each week and the values summed to yield the estimated total immigration. Fish for marking were obtained from the migrant dipper catches.

It was sometimes necessary to supply information by extrapolation when reliable data were lacking. When data on catch, recovery of marked fish, or marked fish released were unreliable or lacking, reliable data for 1 or 2 weeks preceding, bracketing, or following were used to supply an approximation of the needed data.

Studies on fish distribution in the Snake River in 1964 indicated that fingerling salmon were more concentrated near the surface during the day than at night (Monan, McConnell, Pugh, and Smith, 1969). Moreover, the increased length of louver leads in 1965 accentuated the difference between the percentage of the migration captured by the traps by day and by night. This difference necessitated the use of two catch figures in estimating the 1965 recruitments. Table 9 shows yearly differences in the ability of the migrant dipper traps to capture fish during the peak of migration.

SNAKE AND WEISER RIVERS

The number of juvenile native chinook salmon that entered Brownlee Reservoir after 1962 decreased each year. One of the reasons was that the adult spawners were intercepted and diverted to hatcheries downstream from Brownlee Dam. Our highest estimate of recruitment was in 1962 when 529,000 young chinook salmon entered from the Snake River (table 10); these fish were offspring of adults that had been transported past the dam and spawned in the fall of 1961. The highest number of juvenile chinook salmon from Weiser River (122,500) was also in 1962; these fish were offspring of spring migrants that had spawned in 1960.

The number of kokanee increased each year; nearly one-half million entered the reservoir in 1965.

Of the hatchery-reared fish released in the Snake River, sockeye salmon had the highest survival to

TABLE 9.—*Ability of migrant dipper traps to capture juvenile salmon during peak migration from the Snake River into Brownlee Reservoir, 1962–65*

Year of migration	Chinook		Coho[1]	Sockeye[1]	Kokanee[1]
	0	I			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1962	2.36	(5)	(4)	(4)	(4)
1963	3.56	16.70	(4)	(4)	(5)
1964	8.13	16.85	13.46	(4)	6.2
1965 a.m.[3]	5.97	(4)	(4)	9.17	6.31
1965 p.m.[3]	2.35	(4)	(4)	7.10	1.10

[1] All age-group I.
[2] 6:00 a.m.–6:00 p.m.
[3] 6:00 p.m.–6:00 a.m.
[4] Not present in migration.
[5] Not tested.

TABLE 10.—*Estimates of juvenile salmon that entered Brownlee Reservoir from the Snake River system, 1962–65*

Year	Native species			Hatchery-reared species		
	Fall chinook	Spring chinook	Kokanee	Fall chinook	Coho	Sockeye
	Number					
1962 [1]	529,000	122,500	(2)	(3)	(3)	(3)
1963	374,000	15,000	500	(3)	(3)	(3)
1964	(2)	6,800	5,500	111,500	69,000	(3)
1965	(2)	3,200	506,800	162,800	(3)	360,000

[1] Calculated from data supplied in part by Idaho Fish and Game Department.
[2] Negligible numbers.
[3] Not present in migration.

the reservoir, and coho salmon the lowest. Survivals from release point to reservoir were inversely correlated with time spent in the river but not to distance traveled (table 11).

TABLE 11.—*Time in river and survival of hatchery fish from release site to Brownlee Reservoir, 1964 and 1965*

Year and distance	Species of salmon	Median release time	Migration peak	Time in river	Released	Estimate of fish passing collection facilities	Survival
				Weeks	*Number*	*Number*	*Percent*
1964	Coho	Mar. 23	Mid-May	7	375,000	69,000	18.4
120 km.	Chinook	Apr. 1	Mid-May	6	250,000	111,500	44.6
1965	Chinook	Mar. 20	Mid-May	7	592,000	162,800	27.5
88 km.	Sockeye	Mar. 27	Early April.	2	473,000	360,000	76.1

EAGLE CREEK

Estimates of migration from Eagle Creek were based on average efficiencies of the louver facility throughout the year (table 12). In 1962, the average efficiency was 10.2 percent but the louver was selective for larger fish. Alteration of the structure in 1963 increased the efficiency to 57.5 percent and eliminated selectivity. Straightening of the river channel above the louver in 1964 provided a straighter angle of approach for the current and further increased the efficiency of the louvers to 91.3 percent during the fall migration. In the spring of 1965, efficiency was less (85.2 percent) as a result of ice and high flows, which created currents that varied in velocity and direction of approach across the face of the louver.

