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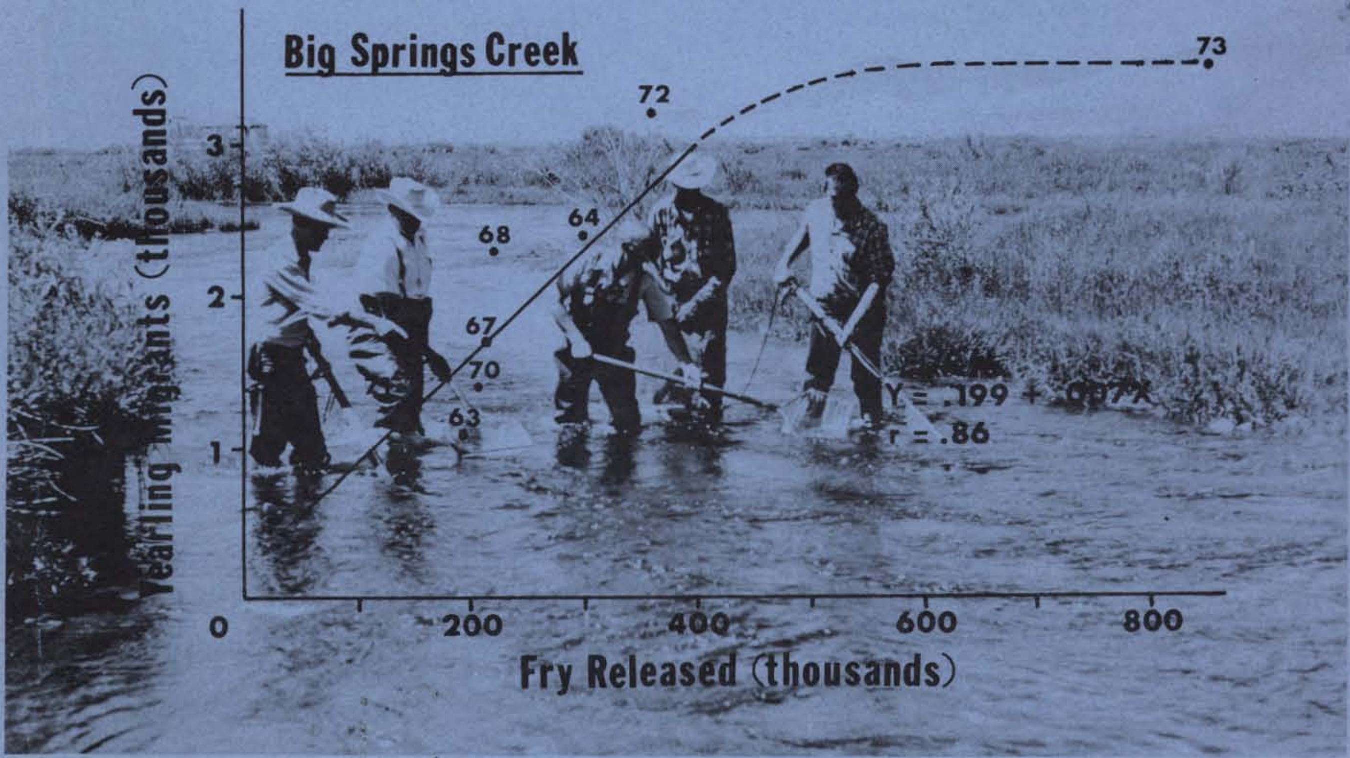
SURVIVAL, PRODUCTION, AND YIELD OF TROUT AND CHINOOK SALMON IN THE LEMHI RIVER, IDAHO

T. C. Bjornn



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Survival, Production, and Yield of Trout and Chinook Salmon in the Lemhi River, Idaho

by
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A Final Report
Federal Aid to Fish Restoration
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Salmon and Steelhead Investigations

of the
IDAHO DEPARTMENT OF FISH AND GAME
Joseph C. Greenley
Director

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ABSTRACT

Steelhead trout (*Salmo gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*), and non-anadromous salmonids were studied in the Lemhi River and a tributary, Big Springs Creek, from 1962 to 1975. Four major points were evaluated: the reintroduction of steelhead trout into the Lemhi River, the production and yield of allopatric trout versus sympatric populations of salmon and trout, the spawner-yield relationship for chinook salmon, and the effects of introduced anadromous fish on resident trout.

Steelhead trout fry that emerged from the gravel of the incubation channel and fry from stack incubators were equally viable in Big Springs Creek. Survival to subyearling migrant stage ranged from 6.4 to 12.0 percent for incubation channel fry and from 4.3 to 15.0 percent for incubator fry.

Steelhead trout fry released into Big Springs Creek in June or July did not begin leaving the stream until fall. Many subyearling rainbow-steelhead trout left Big Springs Creek (in numbers related to the number of fry released) during the fall, winter, and spring following their first summer. Subyearling steelhead that remained in Big Springs Creek for their first winter and the next summer migrated as yearlings during the fall or as smolts during the following spring. The subyearlings that left Big Springs Creek apparently found suitable winter habitat in the upper Lemhi River, where they remained an additional year before migrating seaward as smolts.

The yield of subyearling rainbow-steelhead trout from Big Springs Creek ranged from 5200 to 37,700 (9.5 to 67.7 fish/100 m^2) when seeding rates were 116 to 1532 fry/100 m^2. The yield of yearling rainbow-steelhead trout ranged from 800 to 3500 (1.5 to 6.3 fish/100 m^2). From 400,000 to 600,000 fry released into the stream (approximately 900 fry/100 m^2) would yield 30,000 to 40,000 subyearling migrants and a near maximum number of yearlings.

The largest densities of fish that occurred in Big Springs Creek (150 subyearling chinook salmon and steelhead trout migrants/100 m^2) slowed the growth of subyearling rainbow-steelhead trout slightly, but had no measurable effect on the size of yearling migrants.

The mortality rate of steelhead trout fry (80-90%) during their first summer was independent of fry densities when densities were less than 700 fry/100 m^2. Random encounters with predators (fish and birds) could have caused the density-independent mortality rate observed.

Fish production (tissue elaboration) and yield of migrants (salmon and trout combined) were larger when chinook salmon and steelhead trout were both placed in the stream than when only steelhead fry were released. Steelhead trout production and yield of migrants from a given number of fry were reduced when chinook salmon were added to the stream.

An estimated 2300 to 19,000 steelhead smolts of Big Springs Creek origin left the upper Lemhi River annually during the years of study. A large percentage (39-82%) of the smolts stayed in the creek during their first summer but moved into the upper Lemhi River for their second summer. The large number of steelhead fry released in the upper Lemhi River in 1972 (2.2 million) and 1973 (3.7 million) resulted in an estimated 65,600 and 57,600 steelhead smolts (survival rates 3.0 and 1.6%, respectively). Two to three million steelhead fry released into the upper Lemhi River and Big Springs Creek each year should yield the maximum number of smolts.

Adult steelhead trout returned to the upper Lemhi River in April and May (just before spawning) after spending 2 to 4 years traveling to, from and in the sea. The number of adult steelhead captured at the Lemhi River weir ranged from 14 to 73 for each of the 1962 to 1970 year-classes. The percentage of smolts that returned as adults ranged from 0.5 to 2.2. Except for the 1965 year-class, adult steelhead returning to the Lemhi River did not provide enough eggs to replace those used to stock the stream originally.

The Lemhi River and Big Springs Creek supported twice as many fish during the summer as remained in the stream overwinter. The amount of suitable winter habitat in Big Springs Creek was apparently limited, since most subyearling chinook and many rainbow-steelhead trout left the stream after their first summer. The Lemhi River contained more winter habitat than Big Springs Creek, but large numbers of subyearling chinook salmon and yearling steelhead also left the upper Lemhi River during the fall and winter.

Steelhead fry outnumbered, if not outcompeted, resident rainbow trout fry in Big Springs Creek and caused a reduction in the abundance of resident rainbow trout. Steelhead fry had little, if any, effect on the population of brook trout (*Salvelinus fontinalis*).

Chinook salmon adults entered the upper Lemhi River during the summer and spawned during late August and early September. The relationship was nearly 1:1 between redds counted during spawning ground surveys and the number of female salmon available to spawn.

The number of chinook salmon smolts produced in the upper Lemhi River was directly related to the number of spawners (eggs deposited) for the range of escapements observed. The upper Lemhi River can produce at least 400,000 chinook salmon smolts from a deposition of 4.3 million eggs (1000 redds, 940 females). Spawning escapements during the 1960s and 1970s did not fully seed the rearing area. Increased numbers of juvenile salmon were produced in the Lemhi River during years when the rearing capacity was not fully used by the release of chinook salmon fingerlings from a hatchery in early summer.

Survival, Production, and Yield of Trout and Chinook Salmon in the Lemhi River, Idaho

T. C. Bjornn

INTRODUCTION

In this report I summarize the studies of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*) conducted in the Lemhi River and one of its tributaries, Big Springs Creek, from 1962 through 1975. I evaluated 1) the viability of steelhead trout fry from an incubation channel versus that of fry from stack incubators, 2) the yield of steelhead trout fry and chinook salmon fingerlings, 3) fish production of allopatric and sympatric populations of salmon and trout, 4) the effects of steelhead fry introductions on the resident trout population, 5) the summer and winter capacity of the upper Lemhi River for juvenile salmon and steelhead, 6) smolt-to-adult survival of salmon and steelhead trout, and 7) the spawning escapement needed to seed the rearing area.

The studies in Big Springs Creek began as an evaluation of a steelhead trout reintroduction program in 1962 and those in the Lemhi River began in 1964 with the construction of a fish weir used to enumerate the adult salmon and steelhead returning to the Lemhi River and the number of juveniles migrating seaward.

Chinook salmon and steelhead trout were both indigenous to the Lemhi River drainage, but the steelhead trout were virtually eliminated by a water diversion dam used for hydroelectric power generation. The chinook salmon population may also have been altered by the hydroelectric diversion dam and by temporary dams built for irrigation diversions. Historically both spring and summer chinook salmon were probably present in the Lemhi River. The spring chinook usually arrived during the peak of spring run-off and thus were able to migrate upstream past the diversion dams. The summer chinook that arrived later were unable to get past the diversion dams because of the low flows in the river in July and August.

The author is Leader, Idaho Cooperative Fishery Research Unit.

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Fishery managers generally avoid the stocking of fry because of the high mortality rates and the questionable need for fry in most streams with natural reproduction. Our studies in Big Springs Creek began as an evaluation of the survival of steelhead trout fry released into the stream from an incubation channel adjacent to the stream and in later years from a hatchery, after the eggs were incubated in stack incubators. After I found that steelhead fry would survive in the streams to the smolt stage, I then wanted to know how many smolts Big Springs Creek and the Lemhi River could support and the number of fry needed to get maximum smolt yield.

Chinook salmon and steelhead trout have evolved together in many streams of the Pacific Northwest. Chinook salmon spawn in the fall, and the fry emerge in the spring and remain in the stream one year before migrating to the ocean. Steelhead trout spawn in the spring, and fry emerge in mid-summer. The juvenile steelhead then live in the stream 1 to 4 years (usually 2 or 3) before migrating to the ocean. Because of the differences in time of spawning and fry emergence, subyearling steelhead and salmon have different mean lengths at any given time.

Everest and Chapman (1972), who studied the behavior of sympatric and allopatric populations of steelhead and chinook salmon, found that there was little social interaction between them because of the different sizes of the two species. They assessed microhabitat preferences of steelhead and chinook salmon by relating length of fish at specific locations in streams with various habitat characteristics. They found that subyearling chinook salmon occupied deeper sections of the streams with faster water velocities than were present in areas occupied by steelhead of the same age but of smaller size. Yearling and older steelhead, which were larger than the subyearling salmon at any given time, occupied even deeper and faster water.

Salmon and steelhead had been virtually eliminated from some streams in Idaho. During the early 1960s, Department of Fish and Game personnel began efforts to reestablish these species in streams where they had been reduced or eliminated. Because of the spatial separation between young salmon and trout observed by Everest and Chapman (1972), I theorized that adding chinook salmon to an already existing steelhead trout population might reduce the yield of steelhead smolts, but that the combined yield of salmon and steelhead smolts would exceed the yield of either species alone. Everest and Chapman were unable to measure the yield of smolts in the streams they studied, but I was able to evaluate the production and yield of allopatric trout and sympatric salmon and trout populations in Big Springs Creek in 1969, 1971, 1972, and 1973 after the studies of steelhead fry survival had been completed.

In 1964, studies were begun to 1) assess the escapement of adult salmon into the Lemhi River, 2) relate counts of adult salmon at the Lemhi River weir to counts of redds upstream from the weir, 3) assess the chinook smolt yield from natural spawning in the upper Lemhi River, 4) evaluate the smolt yield when hatchery-reared chinook fingerlings were released into the rearing areas, and 5) assess the survival of salmon from the smolt to the adult stage. The chinook salmon run entering the upper Lemhi River was naturally produced except for our test groups of fingerlings released into the rearing areas in 4 of the study years.

The redds made by spawning chinook salmon in Idaho streams have been counted since the early 1950s and used as an index of salmon abundance and spawning escapement. After the construction of the Lemhi River weir in 1964, the number of salmon entering the upper Lemhi River spawning area was enumerated and then related to the redd count made later that fall. The yield of salmon smolts from natural spawning escapements of various sizes and from hatchery fingerlings released in early summer were also evaluated.

Until recent years the chinook salmon and steelhead trout entering the Snake River were produced entirely by natural spawning and rearing. Chinook salmon rearing facilities have been constructed in the drainage in recent years and more are planned. Mortality related to the dams in the Columbia and Snake rivers has placed the runs of wild chinook salmon and steelhead trout in jeopardy. Meanwhile the increase in abundance of hatchery fish has created a serious mixed-stock management problem. If wild stocks of salmon and steelhead are to be perpetuated, fishery managers must know the capacity of natural rearing areas and the number of spawners required to adequately seed those areas.

The salmon that spawned in the Lemhi River were exclusively spring chinook salmon that enter the Columbia River during March, April, and May, judging from the recovery in the Lemhi River of salmon tagged at Bonneville Dam (Fish Comm. of Oregon 1975). Summer chinook salmon were probably present in the Lemhi River before man began diverting water from the river, but have now been eliminated from the drainage. The summer chinook run may have been larger than the spring run under pristine conditions because the time of spawning and fry emergence of summer fish might have resulted in a more fully seeded rearing area. Considering the water diversions present in the 1970s, reintroduction of summer chinook salmon into the Lemhi River seems impractical; however, the production of spring chinook smolts can be increased by adding hatchery fingerlings to the stream each summer.

THE STUDY STREAMS

The Lemhi River, in east central Idaho (Fig. 1), drains into the Pacific Ocean via the Salmon, Snake and Columbia rivers. It flows 90 km (59 miles) from its source at the confluence of Eighteen Mile and Texas creeks at Leadore, Idaho and enters the Salmon River 1241 river km (771 miles) upstream from the Pacific Ocean. Big Springs Creek, formed by several springs that discharge from the toe of the broad alluvial fans in the valley, flows parallel with the upper Lemhi River throughout its 8-km length and joins the Lemhi River 77 km upstream from its mouth. The two streams meander through a flood plain 0.8 to 1.6 km wide.

Big Springs Creek and the Lemhi River are productive streams (total dissolved solids, nearly 300 parts per million). During these studies, the volume of flow in both

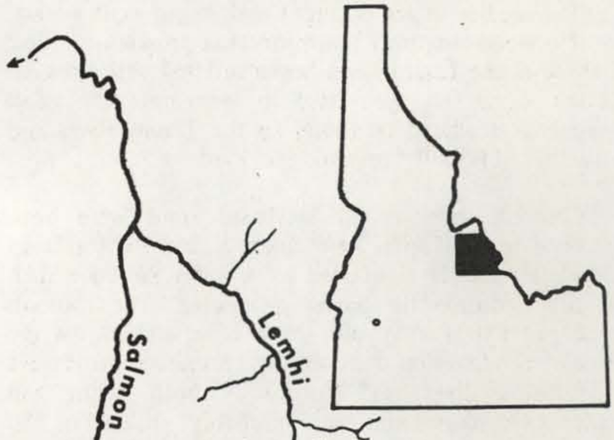

Fig. 1. Lemhi River drainage in Idaho, showing location of fish weirs on the Lemhi River and Big Springs Creek.