Juvenile fish that entered the reservoir from Eagle Creek in 1962–63 (table 13) were progeny of native adults that were transported around Brownlee Dam in 1960–62. Thereafter natural production in the creek declined markedly because the policy of passing fish changed. Juvenile migrants in 1964–65 were primarily from adults that were surplus to hatchery needs and were transported from a collection facility at Oxbow Dam (19 km. downstream from Brownlee Dam) to holding ponds near the spawning area. Prespawning fish were held in these ponds until nearly mature and then released into Eagle Creek.

TABLE 12.—*Collection efficiencies of the louver system at Eagle Creek, 1962–65*

Year	Efficiency of collection by period of migration	
	Spring	Fall
	Percent	*Percent*
1962		10.2
1963	14.7	57.5
1964	42.0	91.3
1965	85.2	(1)

[1] Not in operation.

TABLE 13.—*Estimates of juvenile spring chinook salmon that entered Brownlee Reservoir from Eagle Creek, 1962–65*

Year of migration	Estimated recruitment by season and age-group					Total
	Spring migration			Fall migration		
	0	I	II	0	I	
1962	(1)	(1)	(1)	116,000	1,200	117,200
1963	600	13,500	(2)	7,500	(2)	22,300
1964	(2)	6,700	(2)	(2)	(2)	7,200
1965	(2)	(2)	(2)	(1)	(1)	

[1] Not in operation. [2] Negligible numbers.

SUMMARY AND CONCLUSIONS

Movements of juvenile salmon and rainbow trout from tributary streams into Brownlee Reservoir were examined in 1962–65 as part of a study on the effect of a large impoundment on the migration and survival of anadromous fish. Estimated numbers of migrant juvenile salmon were determined by sampling of juvenile fish populations that were en route to the reservoir from the Snake and Weiser Rivers and Eagle Creek, the three tributaries supporting indigenous populations of salmon and anadromous rainbow trout. Juvenile fall and spring chinook salmon, kokanee salmon, and rainbow trout entered the upper reservoir via the Snake River. Hatchery-reared fall

chinook and coho salmon were released in the Snake River in 1964 and fall chinook and sockeye salmon in 1965. Migrations from Eagle Creek near the lower end of the reservoir included native spring chinook salmon and rainbow trout.

Progeny of spring chinook salmon from the Weiser River were fish of age-group I that ranged from 94 to 165 mm. long. This migration began before but partially overlapped a migration of fall chinook juveniles from the Snake River. The migration usually peaked in late April and early May. Estimated numbers of fish were: 1962—122,500; 1963—15,000; 1964—6,800; and 1965—3,200.

The migration of juvenile fall chinook salmon (age-group O) from the Snake River began in mid-April, peaked in mid-May, and was almost complete by mid-June. The fish were 33 to 103 mm. long. Estimated recruitments to Brownlee Reservoir in 1962 and 1963 were 529,000 and 374,000. Because few fish were passed above Brownlee Dam after 1962, migrations of wild fish in 1964–65 were negligible.

Migrant salmon from Eagle Creek were of wild populations of spring chinook salmon. The principal migration of juvenile chinook salmon (age-group 0; 53–125 mm.) was in the fall as irrigation decreased and water flows correspondingly increased. Temperatures ranged from 0° to 13° C. A lesser migration of age-groups 0, I, and II (45–168 mm.) occurred in the spring. Estimated recruitments from Eagle Creek were: 1962—117,200 (fall migration only); 1963—22,300; and 1964—7,200.