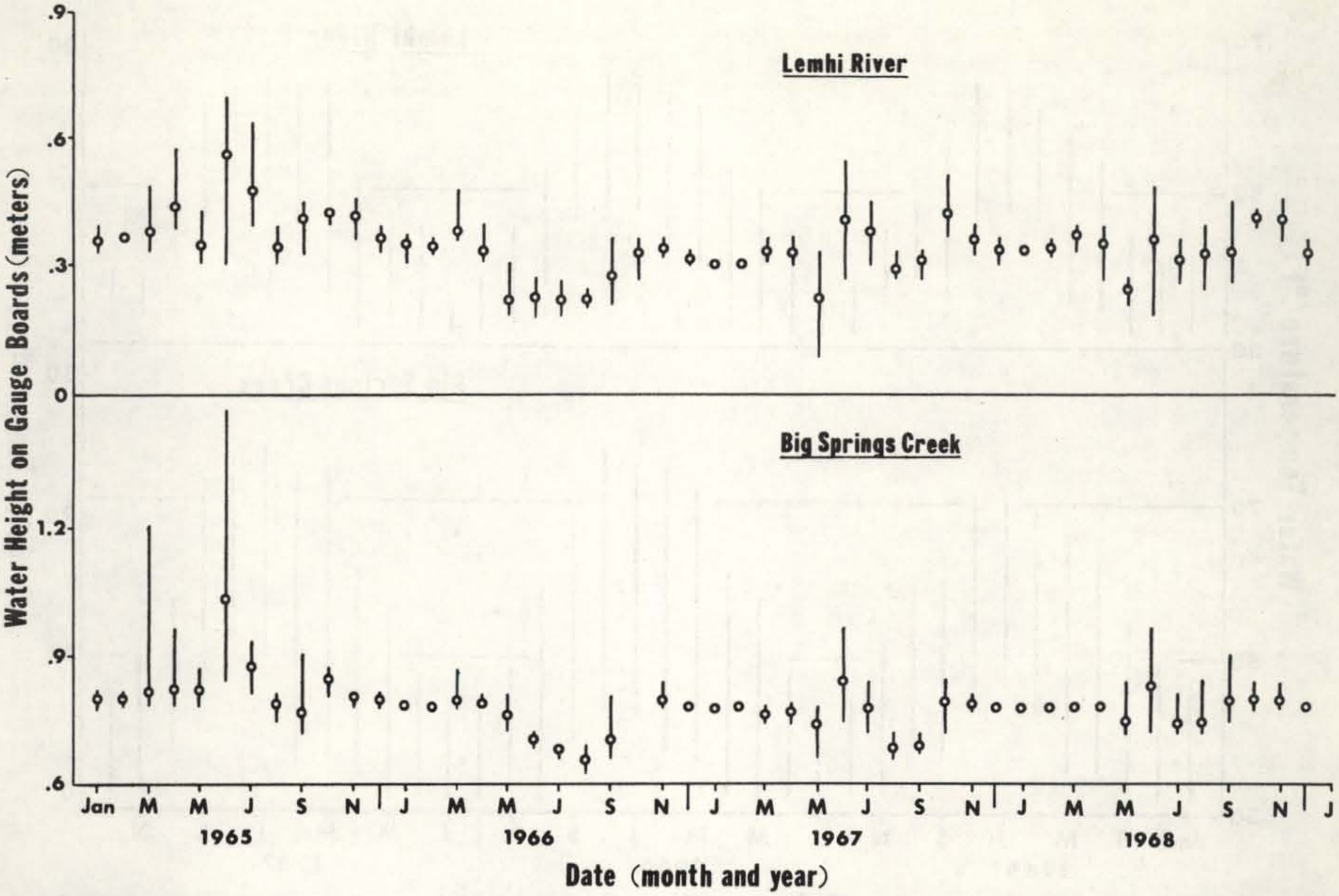

Fig. 2. Monthly means (circles) and ranges (vertical lines) of gauge board readings at the Lemhi River and Big Springs Creek weirs, 1965-1968.

streams usually fluctuated within a narrow range (Fig. 2). Use of water from the Lemhi watershed for irrigation influenced discharge patterns in the Lemhi River and Big Springs Creek more than any other factor. Peak discharge of snow melt normally occurred in late May and early June, the same time that farmers began withdrawing water from both streams and their tributaries. Flow in the tributaries exceeded the needs for irrigation and entered the study streams in large quantities only in those years when the snow pack was deep in the surrounding mountains and abnormally large amounts of precipitation fell in the valleys during May and June – e.g., 1965 (Fig. 2). Irrigation water spread on the alluvial fans in the valley entered the study streams as ground water 2 to 6 months later and increased the flow in the streams during the late summer and fall.

Temperature of the streams at the weirs followed a relatively constant seasonal pattern from year to year (Fig. 3). Fluctuations in mean monthly temperatures between years did not exceed more than 1 to 2° C. Maximum and mean temperatures of Big Springs Creek usually exceeded those of the Lemhi River at the weirs, probably because cool ground water entered the Lemhi River near the weir site. Daily fluctuations in temperature ranged from nil in the winter, when ice flowed in the streams, to more than 14° C in the summer. Maximum summer temperatures in Big Springs Creek briefly exceeded 24° C on many days. Daily minimum temperatures in summer ranged from 7 to 13° C, depending on the nighttime air temperatures.

Horned pondweed (*Zanichilla palustris*) and buttercup (*Ranunculus aquatilis*) formed dense mats of vegetation in the upper Lemhi River and Big Springs Creek during the summer and fall. The vegetation died and drifted from the streams during the fall and winter and the streams then lacked such vegetation until June, when new plant growth began. The mats of vegetation grew in the stream channel, filled the stream in riffle areas, increased water depth, decreased velocity, and provided midstream cover for fish and invertebrates during the summer.

Before the reintroduction of juvenile steelhead trout, the streams contained large self-sustaining populations of resident rainbow trout (*Salmo gairdneri*) and chinook salmon and smaller populations of brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium*

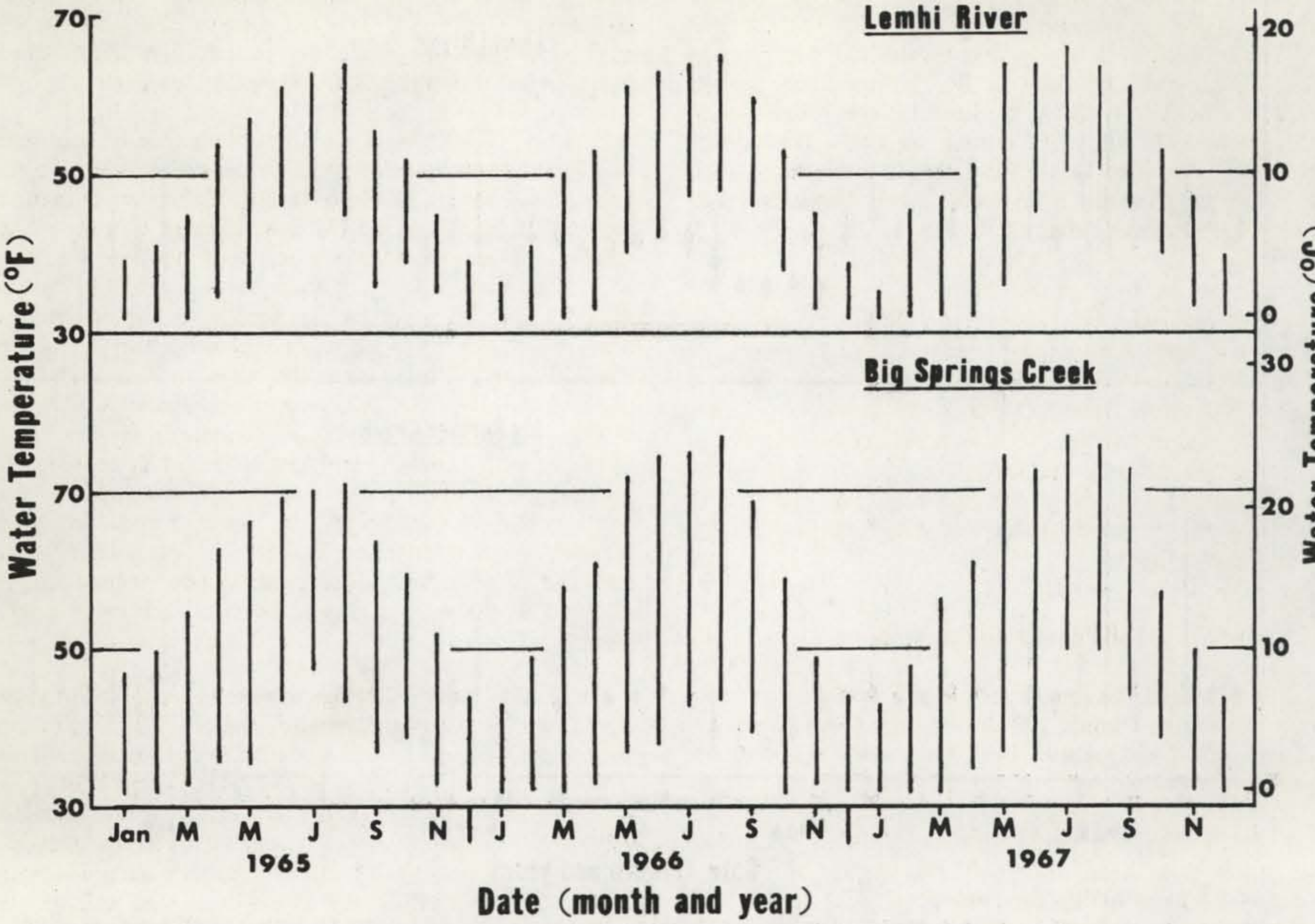

Fig. 3. Monthly ranges of maximum and minimum water temperatures for the Lemhi River and Big Springs Creek at the weir sites, 1965-1967.

williamsoni) and sculpins (*Cottus* sp.). The chinook salmon, mountain whitefish, and sculpins were indigenous to the stream. Hatchery rainbow trout and brook trout had been released into the streams in prior years. The self-sustaining population of resident rainbow trout could have developed from steelhead trout formerly present in the Lemhi River, or from hatchery trout released into the streams.

GENERAL METHODS

Routine annual activities for many phases of these studies included releasing fry and fingerling trout and salmon into the streams, assessing the abundance and production of fish in the streams, monitoring the yield of juvenile salmon and trout migrants, and counting the adults returning to the Lemhi River and the redds made by spawning salmon. Detailed descriptions of the procedures used in different parts of the studies were given by Bjornn (1966), Holubetz (1967), Goodnight (1970), and Bowler (1972).

Releasing Fry and Fingerlings

From 64,500 to 853,200 steelhead trout fry were released into the mainstream of Big Springs Creek during the years 1962 to 1974; 2.16 million steelhead trout fry were released into the Lemhi River in 1972 and 3.71 million in 1973. The fry were usually transferred from incubator stacks to tank trucks and transported to the release sites. In Big Springs Creek, the fry were released at the incubation channel (upper end of stream) and at a site about midway between the origin and the mouth of the stream. In the upper Lemhi River the fry were released at bridges and other points accessible to large transport trucks. The steelhead fry released in Big Springs Creek were from Clearwater River stock (mainly from Dworshak National Fish Hatchery) in all years except 1966, 1967, 1972, and 1973, when they were from the mid-Snake River stock. Fry released in the Lemhi River were from the Snake River stock in 1972, and from the Clearwater River stock in 1973. The steelhead fry were released from mid-June to the first of August.

Chinook salmon fry (Lemhi River stock) were released into Big Springs Creek near the incubation channel in December 1967 (156,000) and 1968 (171,000). Chinook salmon fingerlings released in later years (1969, 1970, and 1971) had been held in a hatchery until late May or early June. The number released in Big Springs Creek ranged from 21,100 to 291,600; in the Lemhi River, 900,000 were released in 1974 and 1.14 million in 1975. The salmon released in the upper Lemhi River, and in Big Springs Creek in 1971, were mostly from Rapid River Hatchery (mid-Snake River stock of spring chinook).

The main stem of Big Springs Creek contained an estimated 55,700 m^2 of stream area. The fry stocking rate in the main stem of the stream ranged from 116 to 1532 per 100 m^2. The number of adult female steelhead needed to achieve a similar seeding rate would range from 12 to 171 adult females (5000 eggs per female) if all eggs survived and entered the stream as fry, or from 48 to 684 if only 25 percent of the eggs survived. The seeding rate used in the Lemhi River was within the range used in Big Springs Creek.

Fall Population Estimates

I estimated the abundance of age 0 rainbow-steelhead trout (fish that I could not distinguish as being resident rainbow trout or juvenile steelhead trout) and chinook salmon in the main stem of Big Springs Creek in the fall of 1969 and 1971 through 1973, to estimate fish production. In all 4 years catch-removal methods of population estimation were used – in 1969 the Leslie (or Delury) method described by Ricker (1958), in 1971 the removal method described by Zippin (1956, 1958), and in 1972 and 1973 the two-catch method described by Seber and LeCren (1967), because a large proportion of fish could be collected during consecutive passes through the sample sections with the electrofishing gear.

I estimated the abundance of fish in the main stem of Big Springs Creek by estimating abundance in six or more sample sections of the stream and then expanding those estimates to the entire stream. In 1969, several short sections (usually 30 to 60 m long) evenly distributed throughout the stream were used. In 1971 and later years, I divided the main stem of the stream into six equal lengths and systematically selected one section (about 150 m long) to sample in each part of the stream (Fig. 4). The first section was located by pacing downstream from the tributary forks a randomly selected distance. Each of the remaining sections was located by pacing a constant distance (1400 paces) from the end of the preceding section.

In 1969, a typical sample section usually consisted of a pool or run bounded by riffles on either end to minimize movement of fish into or out of the sample section during electrofishing. In 1971, we increased the size of the sample sections to include a series of pools and riffles, with riffles serving as the boundaries on either end (Fig. 5). In 1969, the netting crew was unable to net all the fish from pools with many fish after they were stunned by the electrofishing gear; consequently, a few drifted out of the pool on our first pass and were not available for capture in later passes. In the longer sample sections used in 1971 through 1973, the crew still lost some fish from the first pool, but fish that moved downstream from the second and third pools usually held in the next pool and were available for collection during the next pass. Thus, most fish were available for capture during later fishing efforts and one of the assumptions of the two-catch method was more fully met.

In 1969 and 1971, the crew made repeated population estimates during the summer and fall. The area of the sample sections was 4 to 7 percent of the total stream area in 1969 and 7 to 13 percent in 1971. During the later years with only a single fall population estimate, we sampled 2.1 percent of the area in 1972 and 11.6 percent in 1973. In 1969, a pass or fishing effort through a sample section consisted of starting at the downstream end and fishing upstream through the section. In later years a pass consisted of starting at the downstream end, fishing upstream, and then fishing back downstream. The second pass was a repetition of the first effort. Fish were removed from the stream as they were caught with the electrofishing gear and held in perforated plastic garbage cans until they could be counted and measured by species after the final fishing effort. After the fish were counted, they were returned to the sample section.

The estimates of fish abundance within the sample sections were relatively precise; 95 percent confidence limits were usually less than ± 10 percent of the mean. The estimates of fish abundance within the sample section were accurate, first because we met the requirements of

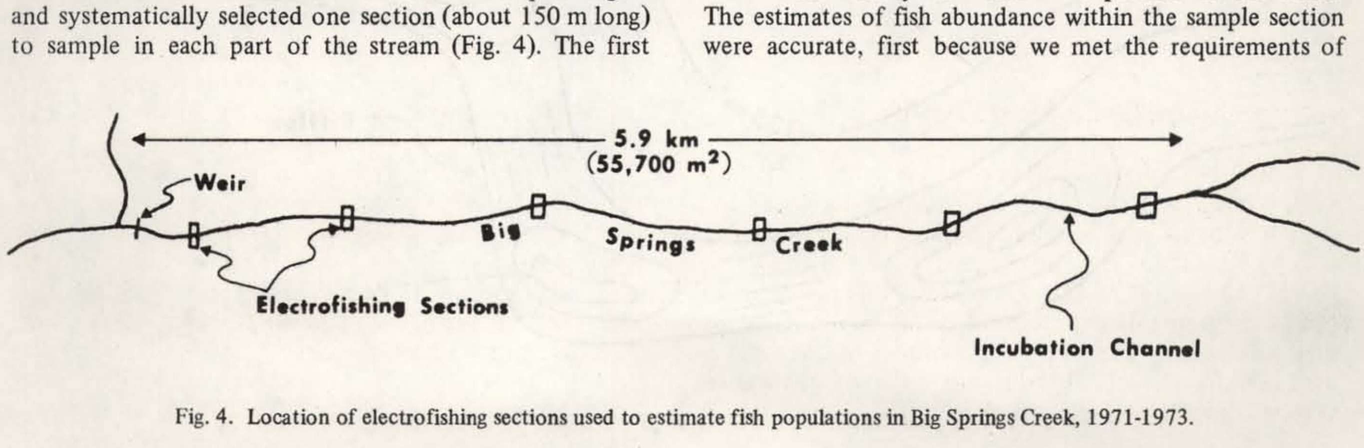

Fig. 4. Location of electrofishing sections used to estimate fish populations in Big Springs Creek, 1971-1973.

the two-catch method and second because we could remove virtually all of the fish from the sample section in two fishing efforts.

The accuracy of the population estimates for the entire main stem of Big Springs Creek depends on the validity of our assumption that the sample sections were representative of the rest of the stream. I believe the sample sections were representative of the unsampled portions of the stream and that the population estimates were reasonably accurate. After sampling the fish populations in Big Springs Creek, I concluded that the fish were not uniformly or randomly distributed through the length of the stream. I concluded that randomly selecting the locations of the small number of sections (6) that we sampled could lead to larger inaccuracies in the population estimates than if we selected the sites systematically. If there was an inaccuracy in the population estimates, the inaccuracy should be consistent from year to year since the sample sections were in nearly the same location each year.

Production Estimates

To evaluate the effects of adding chinook salmon to an already existing allopatric steelhead trout population, I released juveniles of both species into the stream, assessed the production (weight of tissue elaborated) and monitored the yield as subyearlings and yearlings that migrated from the stream.

In the initial attempts to release large numbers of chinook salmon into Big Springs Creek, I placed eyed eggs in the incubation channel, but the large amount of organic debris that entered the channel during the fall caused an oxygen deficiency, and the eggs smothered. I then incubated eggs in a hatchery and released chinook salmon fry into the stream during December. The December release time was ahead of the natural emergence time (February and March) observed in the Lemhi drainage, but was the only time I could release swim-up fry into the stream with the incubation facilities available. Many of the fry released in 1967 and 1968 migrated downstream out of the stream soon after release. Insufficient numbers of chinook salmon subyearlings were left in the stream the following summer to provide sympatric populations of chinook salmon and steelhead trout.

The downstream migration of the chinook salmon fry released into Big Springs Creek in December was not an unusual phenomenon. In the Lemhi River, large numbers of naturally produced chinook salmon fry migrated downstream out of the nursery areas soon after emergence in February and March. The downstream migration of chinook salmon fry decreased as water temperatures warmed in April and May. I concluded that chinook salmon fingerlings would have to be released into Big Springs Creek in late May for the fish to stay in the stream and create a sympatric population. Consequently, in 1971 and 1972 the chinook salmon were held in a hatchery until early June when they were released in Big Springs Creek at a mean total length of 50 to 60 mm (Table 1).

In the studies of sympatric populations, I planned to release approximately 300,000 steelhead fry and a similar number of chinook salmon fingerlings because a good base of steelhead yield data was available for releases of fish of that size from previous years of study. In 1971, 255,000 chinook salmon fingerlings were released in early June but only 136,000 steelhead trout fry were available, and they could not be released until 2 August – much later than the

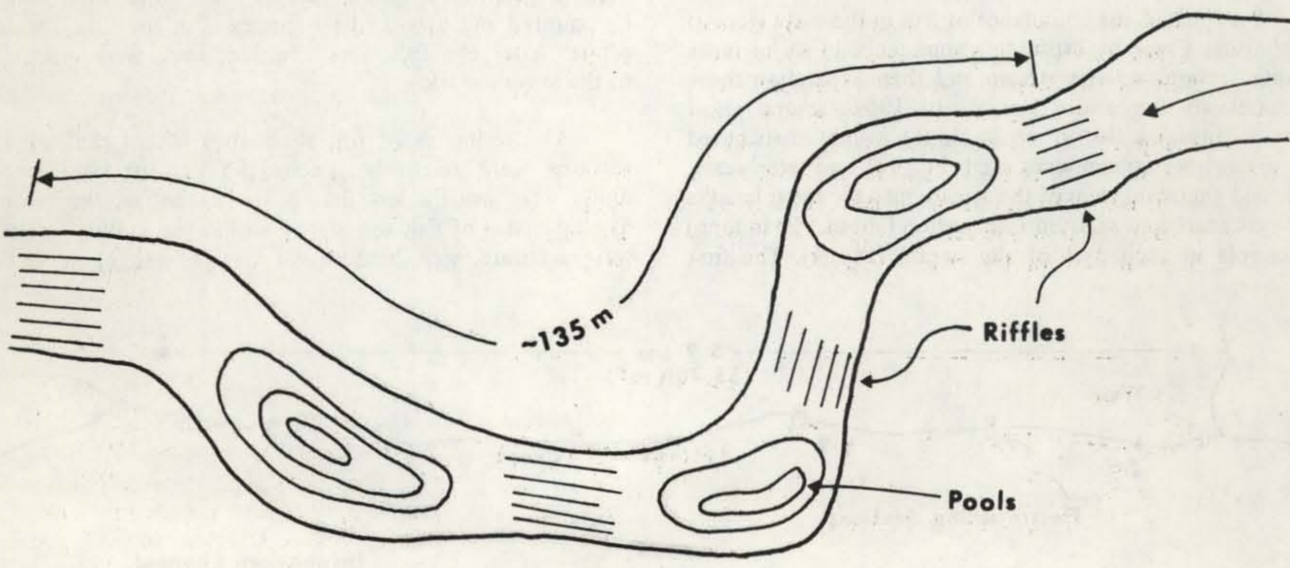

Fig. 5. Typical pool-riffle section of Big Springs Creek used for electrofishing, 1971-1973.

Table 1. Number of steelhead fry and chinook salmon fingerlings released into Big Springs Creek for studies of production and yield of allopatric and sympatric populations of salmon and trout.

Phase of study and year of release	Steelhead fry		Chinook fingerlings	
	Date	Number	Date	Number
Allopatric				
1969	July 1	327,400	–	–
1973	June 14	853,200	–	–
Sympatric				
1971	August 2	136,800	June 4-8	255,500
1972	June 21	358,190	June 1	291,600

fry were stocked in 1969 (Table 1). In 1972, I released 292,000 chinook salmon fingerlings into the stream on 1 June and 358,000 steelhead fry on 21 June.

In 1973, the stream was stocked with 853,000 steelhead trout fry on 14 June. I wanted to release at least 600,000 steelhead fry into the stream to compare production and yield from a release of steelhead alone comparable in number to the combined release of chinook and steelhead in 1972. I also wanted to test the upper limits of the rearing capacity of Big Springs Creek for subyearling steelhead by releasing a large number of fry. Before 1973, 358,000 was the largest number of fry released and the yield of downstream migrants for releases up to that number had been proportional to the number of fry released. The large number of steelhead fry was released in 1973 to gain information on both rearing capacity and allopatric-sympatric segments of the studies.

To estimate production (tissue elaboration) of age 0 rainbow-steelhead trout and chinook salmon, the number and weight of fish at the beginning of the growing period (number and weight of fish released) and the number and weight of fish at the end of the growing period (from the fall population estimates) were used. The biomass at the start and end of the growth period and the instantaneous rates of mortality (Z) and growth (G) were calculated, using the following formulas presented by Chapman (1971):

$$Z = \frac{-(\log_e N_2 - \log_e N_1)}{\Delta t}$$

where N_1, N_2 = numbers of fish present at times t_1 and t_2, respectively.

$$G = \frac{\log_e \bar{W}_2 - \log_e \bar{W}_1}{\Delta t}$$

where $\bar{W}_1, \bar{W}_2$ = mean weights of fish (g) at times t_1 and t_2, respectively.

In using these formulas, I assumed that both growth of fish and population decrease were exponential during the time period involved.

The mean biomass ($\bar{B}$) in grams of fish during this time period was calculated with another formula given by Chapman for the situation where the instantaneous growth rate is larger than the instantaneous mortality rate:

$$\bar{B} = \frac{B_1 (e^{G-Z} - 1)}{G - Z}$$

Production in grams was calculated as $P = G\bar{B}$ (Table 2).

The time between the initial and the final measurements of population size and mean weight ranged from 2 to 3.5 months. Growth of fish and population decrease may not be exponential over such a long period. In 1969 and 1971, when the abundance and mean weight of fish were measured at shorter intervals during the growth period, neither population decrease nor fish growth was strictly exponential between the first and final measurements (Fig. 6). The abundance of both rainbow-steelhead trout and chinook salmon decreased at a faster rate during their first month in the stream than during the latter part of the growth period. Because of the assumption that the population decreased at an exponential rate throughout the growth period when, in fact, it decreased at a fast rate early in the growth period and at a slower rate later, the production estimates were biased in a positive direction. The assumption that fish growth was exponential over the entire growth period, when, in fact, growth slowed during the latter part, introduced a negative bias into the production estimates. These two sources of error partially compensated for one another, but the production estimates in which only the initial and final measurements were used were larger than the estimates made in 1969 and 1971 when time intervals between measurements were shorter (Table 2).

Because the estimates of production for 1972 and 1973 were known to contain a positive bias, I adjusted the estimates by the rate of bias in the estimates for 1969 and 1971. In 1969, when steelhead fry were released in June and only the initial and final population estimates were used, the estimate of production was 47 percent larger than the production estimated from repeated population sampling throughout the growing season. Inasmuch as steelhead fry were released in June in 1972 and 1973 also, I assumed the production estimates in those years contained the same positive bias as in 1969 and adjusted the estimates accordingly (Table 2). For chinook salmon, the estimate of production in 1971, using only the initial and final population estimates, was 18 percent larger than the estimate obtained from repeated population samplings throughout the summer. Assuming that the 1972 estimate of chinook production contained a similar positive bias, that estimate was adjusted accordingly.

October 1 was designated the end of the growth period for rainbow-steelhead trout and September 1 for chinook salmon. Although growth of steelhead slowed during September, some growth occurred, whereas growth of chinook salmon slowed during August and virtually ceased during September (Fig. 6).

Assessing the Yield of Juveniles

I defined yield as the number of juvenile rainbow-steelhead trout or chinook salmon that migrated from Big Springs Creek or the upper Lemhi River. Although yield is commonly thought of as the harvest from a fishery, the yield of juvenile trout and salmon that would migrate to the ocean and return as adults was the concern in these streams. Because the primary interest was the number of juvenile steelhead and salmon that left the streams, I did not include fish taken in the sport fishery as part of the yield. I did not conduct a census of the fishery in the stream, but since relatively few anglers fished there, I believe the yield of migrant steelhead was not appreciably affected by the fishery. The number of downstream migrants for each year-class was estimated from counts of fish at the Big Springs Creek and Lemhi River weirs.

The weir in Big Springs Creek was located near the stream mouth and the one in the Lemhi River was about 48 km (29.8 miles) upstream from the mouth (Fig. 1). The weir in Big Springs Creek consisted initially of inclined screen traps to capture downstream migrants. Later a large rotary drum screen with a bypass trap was installed (Fig. 7) to reduce maintenance and pass the large amounts of aquatic vegetation that drifted in the stream. The entire flow of the stream passed through the screens and fish moving downstream entered the traps. The weir was usually operated 5 days each week, unless ice formation or equipment breakdown interfered. The total number of migrants

Table 2. Population estimates and mean weights of age 0 rainbow-steelhead trout and chinook salmon in the main stem of Big Springs Creek; estimates of biomass (B), instantaneous mortality rate (Z), instantaneous growth rate (G), mean biomass ($\overline{B}$), and production (P) based on initial and final population estimates and on repeated population estimates; percentage positive bias in production estimates using initial and final population estimates; production estimates adjusted for bias for years 1969, 1971, 1972, and 1973.

Year, species and date	Population estimate $\hat{N}$	Mean weight $\overline{W}$	Biomass (kg) B	Instantaneous rates: Mortality Z	Instantaneous rates: Growth G	Mean biomass (kg) $\overline{B}$	Production estimates (kg): Initial-final estimates P	Production estimates (kg): Repeated estimates P	Production estimates (kg): Percentage bias	Production estimates (kg): Adjusted for bias P
1969, rainbow-steelhead										
June 30	322,400	0.15	48.4	2.01	3.65	122.6	447.6	304.8	+46.9	304.8
October 1	43,000	5.8	249.4							
1971, rainbow-steelhead										
August 2	136,800	0.19	26.0	2.31	3.37	46.0	154.9	133.0	+16.5	133.0
October 1	13,600	5.5	74.8							
1971, chinook salmon										
June 5	255,500	1.6	408.8	1.53	1.84	479.3	881.8	748.4	+17.8	748.4
September 1	55,100	10.1	459.6							
1972, rainbow-steelhead										
June 21	358,200	0.15	53.7	2.21	3.40	103.3	351.2	–	+47.0[a]	238.9
October 1	39,200	4.5	176.4							
1972, chinook salmon										
June 1	291,600	1.5	437.4	1.35	1.85	567.5	1049.9	–	+18.0[a]	889.8
August 22	75,400	9.5	716.3							
1973, rainbow-steelhead										
June 14	853,200	0.15	128.0	2.66	3.64	216.6	788.3	–	+47.0[a]	536.3
October 1	59,600	5.7	339.7							

[a] Assumed percentage bias based on 1969 for steelhead and 1971 for chinook.

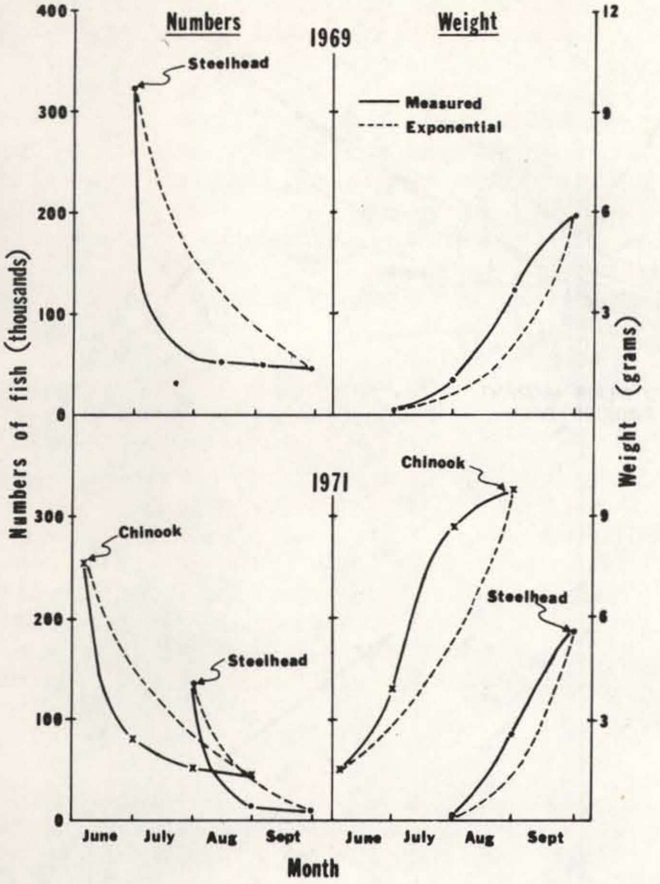

Fig. 6. Measured versus exponential decrease in numbers and increase in weight of age 0 rainbow-steelhead trout and chinook salmon in Big Springs Creek during the summers of 1969 and 1971.

was estimated by multiplying the monthly catch by the ratio: number of days in month/number of days of weir operation.

I estimated the number of juvenile salmon and trout migrating downstream out of the upper Lemhi River from catches in the louvre trap and with a mark-and-recapture program. The louvre guidance system and downstream migrant trap in the Lemhi River weir (Fig. 8) were operated year-round except for brief periods when cold weather caused severe icing. Because most of the fish moved downstream during periods when the weir was operating efficiently, I believe the estimated numbers of smolt-sized migrants are reasonably accurate.

Two assumptions were necessary in the mark-and-recapture program used to estimate the total number of migrants passing the Lemhi River weir site: first, that the migrants captured at the weir and released back upstream in the river would again migrate downstream past the weir site, and second, that the marked fish were randomly distributed in the river as they passed the weir site. If all marked fish did not return downstream past the trapping site or were not as readily captured as unmarked fish the second time, then my estimates of the number of downstream migrants contain a positive bias.

The louvre guidance facility and downstream migrant trap were at the downstream end of a barrier rack installed across the river at a 60° angle to the direction of flow. The

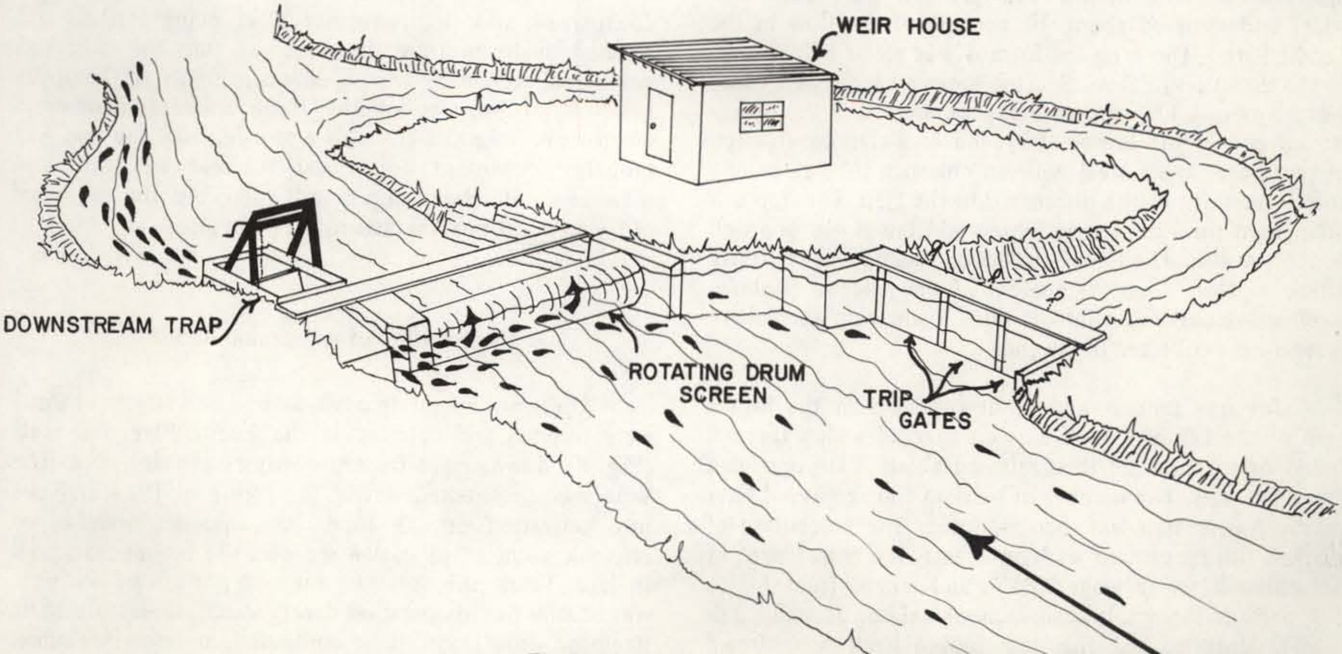

Fig. 7. Big Springs Creek weir.