Native juvenile kokanee salmon (70–155 mm.) were observed in the Snake River each year in June and July, except in 1962. Their migrations were relatively short; most fish migrated in a 1-week period in late June or early July. Estimated recruitment of this species was 500 in 1963, 5,500 in 1964, and 506,800 in 1965.

Juvenile rainbow trout migrating from the Snake River and Eagle Creek were wild steelhead trout and wild and hatchery-reared rainbow trout. The Snake River populations (95–382 mm.) migrated in the spring from mid-March to late July, peaking from mid-April to mid-May. Juvenile trout, 52–285 mm. long, migrated from Eagle Creek in the fall and spring, but the principal movement coincided with high spring flows.

Juvenile fall chinook salmon, reared in a hatchery (age-group 0; 46–135 mm. long), were released in the Snake River above the reservoir during March and April, 1964–65. Some moved downstream past the trapping site within 3 days after release, but the migration peaked in mid-May, which was comparable to native migrations. The migration ended in late June in 1964 and in early July in 1965. Of 250,000 juvenile fall chinook salmon released in 1964, 111,500 were estimated to have entered the reservoir. In 1965, the estimated recruitment was 162,800 of the 592,000 fish released.

Hatchery-reared coho salmon yearlings (71–166 mm.) released in middle to late March 1964, migrated slowly; they appeared at the trap site 4 weeks after the first release, peaked during the first week of May, and continued to migrate until mid-June. Of the 375,000 coho salmon released, 69,000 entered the reservoir.

Hatchery-reared sockeye salmon (86–175 mm.) appeared at the Snake River trap 2 days after their release in mid-March; the migration peaked in the first week of April and was complete by the end of April. An estimated 360,000 of 473,000 fish released entered the reservoir.

Survival to the reservoir of hatchery-reared salmon varied inversely with time spent in the Snake River but was not related to distance of planting site above Brownlee Reservoir.

LITERATURE CITED

BATES, DANIEL W., and RUSSELL VINSONHALER.
1957. Use of louvers for guiding fish. Trans. Amer. Fish. Soc. 86: 38–57.

CONTE, F. P., H. H. WAGNER, J. FESSLER, and C. GNOSE.
1966. Development of osmotic and ionic regulation in juvenile coho salmon *Oncorhynchus kisutch*. Comp. Biochem. Physiol. 18: 1–15.

DEACON, JAMES E.
1961. A staining method for marking large numbers of small fish. Progr. Fish-Cult. 23: 41–42.

DURKIN, JOSEPH T., DONN L. PARK, and ROBERT F. RALEIGH.
1970. Distribution and movement of juvenile salmon in Brownlee Reservoir, 1962–65. U.S. Fish Wildl. Serv., Fish. Bull. 68: 219–243.

EBEL, WESLEY J., and CHARLES H. KOSKI.
1968. Physical and chemical limnology of Brownlee Reservoir, 1962–64. U.S. Fish Wildl. Serv., Fish. Bull. 67: 295–335.

HOAR, WILLIAM S.
1963. The endocrine regulation of migrating behavior in anadromous teleosts. Proc. 16th Int. Congr. Zool. 3: 14–20.

MASON, JAMES E.
1966. The migrant dipper: a trap for downstream-migrating fish. Progr. Fish-Cult. 28: 96–102.

MONAN, GERALD E., ROBERT J. MCCONNELL, JOHN R. PUGH, and JIM ROSS SMITH.
1969. Distribution of debris and downstream migrating salmon in the Snake River above Brownlee Reservoir. Trans. Amer. Fish. Soc. 98: 239–244.

SIMS, CARL W.
1970. Emigration of juvenile salmon and trout from Brownlee Reservoir, 1963–65. U.S. Fish Wildl. Serv., Fish. Bull. 68: 245–259.

TREFETHEN, PARKER S., and DOYLE F. SUTHERLAND.
1968. Passage of adult chinook salmon through Brownlee Reservoir, 1960–62. U.S. Fish Wildl. Serv., Fish. Bull. 67: 35–45.

VOLZ, CHARLES D., and CHESTER O. WHEELER.
1966. A portable fish-tattooing device. Progr. Fish-Cult. 28: 54–56.