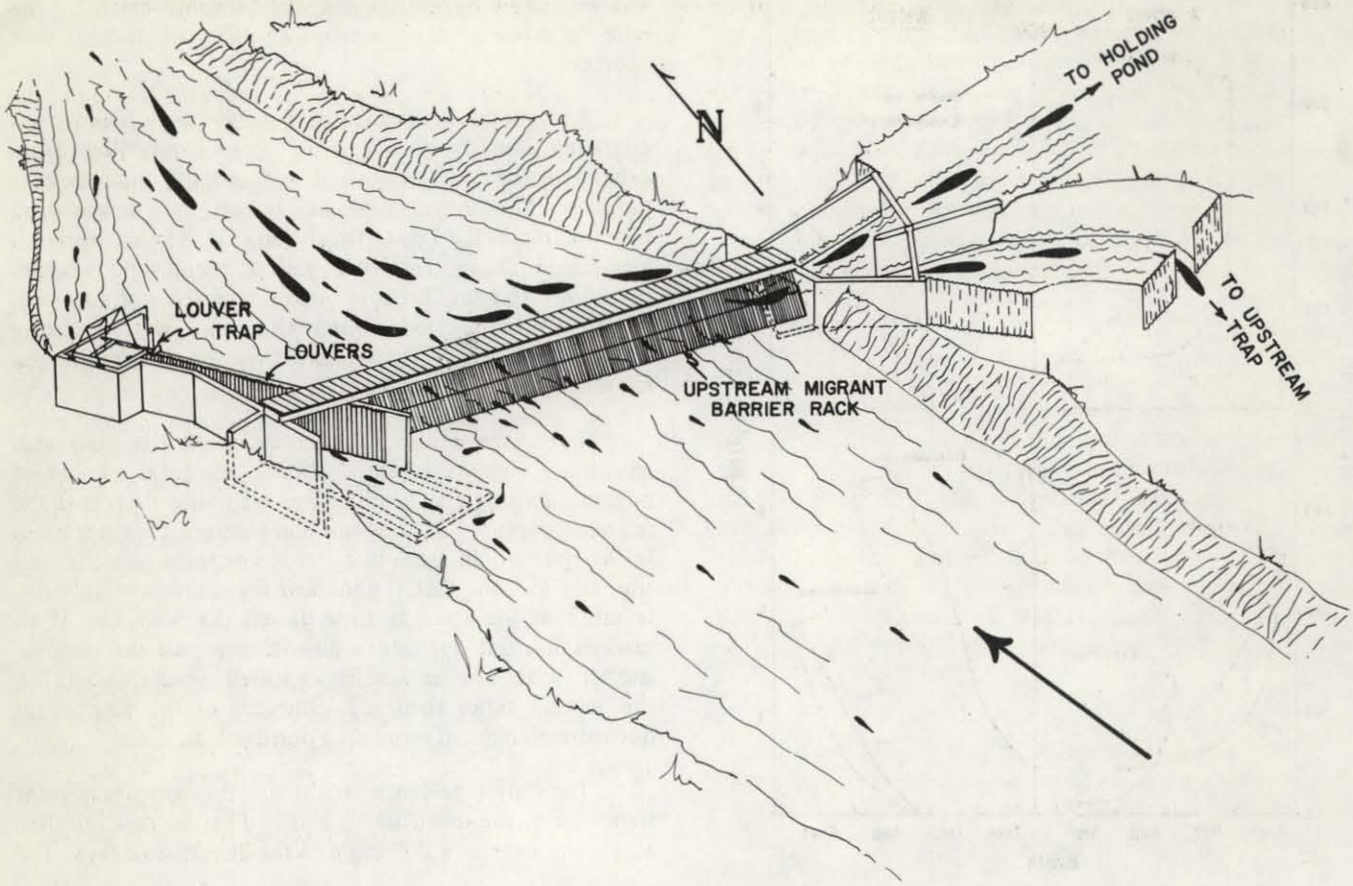

Fig. 8. Lemhi River fish weir.

upstream opening of the louvre array was about 2 m wide, and sampled about 10 percent of the flow in the Lemhi River. The array of louvres was set at a 20° angle to the direction of flow. Spacing between the louvre vanes was 50 mm. A 150-mm wide bypass, located at the downstream end of the louvre array, led to a trap constructed of perforated plate steel with an entrance tube extending about one-third of the distance into the trap. The trap was disengaged from the louvre bypass and raised out of a well to remove fish. The louvre collection facility was relatively efficient. More than 90 percent of the juvenile rainbow-steelhead trout and chinook salmon entering the louvre system were collected in the trap.

Juvenile salmon and trout collected in the louvre trap of the Lemhi River weir were marked with a thermal brand or fin clip and then released about 3 km upstream from the weir. The number of marked fish recovered later in the louvre trap was then recorded. The percentage of marked fish recaptured was consistently less than 1 percent for chinook fry (average 0.35%) and ranged from 1.7 to 5.2 percent for smolt-sized chinook salmon (usually 3.0-3.5%). Most marked fish that moved back downstream were recaptured within a week after release.

Chinook fry might be the least likely to return downstream past the weir site after being marked and released upstream from the weir, and thus the estimated number of salmon fry moving downstream out of the upper Lemhi River might be inflated. If the estimated number of downstream migrants contains a positive bias, the bias was probably consistent from year to year and thus the spawner-smolt relationship is still valid, but the estimates of fry-to-smolt survival rates might be in error.

Enumeration of Adults and Redds

Upstream migrating adult salmon and steelhead trout were trapped and counted at the Lemhi River fish weir (Fig. 8), downstream from the major spawning area. The weir was constructed during the spring of 1964 and put into operation on 23 June. An unknown number of chinook salmon had passed the weir site before that date. In later years, the upstream migrant portion of the weir was usually put in operation during March, to capture adult steelhead trout, and then continued in operation until the end of the chinook salmon migration in September.

In 1971, the weir was not operated from 1 to 26 June because the spring runoff was extraordinarily large. Some adult salmon may have passed the site while the weir was out of operation, but, if so, the number was probably small. The upstream migration of chinook salmon is usually retarded by turbid water, such as occurred during the 1971 spring runoff, and since only two adult salmon were caught in the first 6 days after operation of the weir was resumed on 26 June, I suspect that few, if any, salmon had reached the Lemhi River weir site prior to late June.

The weir for collecting upstream migrants consisted of a fence of steel grating placed at a 30^{o} angle to a line perpendicular across the river (Fig. 8). As fish approached the fence they moved upstream and across the river into a bypass channel and then into a trap. The fish caught in the trap were counted daily, or more often if necessary, by raising the false floor and allowing the fish to swim out over a marked measuring board. The salmon were classified on the basis of their length as age 3_2 (less than 61 cm long), 4_2 (61-84 cm long), or 5_2 (longer than 84 cm).

Not all chinook salmon released upstream from the Lemhi River weir survived to spawn. Some fish were caught when angling was allowed in the upper Lemhi River. From a special creel census conducted on the upper Lemhi River in 1966, I estimated 136 salmon were caught by anglers upstream from the weir. In 1967 and later years, I used harvest estimates obtained from the salmon report cards each angler was required to turn in at the end of the year to adjust the count of salmon at the weir and arrive at the number of females available to spawn. Fewer than 200 fish were caught by anglers from the Lemhi River upstream from the weir in most years, according to my estimates.

The redds made by adult chinook salmon in the upper Lemhi River were counted each fall by Idaho Department of Fish and Game personnel walking the length of the Lemhi River from Leadore downstream to the weir site after most fish had completed spawning and died (5 to 15 September). Individual redds were usually easy to identify.

USE OF THE INCUBATION CHANNEL TO PRODUCE FRY

In the first years of the study (1962-1967) we introduced steelhead trout fry into Big Springs Creek through an incubation channel. Eyed eggs of steelhead trout were placed in the incubation channel, where they completed development, emerged from the gravel, and entered the stream.

Description of the Incubation Channel

The incubation channel was 3 m wide by 46 m long in a cut through an oxbow adjacent to the upper end of Big Springs Creek. Headgates at the upstream and downstream ends of the channel controlled water flow. Washed gravel 2 to 10 cm in diameter was placed in a 30-cm thick layer in the center 30 m of the channel. Timber retaining walls were placed across the channel to hold the gravel in place. The surface gradient of the gravel was 0.15 m per 30 m of length. The water flowing over the gravel was usually maintained at a 10- to 15-cm depth. The velocity of the water flowing over the gravel ranged from 0.3 to 0.9 m/s. A large box with woven wire screen placed in the inlet headgate collected trash and prevented fish from entering the channel. A trap for capturing emerging fry was placed immediately downstream from the gravel portion of the channel. The water flowing through the channel passed through a V-shaped screen, which guided fish into the trap box.

Although Big Springs Creek was primarily spring fed, surface runoff occasionally entered the stream and deposited significant amounts of silt and organic debris in the gravel of the channel. These deposits impeded the flow of water and had a relatively high oxygen demand, which rapidly depleted the dissolved oxygen in the water flowing through the gravel.

We cleaned the gravel thoroughly each year before the eyed steelhead eggs were placed in the channel. A rake type device attached to the blade of a small crawler tractor was pulled through the gravel with a full head of water running through the channel. The gravel was displaced downstream during the cleaning process and then pushed back into place.

We reduced water flow through the channel to a trickle and poured eggs into trenches 15 to 20 cm deep and 30 cm wide, dug perpendicular to the long axis of the channel. The density of eggs placed in the gravel averaged about $5500/m^2$ but varied because the eggs could not be spread evenly throughout the channel with the trench method of planting.

The fry trap was installed at the downstream end of the gravel bed before the estimated time of emergence. Fish were removed from the trap daily and the number was determined by counting them individually or by volumetric displacement. The fry were then released into a pool at the lower end of the channel between the fry trap and outlet headgate. Fry released into the pool during daylight usually remained in the pool until evening, then left the channel and entered Big Springs Creek.

Survival of Eggs Placed in the Channel

The number of swim-up fry removed from the channel trap ranged from 40 to 95 percent of the eyed eggs placed in the gravel during the 6 years the incubation channel was used (Table 3). Usually the eggs were placed in the gravel during late May or early June and the fry emerged during late June and early July (Fig. 9).

Table 3. Number of eyed steelhead trout eggs placed in Big Springs Creek incubation channel and number of swim-up fry collected in the trap, 1962-1967.

Year	Placement of eggs in gravel: Date	Placement of eggs in gravel: Number	Fry collected in trap	Percentage of eggs collected as fry
1962	June 19, 21	69,200	65,900	95.2
1963	May 27, 31	460,100	195,700	42.5
1964	June 2, 10	333,100	298,900	89.7
1965	May 28, June 9	337,000	152,500	45.3
1966[a]	--	144,000	137,300	95.3
1967	May 28, June 3	549,500	217,300	39.5

[a] Record of egg placement date for 1966 lost.

The variation in survival of eggs placed in the gravel was directly correlated with runoff flows in Big Springs Creek – and hence with the amount of silt and organic debris brought into the channel by the water (Fig. 9). In 1962, 1964, and 1966, when egg-to-fry survival exceeded 90 percent, the flows in Big Springs Creek did not increase significantly while the eggs were in the gravel. In 1963, 1965, and 1967, when survival was less than 50 percent, significant increases in flow occurred in Big Springs Creek after egg deposition and noticeable amounts of silt and organic debris were deposited in the channel.

In late August 1966, 156,000 green chinook salmon eggs were placed in the channel to assess the survival of eggs during the fall; however, fewer than 1000 swim-up fry were collected in the channel trap, even though it was operated well past the usual period of fry emergence. During the fall the mats of vegetation in Big Springs Creek died and drifted from the stream, and the plant parts and other organic debris carried into the channel settled out in the interstitial spaces of the gravel bed. Intragravel flow was soon blocked and dissolved oxygen concentration declined to zero throughout much of the gravel bed.

Survival of chinook salmon eggs in natural redds in Big Springs Creek and in the nearby Lemhi River must exceed the survival rate observed in the incubation channel, or the runs would not continue to exist. Natural redds in the Lemhi River and Big Springs Creek contained significant amounts of sand and small gravel, whereas the gravel bed in the channel did not have particles less than 2 cm in diameter. The sand and small gravel in the natural redds left little space for the plant material drifting in the stream to settle. In streams such as Big Springs Creek and the Lemhi River, with large amounts of organic debris, survival of eggs in spawning gravels containing 20 to 40 percent small particles (less than 6 mm in diameter) might be considerably better than that in spawning gravels without such small particles.

VIABILITY OF FRY FROM THE INCUBATION CHANNEL VERSUS FRY FROM STACK INCUBATORS

The viability of steelhead trout fry from the incubation channel versus the viability of those from the hatchery was assessed by comparing the number of migrants produced. Starting in 1968, the steelhead trout eggs for Big Springs Creek were incubated in stack incubators and the resulting swim-up fry released into the creek instead of incubating eggs in the channel. Although better egg-to-fry survival was obtained in the stack incubators than in the incubation channel during some years (e.g., 1963, 1965, and 1967), I was not sure that the viability of fry from the hatchery equalled that of fry from the incubation channel.

Assessment of Survival

Fry from the incubation channel were released into the stream during the 6 years 1962 through 1967. The eggs placed in the channel came from Clearwater River steelhead in 1962 through 1965 and from mid-Snake River steelhead in 1966 and 1967.

During the years 1968 through 1974 embryos were held in stack incubators in a hatchery until the fry had absorbed their yolk sacs and were then released into Big Springs Creek at the incubation channel and at a site 3.2 km downstream from the channel. The fry released in the stream in 1968 through 1974 also came from Clearwater River and mid-Snake River steelhead stocks. I released variable numbers of fry into the stream each year, depending on the number of fry available and on the objectives of other parts of the research program. I used the number of rainbow-steelhead trout that migrated downstream out of Big Springs Creek either as subyearlings or as yearlings as the measure of fry survival.

The juvenile rainbow-steelhead trout that migrated from Big Springs Creek each fall, winter, and spring originated as steelhead trout fry released into the stream or as offspring of resident rainbow trout. Because of the problems associated with marking fry, I could not determine the exact ratio of juvenile steelhead to resident rainbow trout among the migrants. An indication of the number of resident rainbow trout that normally left the

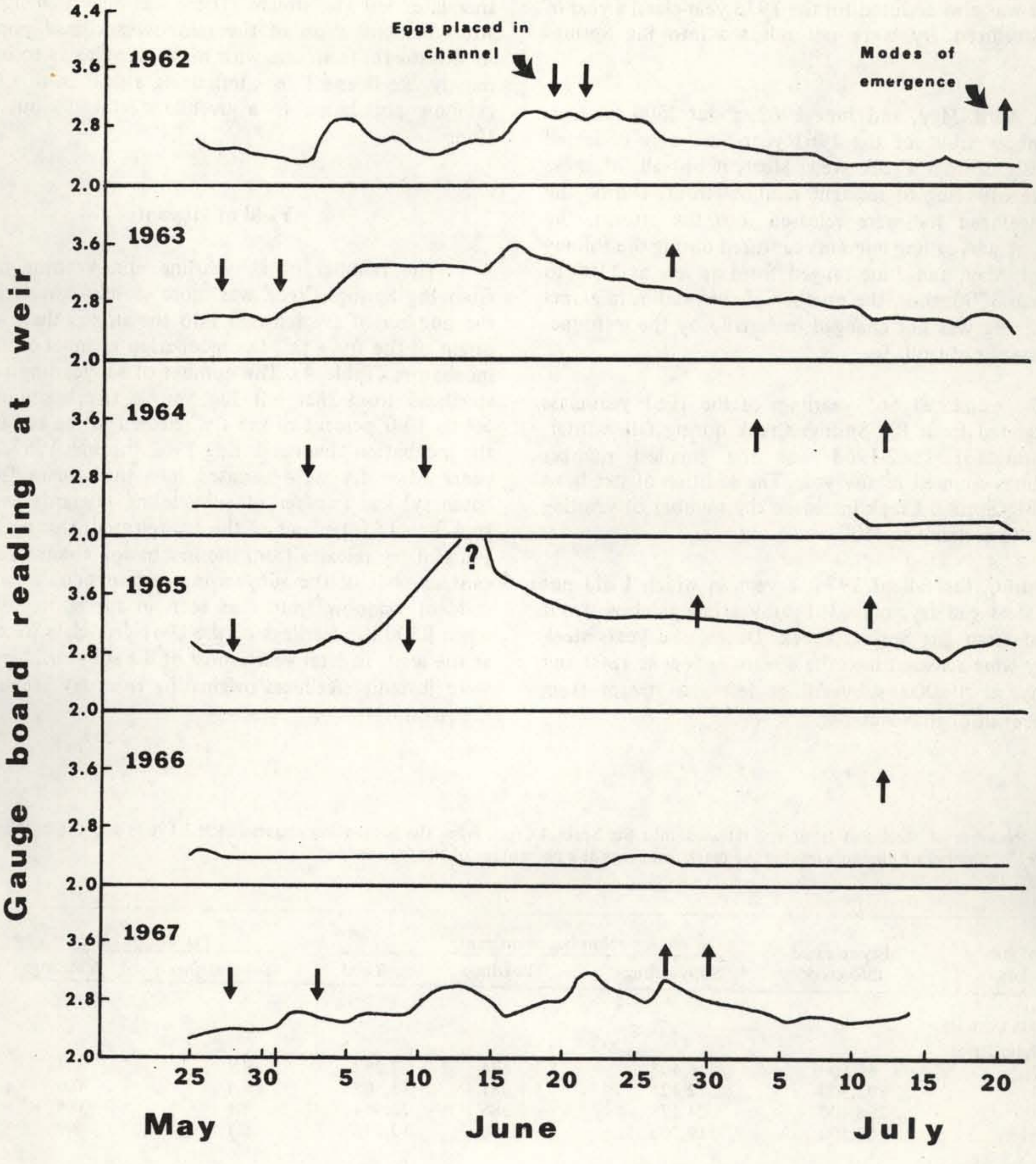

Fig. 9. Gauge board readings in feet (discharge about 36 cfs at a gauge reading of 2.7 feet) at Big Springs Creek weir; dates eyed steelhead eggs were placed in incubation channel (↓); dates of maximum fry emergence from gravel (↑), 1962-1967. Gauge records not kept during June 1964 and record of egg placement date in 1966 lost.

stream was obtained by counting the migrants of the 1961 year-class that left the stream as subyearlings during the spring of 1962 and as yearlings during the fall, winter, and spring of 1962-1963. The number of subyearling migrants was also counted for the 1975 year-class, a year in which steelhead fry were not released into Big Springs Creek.

In April, May, and June 1962, about 2500 subyearling rainbow trout of the 1961 year-class were collected at the Big Springs Creek weir. Most, if not all, of these fish were offspring of resident rainbow trout. During the years steelhead fry were released into the stream, the number of subyearling migrants captured during the following April, May, and June ranged from as few as 1100 to more than 3700; thus, the number of subyearling migrants in the spring was not changed materially by the introduction of steelhead trout fry.

The estimated 665 yearlings of the 1961 year-class that migrated from Big Springs Creek during fall, winter, and spring of 1962-1963 was the smallest number of yearlings counted in any year. The addition of steelhead fry to Big Springs Creek increased the number of yearling migrants to as many as 3500.

During the fall of 1975, a year in which I did not release steelhead fry, only 361 subyearling rainbow trout migrated from Big Springs Creek. During the years steelhead fry were released into the stream as few as 1800 and as many as 19,000 subyearlings left the stream from September through November.

The most conclusive evidence that most of the juvenile rainbow-steelhead trout were in fact juvenile steelhead was the relatively good correlation between number of fry released and number of subyearling migrants that later left the stream. There was also a change in the size-age distribution of the rainbow-steelhead population in the stream from one with many age classes to one with mostly age 0 and I fish, indicating a shift from a resident rainbow population to a juvenile steelhead trout population.

Yield of Migrants

The number of subyearling and yearling migrants from Big Springs Creek was more closely correlated with the number of fry released into the stream than with the origin of the fry – i.e., the incubation channel or the stack incubators (Table 4). The number of subyearling rainbow-steelhead trout that left Big Springs Creek amounted to 6.4 to 12.0 percent of the fry released in the stream from the incubation channel during 1962 through 1967. For the years when fry were released into the stream from the hatchery, the number of subyearling migrants amounted to 4.3 to 15.0 percent of the fry released. During the first years of fry releases from the incubation channel, a significant number of the subyearling migrants could have been resident rainbow trout – as seen in the spring of 1962, when 2500 subyearlings of the 1961 year-class were caught at the weir. In later years, most of the subyearling migrants were juvenile steelhead originating from fry released into the stream.

Table 4. Number of steelhead trout fry released into Big Springs Creek from the incubation channel (1962-1967) and the hatchery (1968-1970, 1973); number of migrants leaving the creek; migrants as a percentage of the fry released.

Source Stock of fish Year-class	Fry released into creek	Number of migrants			Percentage of fry released		
		Subyearlings	Yearlings	Total	Subyearlings	Yearlings	Total
Incubation channel							
Clearwater River							
1962	64,500	6,403	884	7,287	9.9	1.4	11.3
1963	193,300	12,421	1,081	13,502	6.4	0.6	7.0
1964	298,400	24,178	2,386	26,564	8.1	0.8	8.9
1965	151,500	12,208	1,470	13,678	8.1	0.9	9.0
Mid-Snake River							
1966	136,900	10,304	836	11,140	7.5	0.6	8.1
1967	213,600	25,595	1,655	27,250	12.0	0.8	12.8
Hatchery							
Clearwater River							
1968	219,000	32,785	2,337	35,122	15.0	1.0	16.0
1969	322,400	20,241	1,926	22,167	6.3	0.6	6.9
1970	206,000	8,587	1,355	9,942	4.2	0.6	4.8
Mid-Snake River							
1973	853,200	37,720	3,491	41,211	4.4	0.4	4.8

Hatchery fry released during 1969 through 1974 did not yield as many subyearling migrants as did a corresponding number of fry released from the incubation channel (Fig. 10). The smaller yield from the hatchery fry released in 1970 was probably due to the quality of the fry, but in 4 of the remaining 5 years the yield was reduced because of increased competition in the stream.

In 1970 the hatchery fry released into Big Springs Creek were probably not as viable as fry from the incubation channel. Eyed eggs obtained from Dworshak National Fish Hatchery were hauled to the Hayden Creek Research Station to complete embryo development and then released into the stream. White spot disease was prevalent at the hatchery in the 1970 brood of steelhead and hatchery personnel reported a 32 percent loss from eyed-egg to feeding-fry stage. Mortalities due to white spot disease often do not occur until after the fry have been put into raceways and begin to feed. The occurrence of such losses among the fry released in Big Springs Creek in 1970 might explain the relatively low yield of subyearling migrants from fry released in that year.

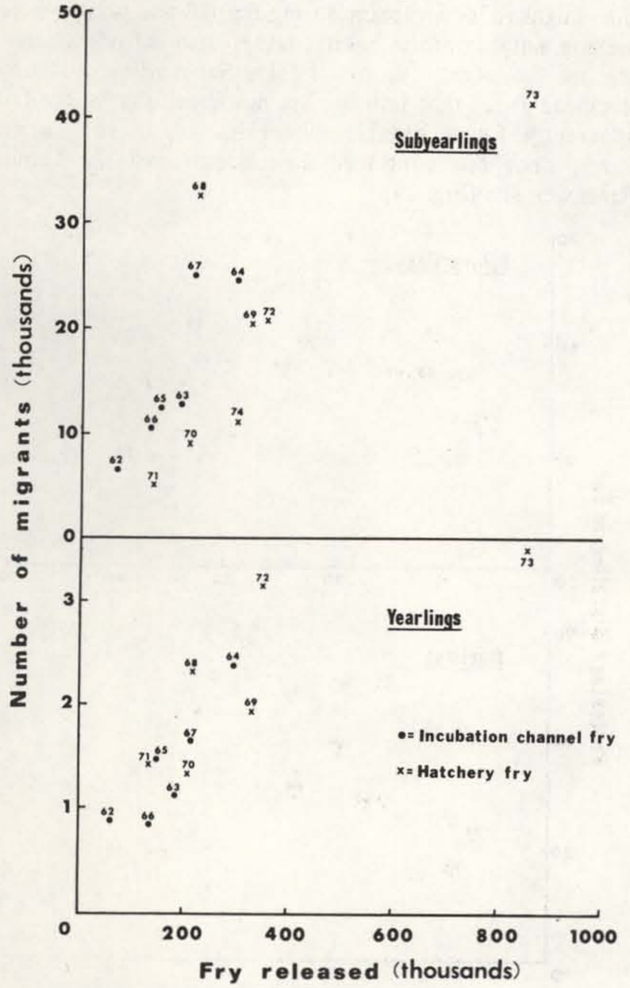

Fig. 10. Number of steelhead trout released into Big Springs Creek and number of subyearling and yearling rainbow-steelhead trout that migrated from the stream for each year-class, 1962-1974 (indicated by numbers above symbols).

In 1971 and 1972 the yield of subyearling migrants was probably reduced because large numbers of chinook salmon fingerlings were released into Big Springs Creek along with the steelhead fry. In 1973, more than twice the number of fry were released into the stream as in any previous year, and probably exceeded the rearing capacity of the stream. In 1974, the yield of subyearling rainbow-steelhead trout was probably reduced because I also released a large number of fry of cutthroat trout (*Salmo clarkii*).

YIELD OF JUVENILE STEELHEAD AND ADULT RETURN

Fry were released into the Lemhi River drainage each year from 1962 through 1974 to rebuild the steelhead trout populations – some each year into Big Springs Creek and in 1972 and 1973 into the Lemhi River. The number of juvenile steelhead trout produced and the number of adults that returned were assessed to determine if a self-sustaining steelhead population could be established.

Few, if any, steelhead were in the upper Lemhi River drainage at the time we began releasing fry. No adult steelhead were captured at the Lemhi River weir until 1967 (the first year of returns from fry released in 1962), even though we operated the weir during both the 1965 and 1966 adult migration seasons.

Timing of Juvenile Migration

Juvenile rainbow-steelhead trout migrated downstream out of Big Springs Creek during most months of their first 2 years of life (Fig. 11). Few of the steelhead fry, which were usually stocked in the upper end of the stream during June or July, left Big Springs Creek immediately after their release. Large numbers began leaving the creek, however, after their first summer. Increased numbers of subyearling rainbow-steelhead trout were captured in September, and the numbers peaked in November and December. The downstream migration of the subyearling fish coincided with decreasing stream temperatures and the loss of mats of aquatic vegetation.

The behavior of indigenous salmonids in Idaho streams changes from one of feeding in summer to "hibernation" in winter as temperatures decline in the fall (Bjornn 1971). Big Springs Creek did not contain large amounts of winter habitat used by salmon and trout; as a result, fish in excess of the capacity of the winter habitat left the stream each fall and winter.

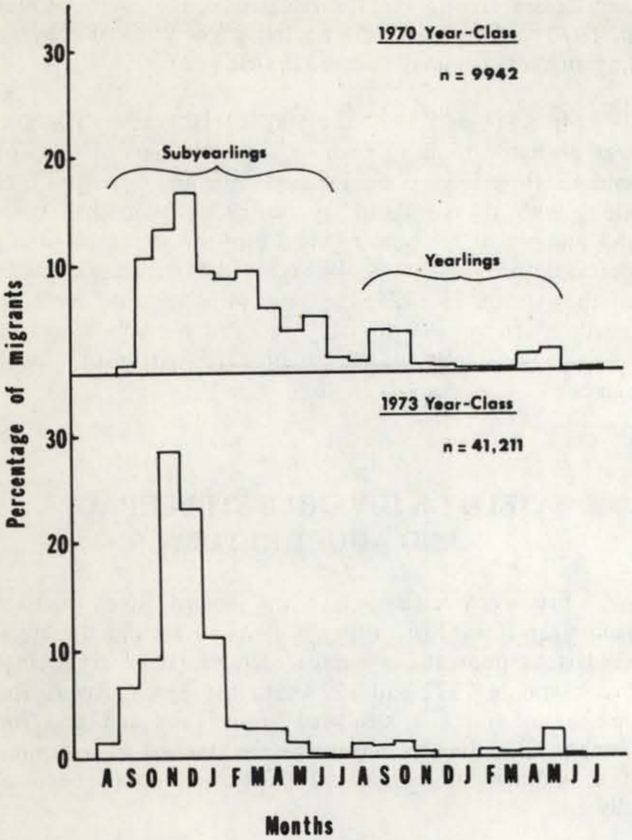

Fig. 11. Percentage of rainbow-steelhead trout from the 1970 and 1973 year-classes that left Big Springs Creek during each month of their first 2 years in the stream.

As with the subyearlings, most of the yearlings left Big Springs Creek during the fall (September and October), a few left during the winter, and some left as 2-year-old smolts during April and May (Fig. 11). A small percentage of the steelhead stayed in the stream a third summer and migrated as 3-year-old smolts.

The proportion of fish of a year-class that migrated as subyearlings versus the proportion that migrated as yearlings and the timing of their migration depended to some extent on the number of fish of that year-class in the stream during the first summer. A relatively small percentage of the total migrants for any year-class stayed in the stream two summers and migrated as yearlings (Table 5). Yearlings made up less than 10 percent of the total migrants of a year-class when large numbers were produced (for the 1973 year-class, for example, 8% were yearlings; Fig. 11). The percentage of yearling migrants in a year-class increased slightly (e.g., 14% for the 1970 year-class) when relatively small numbers of migrants were produced.

When large numbers of subyearlings were present in the stream, a large percentage of the fish migrated during the fall (September through December) (Figs. 11 and 12). When there were 30,000 migrants, 70 to 80 percent migrated from Big Springs Creek during the fall, whereas when there were 10,000 or fewer only half of them migrated during the fall.

The downstream migration of smolt-sized (150-210 mm total length) rainbow-steelhead trout that had completed two summers of rearing in Big Springs Creek or the Lemhi River occurred primarily during the fall after their second summer or during the following spring (April and May) (Fig. 13). Variable, but often large, numbers of rainbow-steelhead trout left Big Springs Creek and entered the Lemhi River after their first summer (Table 6), but few of the subyearling migrants continued down the Lemhi River past the weir site (Fig. 14). Most of the subyearling trout that entered the Lemhi River from Big Springs Creek remained in the upper Lemhi River through their second summer and then migrated from the stream in either the fall or the following spring.

True seaward migration of steelhead smolts occurred only during the spring (primarily April and May). The fish that migrated downstream during the fall and winter were seeking suitable winter habitat rather than actively migrating to the ocean (Bjornn 1971). Subyearling rainbow-steelhead trout that left Big Springs Creek during the fall apparently found suitable winter habitat in the Lemhi River, since few continued downstream past the Lemhi River weir site (Fig. 14).

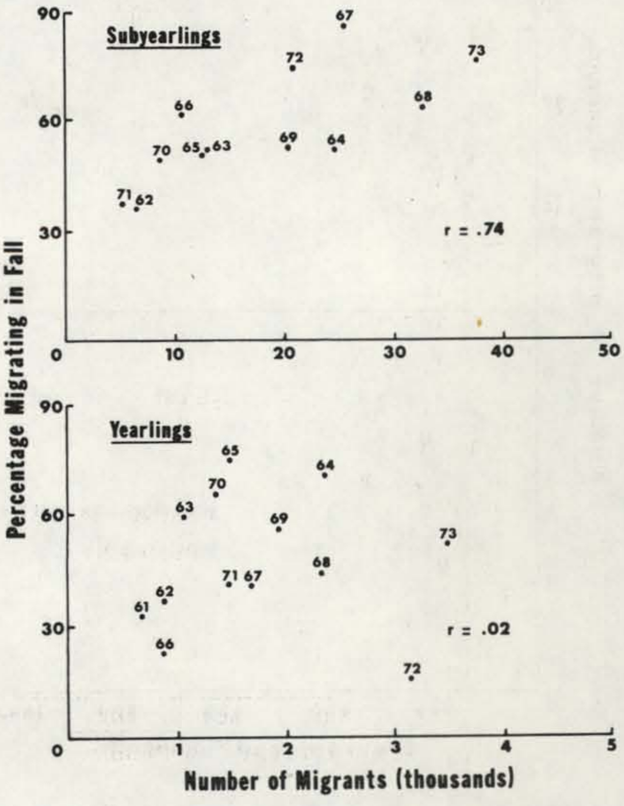

Fig. 12. Number of subyearlings and yearlings of each year-class that left Big Springs Creek and percentage that migrated in the fall after their first summer (subyearlings) or second summer (yearlings) in the stream, 1961-1973 (indicated by numbers above symbols).

Table 5. Number of steelhead trout fry released into Big Springs Creek; number of subyearling, yearling, and April-May smolt migrants leaving the stream; yield per 100 m^2 for each year-class, 1960-1974.

Year-class	Fry released into stream		Rainbow-steelhead migrants: Subyearlings		Yearlings		April-May smolts[a]	
	Number	Number/100 m^2	Number	Number/100 m^2	Number	Number/100 m^2	Number	Number/100 m^2
1960	0	0	–	–	–	–	178[b]	0.3
1961	0	0	–	–	655	1.2	253[b]	0.5
1962	64,500	115.8	6,403	11.5	844	1.5	379	0.7
1963	193,300	347.0	12,421	22.3	1,081	1.9	283	0.5
1964	298,400	535.7	24,178	43.4	2,386	4.3	499	0.9
1965	151,500	272.0	12,208	21.9	1,470	2.6	252	0.5
1966	136,900	245.8	10,304	18.5	836	1.5	537	1.0
1967	213,600	383.5	25,595	46.0	1,655	3.0	455	0.8
1968	219,000	393.2	32,785	58.9	2,337	4.2	557	1.0
1969	322,400	578.8	20,241	36.3	1,926	3.5	561	1.0
1970	206,000	369.8	8,587	15.4	1,355	2.4	324	0.6
1971[c]	136,800	245.6	5,265	9.5	1,433	2.6	593	1.1
1972[c]	358,200	643.1	20,518	36.8	3,184	5.7	1,935	3.5
1973	853,200	1,531.8	37,720	67.7	3,491	6.3	1,179	2.1
1974[c]	300,000	538.6	11,304	20.3				

[a] Not all steelhead smolts, as some smolt-sized resident rainbow trout migrated downstream during April and May (1960 and 1961 year-classes). Number of resident trout probably decreased in later years as more steelhead were released in the stream.

[b] Probably resident rainbow, as no steelhead fry were released.

[c] Other fish released in stream during these years: 255,500 and 291,600 chinook fingerlings in 1971 and 1972, respectively; 310,000 cutthroat trout fry in 1974.

Table 6. Numbers of subyearling and yearling rainbow-steelhead trout that left Big Springs Creek at different stages.

Year-class	Subyearlings	Yearlings[a]: Pre-smolts	Smolts	Total
1960[b]	–	–	200	200
1961[b]	2,700[c]	500	200	700
1962	6,400	600	200	800
1963	12,400	700	400	1,100
1964	24,200	2,100	300	2,400
1965	12,200	1,000	500	1,500
1966	10,300	500	300	800
1967	25,600	1,200	500	1,700
1968	32,800	1,900	400	2,300
1969	20,200	1,400	500	1,900
1970	8,600	1,100	300	1,400
1971	5,300	800	600	1,400
1972	20,500	1,300	1,900	3,200
1973	37,700	2,300	1,200	3,500

[a] Yearling trout that left after their second summer and during the fall and winter months classified as pre-smolts; those that migrated during the spring (April and May) classified as smolts.

[b] Migrants of these year-classes resident rainbow trout; no steelhead fry released until 1962.

[c] Partial year count (April-July); weir operation not begun until April 1962.

The winter habitat in the upper Lemhi River, however, was apparently not adequate for large numbers of yearling steelhead trout. When the numbers of yearling migrants were small, few migrated in the fall; when the numbers were large an increasing proportion migrated during the fall (Fig. 15 and Table 7). A large proportion of the yearlings from the 1972 and 1973 year-classes migrated during the fall, compared with the proportions of other year-classes that had fewer migrants.

Although a larger proportion of the yearling migrants tended to leave in the fall when the number of yearlings in the stream was large (Fig. 15), the actual number that overwintered in the upper Lemhi River was not rigidly regulated by winter habitat or other factors. Before the 1972 and 1973 year-classes were observed, the number of yearlings that overwintered in the upper Lemhi River and then migrated downstream during the spring ranged from 3200 to 7700 (Table 7). On the basis of those data, one might have assumed that no more than 7000 to 8000 eventual spring migrants could overwinter in the upper Lemhi River; however, the large numbers of yearlings produced from the fry released into the Lemhi River in 1972 and 1973 provided evidence that at least 30,000 yearlings could overwinter there (Table 6).

Yield of Subyearlings

The number of subyearling rainbow-steelhead trout that migrated from Big Springs Creek ranged from 5300 to

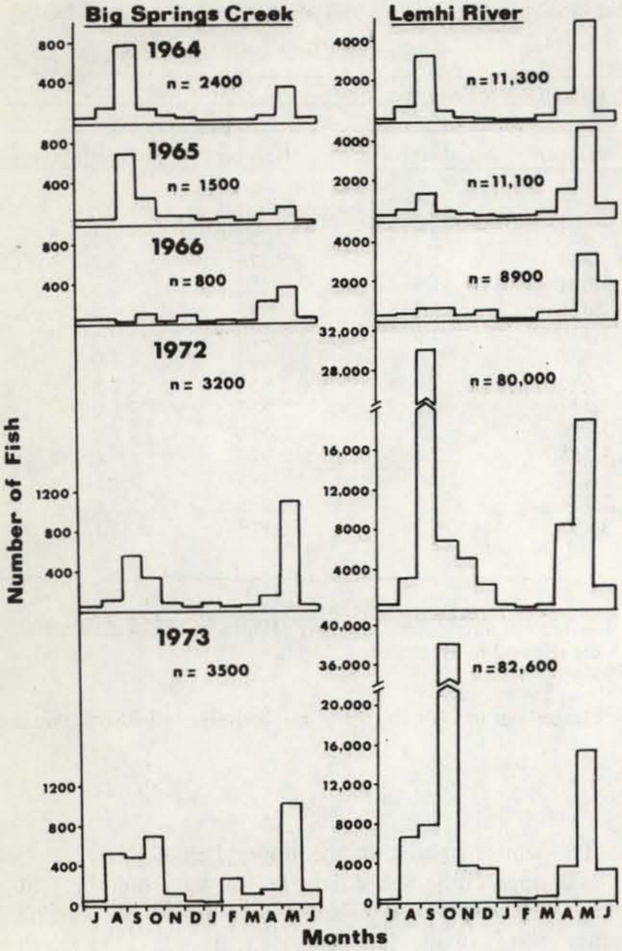

Fig. 13. Number of rainbow-steelhead yearlings that migrated past the Big Springs Creek and Lemhi River weirs each month, starting in July of their second summer, for five representative year-classes.

Table 7. Total estimated number of yearling rainbow-steelhead trout migrating downstream past the Lemhi weir site; number during fall (August-December) and spring (March-June); percentage of total migrating in fall, year-classes 1963-1973.

Year-class	Number of migrants			Percentage migrating in fall
	Total[a]	Fall	Spring	
1963	7,000	2,500	4,400	36
1964	11,300	4,600	6,600	41
1965	11,100	3,400	7,500	31
1966	8,900	2,700	6,100	30
1967	12,200	4,000	7,700	33
1968	20,800	17,100	3,600	82
1969	11,000	4,500	6,000	41
1970	6,300	3,000	3,200	48
1971	10,900	5,700	4,900	52
1972	79,800	49,200	30,000	62
1973	82,600	59,600	22,500	72

[a] Yearlings that migrated during the winter included in the total number.

37,700 for the 13 year-classes studied (Table 5). In numbers per 100 m^2, 9.5 to 67.7 subyearling migrants were produced from seeding rates of 116 to 1532 fry.

The number of subyearling rainbow-steelhead trout migrants produced in Big Springs Creek was directly related to the number of fry released (Figs. 10 and 16). A threefold increase in the number of fry released (from 100,000 to 300,000) resulted in a threefold increase in the number of subyearling migrants (from about 12,000 to 36,000). From the data in Fig. 16, a maximum yield of 30,000 to 40,000 subyearling migrants would be expected if 400,000 to 600,000 steelhead fry were released in the stream.

Before 1973, the number of fry released annually in Big Springs Creek was less than 358,000 and there was no evidence that the summer capacity of the stream had been exceeded. In 1973, however, when a much larger number of fry (853,200) were released in the stream, the yield of subyearling migrants, although the largest on record, did not increase proportionally with the number of fry released (Fig. 16).

In Big Springs Creek, a fertile stream with abundant aquatic vegetation, a stocking rate of up to 700 fry/100 m^2 yielded directly proportional numbers of subyearlings. Fry stocked in excess of 700/100 m^2 yielded the maximum number of subyearlings but the number of subyearlings produced per 100 fry declined. For stocking rates of less than 700 fry/100 m^2 (400,000 fry), an average of 8 subyearlings were produced for every 100 fry released. In 1973, when 1532 fry/100 m^2 were stocked, the subyearling yield was only 4.4 per 100 fry.

The number of subyearling rainbow-steelhead trout that migrated from Big Springs Creek (Fig. 16) appeared to be less than average in the years I released chinook salmon fingerlings (1971 and 1972) or cutthroat trout fry (1974), or when whitespot disease may have been present in the steelhead fry released (1970). The data for all four of those years lie to the right of the other data points in Fig. 16, indicating a less than average subyearling yield.

The reduced rate of subyearling yield in Big Springs Creek during the years when chinook salmon or cutthroat trout were also stocked was not surprising. In 1971 and 1972, respectively, 255,500 and 291,600 chinook salmon fingerlings were released along with 136,800 and 358,200 steelhead trout fry. In addition to the 5300 and 20,500 subyearling rainbow-steelhead trout that migrated from Big Springs Creek following the summers of 1971 and 1972, respectively, 55,100 and 62,800 subyearling chinook also left the stream. In 1974, the 310,000 cutthroat trout fry and 300,000 steelhead trout fry released in the stream at the same time were similar in size and direct competition between the two species was to be expected. The combined yield of subyearling rainbow-steelhead and

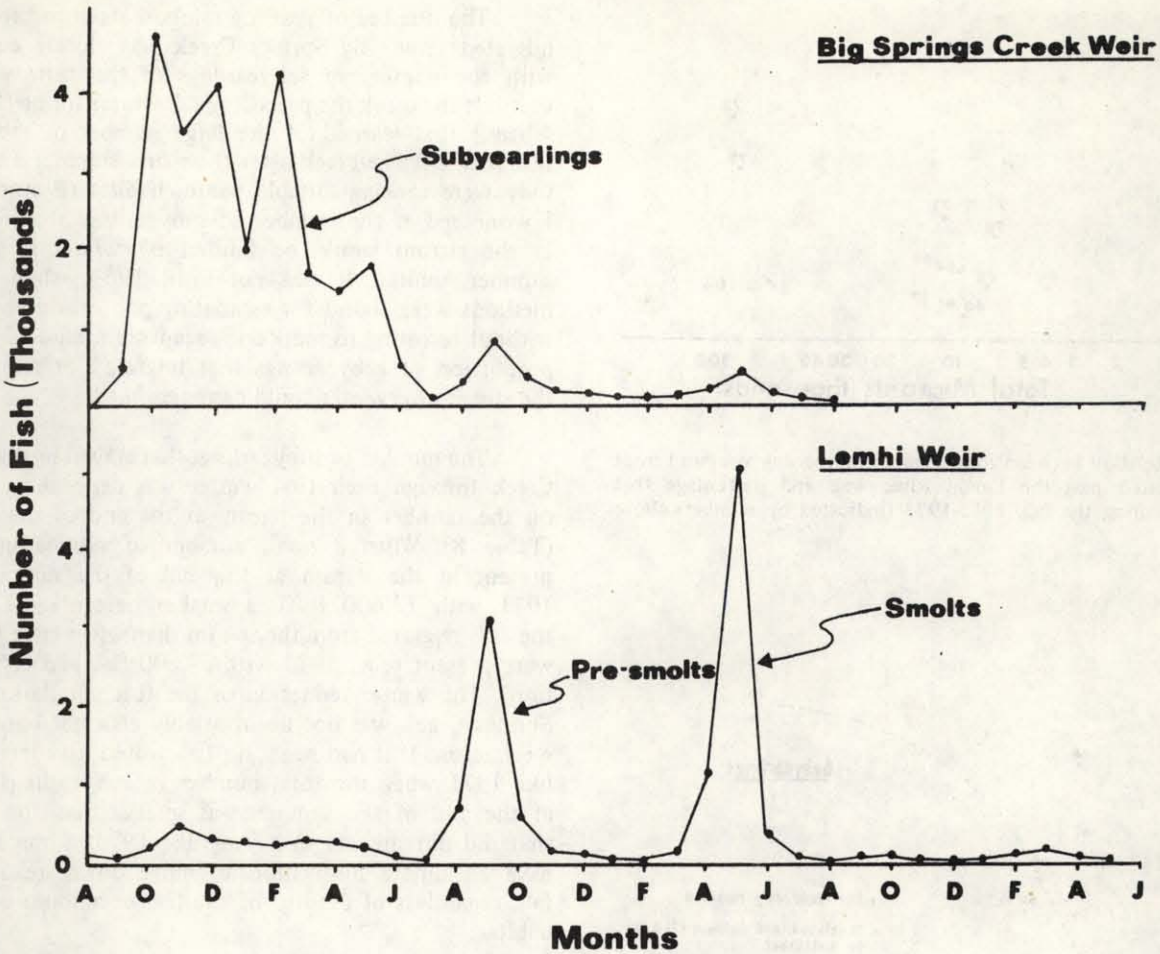

Fig. 14. Estimated number of subyearling and yearling rainbow-steelhead trout of the 1964 year-class that migrated downstream past the Big Springs Creek and Lemhi River weir sites.

cutthroat trout during the fall of 1974 (13,900 fish), from the 610,000 fry of the two species stocked in the stream, did not match the yield expected from releasing a similar number of steelhead fry alone. Based on the fall population estimates, the cutthroat trout (18,000 fish) did not survive as well as the steelhead (40,300), and a larger proportion migrated from Big Springs Creek in the fall.

Yield of Yearlings from Fry Released in Big Springs Creek

The yield of rainbow-steelhead trout yearlings (fish which migrated after their second summer in the stream, but before the beginning of their third summer) from Big Springs Creek ranged from 700 to 3500 (1.3 to 6.3 fish/m^2) for the 12 year-classes studied (Table 5). Most of these yearlings migrated during September and October or the following April and May (Fig. 13). The April-May migrants, with few exceptions, had the typical silvery, elongated body and deciduous scales of steelhead trout smolts. The rest of the yearling migrants might be termed pre-smolts. These pre-smolt migrants left Big Springs Creek during the fall and winter, probably in search of suitable winter habitat, and began their seaward migration the following spring. When calculating smolt-adult survival rates, all yearling migrants were considered as smolts, even though some of the migrants (the pre-smolts) moved downstream during the fall and winter before the normal smolt migration season in the spring.

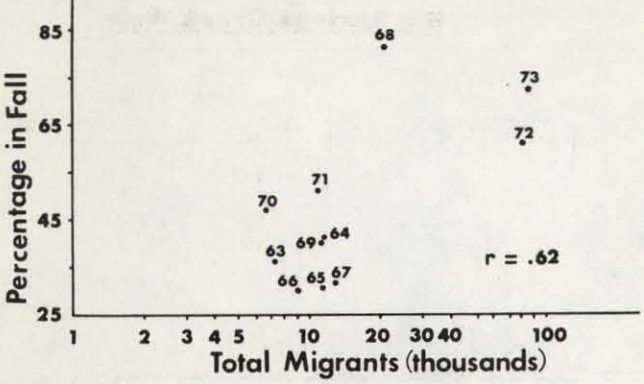

Fig. 15. Relation between total number of yearling steelhead trout that migrated past the Lemhi River weir and percentage that migrated during the fall, 1963-1973 (indicated by numbers above symbols).

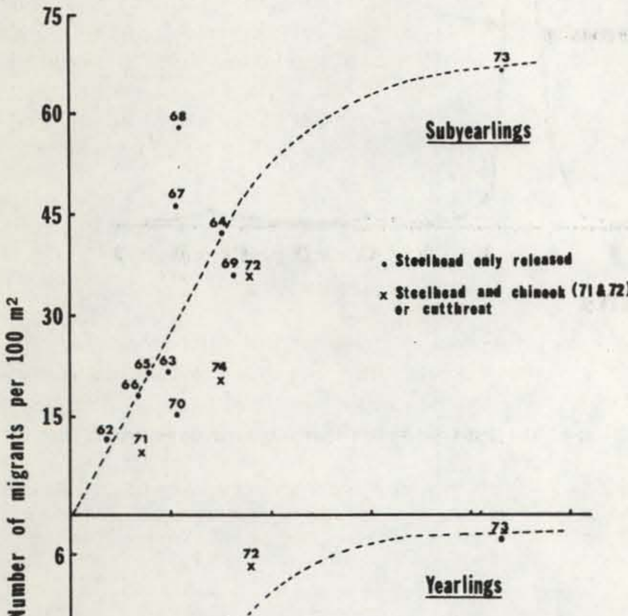

Fig. 16. Relation between steelhead trout fry released in Big Springs Creek and the number/100 m^2 of subyearling and yearling rainbow-steelhead that migrated from the stream for each year-class, 1962-1974 (indicated by numbers above symbols). Curves were fitted by inspection, and include adjustment for conditions discussed in the text.

The number of yearling rainbow-steelhead trout that migrated from Big Springs Creek was closely correlated with the number of subyearlings of the same year-class that left the creek the preceding fall-winter-spring (Fig. 17). When I first learned of the large number of subyearling fish that left the creek after their first summer and found they were seeking suitable winter habitat (Bjornn 1971), I wondered if the number of subyearlings that remained in the stream would be limited by winter rather than summer habitat. It was not until 1969, when suitable methods were found for estimating population abundance without resorting to mark-and-recapture methods, that the proportion of subyearlings that migrated or remained in the stream overwinter could be determined.

The number of subyearlings that stayed in Big Springs Creek through their first winter was dependent, in part, on the number in the stream at the end of the summer (Table 8). When a small number of subyearlings were present in the stream at the end of the summer (e.g., 1971 with 13,600 fish), a smaller percentage (39%) of the fish migrated from the stream than when large numbers were present (e.g., 1973 with 69,600 fish and 63% migration). The winter reduction of the fish population in Big Springs Creek was not an invariably efficient homeostatic mechanism. If it had been, no fish would have left in years like 1971 when the total number of subyearlings present at the end of the summer was smaller than the number that did not migrate in a year like 1973. Some fish may have an innate motivation to move downstream in the fall, regardless of density of the fish or amount of winter habitat.

In 3 of the 4 years for which data are available (Table 8), the yearlings that migrated from Big Springs Creek made up a surprisingly consistent percentage of

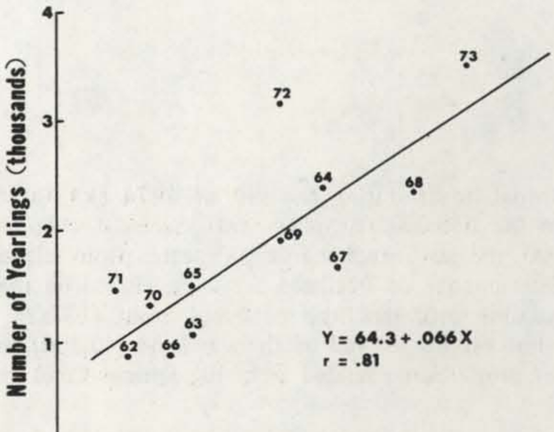

Fig. 17. Relation between the number of subyearling and yearling steelhead trout that migrated out of Big Springs Creek, 1962-1973 (indicated by numbers over symbols).

Table 8. Estimated number of subyearling rainbow-steelhead trout in Big Springs Creek at the end of their first summer (late September), and number and percentage that migrated as subyearlings or yearlings, year-classes 1969 and 1971-1974.

Year-class	Subyearlings in stream at end of summer	Subyearling migrants		Subyearlings not migrating	Yearling migrants	
		Number	Percentage		Number	Percentage
1969	43,000	20,200	47	22,800	1,900	8
1971	13,600[a]	5,300	39	8,300	1,400	17
1972	39,200[b]	20,500	52	18,700	3,200	17
1973	59,600	37,700	63	21,900	3,500	16
1974	40,300[c]	11,300	28	29,000	–	–

[a] Also 55,100 (minimum estimate) chinook salmon subyearlings in stream.

[b] Also 75,400 chinook salmon subyearlings in stream.

[c] Also 18,100 cutthroat trout subyearlings in stream.

the number of subyearlings of the particular year-class that remained in the stream. This similarity may be fortuitous, of course, but it may also be an expression of the consistency of the environment in Big Springs Creek.

In addition to the yearling rainbow-steelhead trout produced in Big Springs Creek, some of the subyearlings which left Big Springs Creek survived and remained in the upper Lemhi River for an additional summer. The number of yearling rainbow-steelhead trout that migrated downstream past the Lemhi River weir site ranged from 7000 to 82,600 for the 1963 through 1973 year-classes (Table 9).

Not all of the yearling migrants at the Lemhi River weir site originated from Big Springs Creek. On the basis of the proportion of marked fish from Big Springs Creek recovered at the Lemhi River weir, the estimated number of yearlings passing the Lemhi weir site that originated from Big Springs Creek ranged from 2300 to 19,000 (Table 9); the rest originated from the upper Lemhi River and were either all resident rainbow trout (1963 through 1971 year-classes) or a mixture of rainbow and steelhead trout (1972 and 1973 year-classes). The number of yearling rainbow-steelhead trout of Big Springs origin that left the upper Lemhi River was closely correlated with the number of subyearling and yearling trout that left Big Springs Creek (Fig. 18).

If all yearlings that left Big Springs Creek had survived and migrated past the Lemhi River weir site, they would have made up 18 to 61 percent of the yearling migrants of Big Springs Creek origin at the Lemhi River weir (Table 10). The remainder of the Big Springs Creek yearlings migrating past the Lemhi River weir site (39 to 82%) left Big Springs Creek as subyearlings and lived in the Lemhi River for one summer before migrating.

The maximum yield of steelhead trout smolts (yearlings) from Big Springs Creek can be obtained with a release of 400,000 to 600,000 fry (Fig. 19). The release of additional fry in Big Springs Creek would not increase the number of yearling migrants from Big Springs Creek, but would increase the number of subyearling migrants and eventual yearling migrants in the Lemhi River. If steelhead fry were released only in Big Springs Creek, rather than in both streams, a larger number of fry would be required to obtain maximum yield of yearling migrants from the upper Lemhi River (Fig. 19).

Survival of Steelhead Fry Released into Big Springs Creek

The soundest estimate of the survival rate of the steelhead fry released into Big Springs Creek was the number of rainbow-steelhead migrants of a particular

Table 9. Number of smolt-sized (primarily yearling) rainbow-steelhead trout that migrated downstream past the Lemhi weir and estimated number originating from Big Springs Creek and from the Upper Lemhi River, year-classes 1963-1973.

Year-class	Total migrants at Lemhi River weir	Origin of migrants	
		Big Springs Creek	Upper Lemhi River[a]
1963	7,500	3,000	4,500
1964	11,700	4,800	6,900
1965	11,300	2,900	8,400
1966	9,100	3,100	6,000
1967	13,100	3,300	9,800
1968	20,900	8,300	12,600
1969	11,200	5,700	5,500
1970	7,000	3,300	3,700
1971	11,400	2,300	9,100
1972	80,700	9,100	71,600
1973	82,600	19,000	63,600

[a] Migrants of the 1963-1971 year-classes from the upper Lemhi River were rainbow trout and those of the 1972 and 1973 year-classes were both rainbow and steelhead trout.

Table 10. Number of subyearling and yearling rainbow-steelhead trout that left Big Springs Creek; number of yearling migrants at the Lemhi River weir site which originated from Big Springs Creek; percentage of yearling migrants that left Big Springs Creek as subyearlings; percentage of the yearling migrants which left Big Springs Creek as yearlings, year-classes 1963-1973.

Year-class	Number of migrants from Big Springs Creek		Yearling migrants at Lemhi weir originating from Big Springs Creek		
				Percentage	
	Subyearlings	Yearlings	Number	Subyearlings	Yearlings[a]
1963	12,400	1,100	3,000	63.3	36.7
1964	24,200	2,400	4,800	50.0	50.0
1965	12,200	1,500	2,900	48.3	51.7
1966	10,300	800	3,100	74.2	25.8
1967	25,600	1,700	3,300	48.5	51.5
1968	32,800	2,300	8,300	72.3	27.7
1969	20,200	1,900	5,700	66.7	33.3
1970	8,600	1,400	3,300	57.6	42.4
1971	5,300	1,400	2,300	39.1	60.9
1972	20,500	3,200	9,100	64.8	35.2
1973	37,700	3,500	19,000	81.6	18.4

[a] Assuming 100% survival between weirs.

year-class divided by the number of fry released. Including both subyearlings and yearlings, the rate ranged from 0.04 in 1973 (the year in which the largest number of fry was released) to 0.16 in 1968 (Table 11).

The number of subyearling and yearling rainbow-steelhead migrants averaged about 8 percent and 0.8 percent, respectively, of the fry released (Fig. 20). There seemed to be little correlation between the number of fry released and the percentage that survived to migration; thus I suspect that the 80 to 90 percent mortality that occurred during the first summer of life might be density independent, as in mortality caused by random encounters with predators (type 2 predation, Ricker 1975). The lower-than-average survival rate of the 1973 year-class might be an indication that compensatory mortality in some form was acting with the larger densities of fry in 1973.

Survival of subyearlings that did not migrate from Big Springs Creek after their first summer, but then migrated as yearlings, ranged from 8 to 17 percent during the 4 years fall population estimates were made (Table 8). Because not all of the subyearlings migrated from the stream as yearlings (not all were steelhead), the survival rate from subyearling to yearling was a minimum estimate, but not a serious underestimate.

The apparent survival of subyearlings that left Big Springs Creek and lived an additional summer in the Lemhi River ranged from 6 to 41 percent (Table 12). The accuracy of these survival estimates depends on the validity of the assumptions that 1) the estimated proportion of Big Springs Creek fish at the Lemhi River weir, based on recovery of marked fish, was relatively accurate; 2) all yearlings that left Big Springs Creek also migrated downstream past the Lemhi River weir site; and 3) all of the subyearling migrants

Table 11. Number of rainbow-steelhead trout that migrated from Big Springs Creek as subyearlings and yearlings, expressed as percentage of steelhead trout fry released, year-classes 1962-1974.

Year-class	Number of fry released	Number of migrants		Percentage		
		Subyearlings	Yearlings	Subyearling	Yearling	Total
1962	64,500	6,400	800	9.9	1.2	11.2
1963	193,300	12,400	1,100	6.4	0.6	7.0
1964	298,400	24,200	2,400	8.1	0.8	8.9
1965	151,500	12,200	1,500	8.1	1.0	9.0
1966	136,900	10,300	800	7.5	0.6	8.1
1967	213,600	25,600	1,700	12.0	0.8	12.8
1968	219,000	32,800	2,300	15.0	1.1	16.0
1969	322,400	20,200	1,900	6.3	0.6	6.9
1970	206,000	8,600	1,400	4.2	0.7	4.9
1971	136,800	5,300	1,400	3.9	1.0	4.9
1972	358,200	20,500	3,200	5.7	0.9	6.6
1973	853,200	37,700	3,500	4.4	0.4	4.8
1974	300,000	11,300	–	3.8	–	–

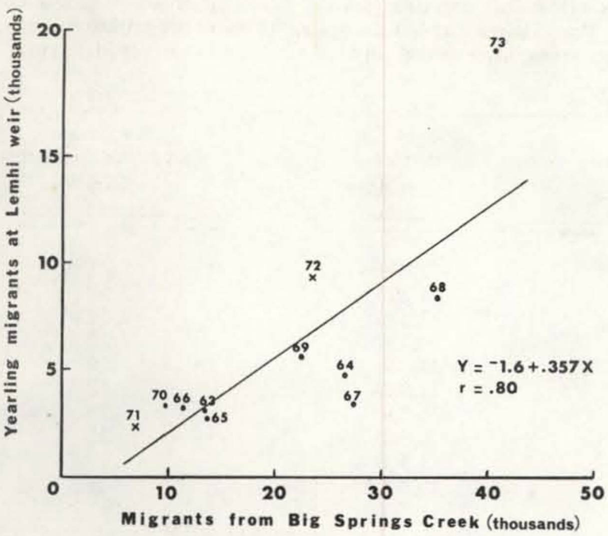

Fig. 18. Relation between the number of subyearling and yearling rainbow-steelhead trout that left Big Springs Creek and the number that migrated past the Lemhi River weir, 1963-1973 (indicated by numbers above symbols). In years designated by an (X) chinook salmon were also released into the stream.

that left Big Springs Creek were steelhead trout rather than resident rainbow trout. Each of these assumptions might have been partly invalid for any particular year-class.

The assumption that all yearlings that migrated from Big Springs Creek also passed the Lemhi River weir site would have been invalid if some of the yearlings died or if some of the yearling migrants at Big Springs Creek were not steelhead and did not continue migrating downstream. If some of the yearlings died between Big Springs Creek and the Lemhi River weir site or failed to migrate because they were not steelhead trout, the proportion of the yearling migrants at the Lemhi River weir that originated as subyearlings from Big Springs Creek would be underestimated, and likewise the survival rate of subyearlings in the Lemhi River. If a large proportion of the subyearling migrants that left Big Springs Creek were resident rainbow trout rather than steelhead trout, there would be fewer steelhead subyearlings to ultimately migrate as yearlings past the Lemhi River weir site, and the survival rate would be underestimated.

The number of rainbow trout produced in Big Springs Creek has probably declined since steelhead trout fry were first introduced in 1962, and the number of steelhead trout has increased. The survival of Big Springs Creek subyearlings in the Lemhi River was probably underestimated for the early year-classes (1963 to 1966) because a significant proportion of the subyearlings were resident rainbow trout rather than steelhead trout. Consequently, the survival of steelhead trout during their second year in the Lemhi River probably ranged from about 20 to 40 percent (Table 12).

Although most of the fish referred to as rainbow-steelhead trout in this report were in fact steelhead trout, some resident rainbow trout were present in the counts of migrants, and thus the survival rates of steelhead fry to the migrant stage contain some positive bias. Although neither the Lemhi River nor the Big Springs Creek weir was operated for a complete year when only resident trout were present, some information is available to provide an indication of the relative abundance of rainbow versus steelhead trout in population estimates and weir counts. For example, the relatively close correlation between the number of fry released and number of subyearling and yearling migrants counted at the Big Springs Creek weir (Fig. 19) is evidence that a large proportion of the trout in the weir counts were indeed steelhead trout.

Before the initial release of steelhead trout fry in 1962, resident rainbow trout were the predominant fish

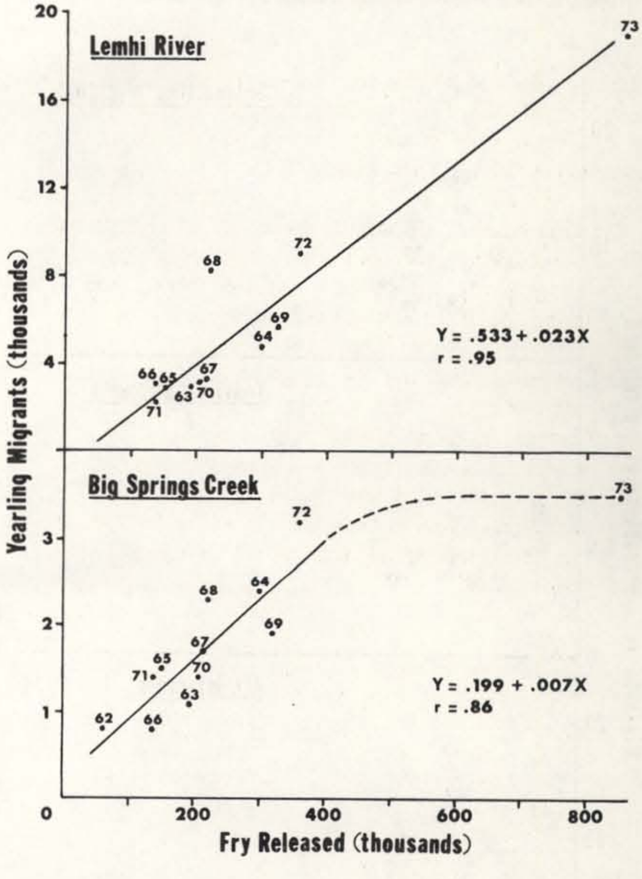

Fig. 19. Number of steelhead trout fry released into Big Springs Creek and number of yearling rainbow-steelhead trout migrating downstream past the Big Springs Creek and Lemhi River weir sites, year-classes 1962-1973 (indicated by numbers above symbols). Migrants at Lemhi River site originated in Big Springs Creek. The dotted portion of the line for Big Springs Creek was fitted by inspection and the full curve portrays my view of the relation between fry released and yearling migrants produced in that stream. The regression equation and correlation coefficient for Big Springs Creek do not include 1973 data because I believe the relation was linear only up to releases of 400,000 fry.

Table 12. Number of yearling rainbow-steelhead trout of Big Springs Creek origin that migrated past the Lemhi River weir site; migrants in Lemhi River that left Big Springs Creek as yearlings[a]; yearling migrants in Lemhi River that left Big Springs Creek as subyearlings; number of subyearlings that left Big Springs Creek; percentage of Big Springs Creek subyearling migrants that survived and migrated as yearlings, year-classes 1963-1973.

Year-class	Yearling migrants in Lemhi River: Total number	Left Big Springs Creek: Yearlings	Left Big Springs Creek: Subyearlings	Subyearlings that left Big Springs Creek	Percentage subyearling-to-yearling survival in Lemhi River
1963	3,000	1,100	1,900	12,400	15
1964	4,800	2,400	2,400	24,200	10
1965	2,900	1,500	1,400	12,200	11
1966	3,100	800	2,300	10,300	22
1967	3,300	1,700	1,600	25,600	6
1968	8,300	2,300	6,000	32,800	18
1969	5,700	1,900	3,800	20,200	19
1970	3,300	1,400	1,900	8,600	22
1971	2,300	1,400	900	5,300	17
1972	9,100	3,200	5,900	20,500	29
1973	19,000	3,500	15,500	37,700	41

[a] Assumed same as number that left Big Springs Creek.

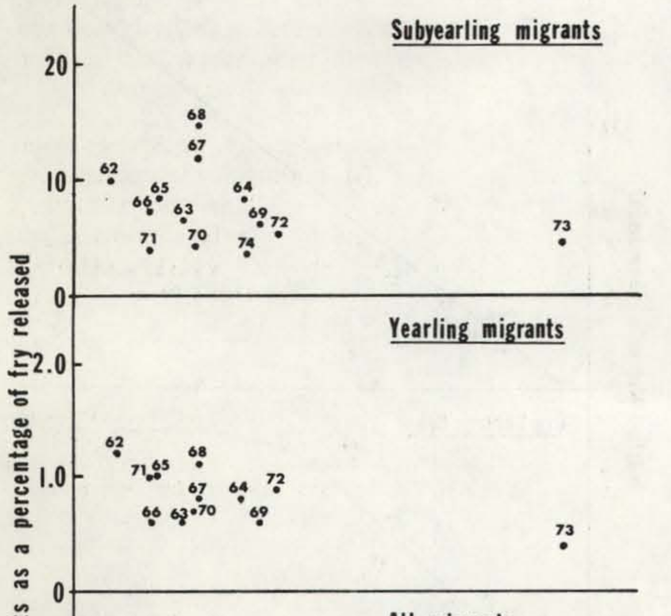

Fig. 20. Relation between number of steelhead trout fry released in Big Springs Creek and the percentage of rainbow-steelhead migrants, 1962-1974 (indicated by numbers above symbols).

in Big Springs Creek. These rainbow trout, a self-sustaining population, might have been offspring of residual steelhead or domesticated rainbow trout released into the stream. Rainbow trout spawners from the Lemhi River entered Big Springs Creek to spawn, and juveniles migrated downstream out of Big Springs Creek.

An indication of the number of rainbow trout that normally migrated from the creek was obtained in the spring of 1962 before any steelhead were present, and when resident rainbow trout of the 1961 year-class were migrating as subyearlings from Big Springs Creek during April, May, and June 1962. During those 3 months, nearly 2500 subyearling rainbow trout left Big Springs Creek (Table 13). In later years, when steelhead trout were present in the stream, the number of subyearling migrants during those 3 months averaged 2000; thus the number of subyearlings migrating in the spring probably did not increase after steelhead fry were released.

An estimate of the number of yearling rainbow trout migrating from Big Springs Creek was available from trapping during the spring of 1962 and the fall, winter, and spring of 1962-1963. During April and May 1962, 200 yearlings of the 1960 year-class left Big Springs Creek and a similar number of the 1961 year-class left the creek in 1963 (Table 6). The number of April-May yearling migrants for later year-classes, when steelhead trout fry had been released in the stream, was only slightly larger than the number when only resident rainbow trout were present, until the migration of the 1972 and 1973 year-classes. Ignoring the 1972 and 1973 year-classes, one could conclude that resident rainbow trout composed up to two-thirds of the yearling rainbow-steelhead trout migrating from Big Springs Creek during April and May (Table 6).

In the early years of steelhead trout fry release, resident rainbow trout probably made up half or more of the rainbow-steelhead trout that lived in Big Springs Creek. In later years, however, resident rainbow trout made up a progressively smaller proportion of the rainbow-steelhead trout population in the stream. The 700 yearlings ("pre-smolts" and "smolts") that migrated from Big Springs Creek during the fall, winter, and spring of 1962-1963 were resident rainbow trout of the 1961 year-class (Table 6), and were the fewest rainbow-steelhead trout yearlings that left Big Springs Creek. If 700 rainbow trout yearlings migrated from Big Springs Creek in 1974-1975, they would have made up 20 percent of the 3500 yearling migrants. I believe, however, that there were fewer than 700 yearling rainbow trout migrants in 1974-1975 and that, therefore, less than 20 percent of the yearling migrants were rainbow trout.

Table 13. Estimated number of rainbow trout (1961 year-class) or rainbow-steelhead trout (1962-1974 year-classes) subyearlings of each year-class that migrated from Big Springs Creek during the spring (April-June) preceding their second summer.

Year-class	Month of migration April	May	June	Total
Before steelhead fry released				
1961	1438	627	423	2488
With steelhead fry released				
1962	1098	895	374	2367
1963	1161	651	171	1983
1964	1428	1736	423	3587
1965	335	675	256	1266
1966	496	448	98	1042
1967	1422	689	98	2209
1968	591	342	98	1031
1969	2280	1156	286	3722
1970	594	363	533	1490
1971	709	442	318	1469
1972	1678	234	117	2029
1973	1129	601	90	1820
1974	583	812	96	1491
1962-1974 average				1962

In 1975, no steelhead trout fry were released into Big Springs Creek and thus there was an opportunity to determine the size of the resident trout population after 13 years of competition with the steelhead trout fry released into the stream. During annual electrofishing in the fall of 1975, 868 rainbow trout were collected, which was only 11 to 21 percent of the number of rainbow-steelhead subyearlings collected in the 3 preceding years, when steelhead trout fry had been released into the stream (Table 14).

Table 14. Number of rainbow (1975) and rainbow-steelhead (1972-1974) trout subyearlings captured in the six sections of Big Springs Creek as part of the fall population assessment.

Section of stream	Year of sample 1972	1973	1974	1975
1	185	459	543	425
2	901	1511	2193	181
3	924	900	1548	191
4	358	1366	2260	48
5	1057	1793	817	14
6	692	363	615	9
Totals	4117	6392	7976	868

During the fall of 1975, an estimated 361 subyearling rainbow trout left Big Springs Creek, compared with an average of 7500 rainbow-steelhead trout for the preceding year-classes when steelhead trout fry had been released in the creek (Table 15). The small number of migrants in 1975 is an indication that resident rainbow trout made up only 10 to 20 percent of the rainbow-steelhead trout population in the stream in the final years when steelhead trout fry were released, and probably made up less than 10 percent of the subyearling and yearling migrants.

The yearling migrants produced in Big Springs Creek constituted only 0.4 to 1.2 percent of the steelhead fry released in the creek (Table 16). The number of yearling rainbow-steelhead trout produced in Big Springs Creek and the upper Lemhi River equaled 1.5 to 3.8 percent of the fry released into Big Springs Creek.

Table 15. Estimated number of subyearling rainbow or rainbow-steelhead trout that left Big Springs Creek during September, October and November when steelhead fry were released into the stream (1962-1974 year-classes) and when no fry were released (1975 year-class).

Year-class	Month of migration September	October	November	Total
1962	72	1,158	532	1,762
1963	218	1,461	2,303	3,982
1964	481	4,685	3,557	8,723
1965	895	1,609	1,466	3,970
1966	531	2,257	2,299	5,087
1967	968	8,026	5,163	14,157
1968	4,584	4,732	6,332	15,648
1969	154	3,220	3,506	6,880
1970	87	1,063	1,351	2,501
1971	23	234	916	1,173
1972	2,742	3,297	4,895	10,934
1973	2,751	3,870	11,850	18,471
1974	635	2,032	2,201	4,868
1962-1974 average				7,550
1975	144	136	81	361

The relative survival of the two stocks of steelhead trout used in Big Springs Creek was about equal (Table 17), even though the Snake River fish were smaller than those from the Clearwater River. The average survival for the Snake River stock of fish might have been higher if it had not been for fish of the 1973 year-class, which were stocked in such large numbers that the survival rate was probably reduced.

Table 16. Number of steelhead trout fry released into Big Springs Creek; number of yearling rainbow-steelhead that migrated from Big Springs Creek; number of yearlings of Big Springs Creek that migrated from the upper Lemhi River; percentage survival from fry to yearling migrants, year-classes 1962-1973.

Year-class	Fry released	Yearling migrants: Big Springs Creek	Yearling migrants: Lemhi River	Percentage survival, fry-to-migrant: Big Springs Creek	Percentage survival, fry-to-migrant: Lemhi River
1962	64,500	800	–	1.2	–
1963	193,300	1,100	3,000	0.6	1.6
1964	298,400	2,400	4,800	0.8	1.6
1965	151,500	1,500	2,900	1.0	1.9
1966	136,900	800	3,100	0.6	2.3
1967	213,600	1,700	3,300	0.8	1.5
1968	219,000	2,300	8,300	1.1	3.8
1969	322,400	1,900	5,700	0.6	1.8
1970	206,000	1,400	3,300	0.7	1.6
1971	136,800	1,400	2,300	1.0	1.7
1972	358,200	3,200	9,100	0.9	2.5
1973	853,200	3,500	19,000	0.4	2.2

Smolts Produced from Fry Released in Big Springs Creek and the Lemhi River

In 1972 and 1973, I attempted to determine if fry released in the Lemhi River would provide yields of steelhead migrants similar to those of fry released in Big Springs Creek. Department of Fish and Game personnel released 2,160,000 steelhead fry of Pahsimeroi River origin (Snake River stock) in the upper Lemhi River in 1972 and 3,711,300 fry of Clearwater River stock in 1973 (Table 18). The number of yearling rainbow-steelhead trout of the 1972 and 1973 year-classes that migrated past the Lemhi River weir site was 8 times larger than the number for most previous year-classes (Table 9). On the basis of the number of yearling migrants of upper Lemhi River origin for the 1963 to 1971 year-classes (which would have been resident rainbow trout), I assumed that 6000 of the migrants for the 1972 and 1973 year-classes were resident trout. I therefore estimated that 74,700 yearling steelhead trout of the 1972 year-class passed the Lemhi River weir site, of which 9100 were from Big Springs Creek and 65,600 from steelhead fry released into the upper Lemhi River (Table 18). For the 1973 year-class, I estimated that 76,600 yearling steelhead passed the Lemhi River weir site – 19,000 from Big Springs Creek and 57,600 from the upper Lemhi River. The estimated survival from fry released in the upper Lemhi River to the yearling migrant stage was 3.04 percent for the 1972 year-class and 1.55 percent for the 1973 year-class (Table 18) – rates similar to those for fry released into Big Springs Creek (Table 16).

The maximum number of steelhead trout smolts (yearlings) could be produced in the main stems of the upper Lemhi River and Big Springs Creek with a release of 2 to 3 million fry each spring (Fig. 21). About 500,000 fry should be stocked in Big Springs Creek (Fig. 19) and the rest in the upper Lemhi River.

Additional steelhead trout smolts could probably be produced in the upper Lemhi River drainage if more intensive management were undertaken. In 1972 and 1973, the trout fry were released into the main stems of both Big Springs Creek and the Lemhi River and the distribution may not have been adequate to obtain maximum smolt production. Use of all the tributary streams in the valley floor plus reduction of the predator population near release sites should increase steelhead trout production.

Growth of Juvenile Steelhead

The growth of subyearling rainbow-steelhead trout in Big Springs Creek was only slightly affected by the large densities of fish in the stream during some years (Table 19). Subyearling migrants of the 1972 year-class were smaller than those of any other year-class. More subyearling rainbow-steelhead trout (20,500 migrants) and chinook salmon (60,700 migrants) lived in Big Springs Creek during the summer of 1972 than in any other summer during the study. The steelhead fry of the 1972 year-class were in the stream for 101 days (longer than all but one of the other year-classes), but they were the smallest fish, probably because of the large density of subyearlings in the stream.

Table 17. Percentage survival to migrant stage of steelhead fry of Snake River versus Clearwater River origin, year-classes 1962-1973.

River of origin and year-class	Percentage survival, fry-to-migrant: Subyearling	Yearling	Total
Clearwater River			
1962	9.9	1.2	11.1
1963	6.4	0.6	7.0
1964	8.1	0.8	8.9
1965	8.1	1.0	9.1
1968	15.0	1.1	16.1
1969	6.3	0.6	6.9
1970	4.2	0.7	4.9
1971	3.9	1.0	4.9
Average	7.7	0.9	8.6
Snake River			
1966	7.5	0.6	8.1
1967	12.0	0.8	12.8
1972	5.7	0.9	6.6
1973	4.4	0.4	4.8
Average	7.4	0.7	8.1

Table 18. Number of steelhead fry released in the Lemhi River and Big Springs Creek in 1972 and 1973; yearling steelhead migrants at the Lemhi River weir from fry released in the Lemhi River and Big Springs Creek; percentage survival of fry to the yearling migrant stage.

	Fry released			Yearling migrants at Lemhi River			Percentage survival fry-to-yearling migrant		
Year-class	Big Springs Creek	Lemhi River	Total	From Big Springs Creek	From the Lemhi River	Total [a]	From Big Springs Creek	From Lemhi River	From all fry released
1972	358,200	2,160,000	2,518,200	9,100	65,500	74,600	2.54	3.04	2.97
1973	853,200	3,711,300	4,564,500	19,000	57,600	76,600	2.23	1.55	1.68

[a] All migrants assumed to be steelhead trout. Total number of yearling rainbow-steelhead migrants was 80,700 for the 1972 year-class and 82,700 for the 1973 year-class. I assumed 6000 of the migrants each year were resident rainbow trout, on the basis of the number of rainbow trout migrants of upper Lemhi River origin from the 1963-1971 year-classes (Table 8).

In a step-wise regression analysis of the data in Table 19, with length of migrants as the dependent variable, days in the stream was the best single-variable model and accounted for 20 percent of the variability in length of fall migrants. Days in the stream plus number of migrants produced the best two-variable model (Fig. 22), but accounted for only an additional 4 percent of the variability in subyearling length.

The number of days spent in Big Springs Creek during the summer was the key factor in determining length of subyearlings at the end of the summer. The number of days in the stream might have accounted for more of the variability in fish length if I had not used two different stocks of steelhead in the creek. Steelhead of mid-Snake River origin were released in 1966, 1967, 1972 and 1973, and fish of Clearwater River origin in the other years. The mid-Snake steelhead fry were smaller (170-210 fry per ounce, displacement volume) when they emerged from the Big Springs Creek incubation channel than were the fry of Clearwater River origin (113-130 fry per ounce). In a plot of the number of fry released and length of migrants (Fig. 23), the data points for the years when mid-Snake steelhead were used fall in the lower left of the graph, indicating a consistently smaller size. For all of the data in the graph, 20 percent of the variability ($r = 0.45$) was accounted for by date of release. If the years in which mid-Snake River fish were used, and 1971 (when chinook fingerlings were also present) are eliminated, 70 percent of the variability in length of migrants ($r = 0.86$) is accounted for by the total days in the stream.

The mean length of age II rainbow-steelhead that migrated from Big Springs Creek during May ranged from 182 to 209 mm during the 12 years of sampling (Table 20). The length of age II smolts was not significantly correlated with the number of other fish in the stream (subyearlings or yearlings), with their length as subyearlings (Fig. 24), or with temperature.

The mean total length of rainbow-steelhead trout that migrated downstream past the Lemhi River weir site during May ranged from 190 to 209 mm for the 10 years

Table 19. Number of steelhead fry released, date released, days in stream by October 1, number of subyearling migrants, and mean length of subyearling migrants in October, 1962-1973.

Year	Fry released	Date fry released	Days in stream	Number of subyearling migrants	Mean length of subyearlings (mm)
1962	64,500	July 20	72	6,400	85.2
1963	193,300	June 27	95	12,400	97.7
1964	298,400	July 6	86	24,200	89.6
1965	151,500	July 5	87	12,200	87.6
1966	136,900	July 12	80	10,300	80.6
1967	213,600	July 1	92	25,600	88.5
1968	219,000	July 13	79	32,800	82.1
1969	322,400	June 30	93	20,200	91.1
1970	206,000	July 21	71	8,600	83.1
1971	136,800	August 2	59	5,300[a]	82.2
1972	358,200	June 21	101	20,500[b]	79.7
1973	853,200	June 14	108	37,700	89.7

[a] Plus 55,100 chinook salmon subyearling migrants.

[b] Plus 60,700 chinook salmon subyearling migrants.

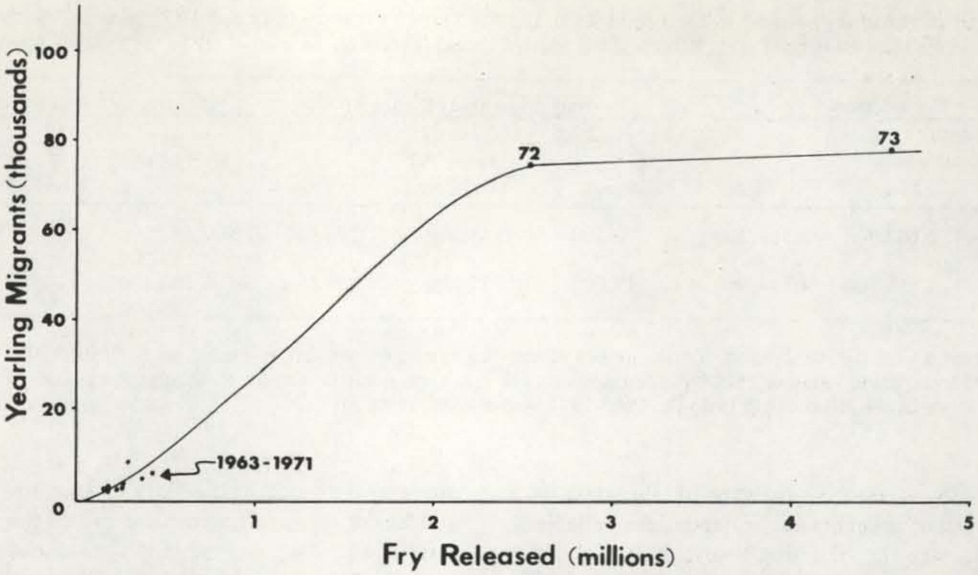

Fig. 21. Number of steelhead trout fry released into the upper Lemhi River drainage (including Big Springs Creek) and the estimated number of yearling steelhead trout that left the drainage, for year-classes 1963-1973. Line fitted by inspection.

of sampling (Table 21). The average length of May migrants captured at the weir usually was more than 200 mm, except for fish of the 1972 and 1973 year-classes. The much larger number of juvenile rainbow-steelhead stocked in Big Springs Creek and the Lemhi River in 1972 and 1973 may have caused a reduction in growth rate.

Migrants trapped at the Big Springs Creek weir during May were often smaller than those trapped at the Lemhi River weir (Table 21). Growth of fish that entered the Lemhi River as subyearlings was apparently faster than growth of subyearlings that remained in Big Springs Creek their second summer.

Rainbow-steelhead trout that left either Big Springs Creek or the upper Lemhi River in September, after their second summer in the stream, were shorter than steelhead that left the streams the following May (Fig. 25 and Table 21). The greater length of the May migrants probably resulted from growth between September and May, rather than from the migration of smaller individuals in September.

Although steelhead fry of Snake River origin were slightly smaller than fry from the Clearwater stock, this difference was insignificant after 2 years of growth in the stream. Steelhead smolts originating from mid-Snake River fry (released in 1966 and 1967) were as large as smolts of Clearwater River stock released in other years (Table 21).

Dates of Return of Adult Steelhead

Most adult steelhead trout returned to the Lemhi River during the period 10 April to 20 May; 50 percent of the fish had been trapped at the Lemhi River weir by 1 May (Fig. 26). March 21 was the earliest date and 25 April the latest date when the first adult steelhead was collected at the Lemhi River weir. From the limited data available, I believe both Clearwater River and Snake River stocks of fish passed the Lemhi River weir during similar periods.

The introduced stocks of steelhead appeared to have retained the spawning date of the parent stock. Natural spawning of Clearwater River steelhead occurred primarily during mid-May, which corresponds with the timing for most fish trapped at the Lemhi River weir. Resident rainbow trout spawned in the Lemhi River during late March and April, and I suspect the original steelhead stock in the Lemhi River might have spawned at that time. I observed wild indigenous steelhead spawning in the Pahsimeroi River, a stream similar to the Lemhi River in many respects, during early April. I suspect steelhead entering both the Pahsimeroi and the Lemhi rivers in historic times spawned on about the same dates, since both streams are fed primarily by groundwater.

Number of Returning Adults

From 14 to 73 adult steelhead trout of Big Springs Creek origin of the 1962 through 1970 year-classes returned and were captured at the Lemhi River weir (Table 22). The number of steelhead returning to the Lemhi River weir in any given calendar year (fish from two or three year-classes) ranged from 14 to 72.

Adult steelhead returning to the Lemhi River in any given year might have belonged to three different year-classes or two different stocks of fish. The Clearwater steelhead fry stocked in Big Springs Creek were primarily from a group that passed Bonneville Dam from late August through October (referred to as "B group" fish by

Table 20. Mean total length of age II rainbow-steelhead trout smolts migrating from Big Springs Creek during May; number of subyearling rainbow-steelhead trout in the stream during the first and second summers (as determined by number that ultimately migrated); number of smolts migrating, 1964-1975.

Year of migration	Number measured	Length at migration (mm)	Number of subyearling migrants in stream		Number of yearling migrants
			First summer	Second summer	
1964	73	208	6,400	12,400	800
1965	140	206	12,400	24,200	1,100
1966	140	189	29,200	12,200	2,400
1967	153	184	12,200	10,300	1,500
1968	219	187	10,300	25,600	800
1969	180	194	25,600	32,800	1,700
1970	332	194	32,800	20,200	2,300
1971	385	200	20,200	8,600	1,900
1972	183	205	8,600	5,300[a]	1,400
1973	405	193	5,300[a]	20,500[b]	1,400
1974	995	195	20,500[b]	37,700	3,200
1975	803	192	37,700	11,300	3,500

[a] In addition to rainbow-steelhead trout, the stream also eventually yielded 55,100 chinook salmon migrants.

[b] Plus 60,700 eventual chinook salmon migrants.

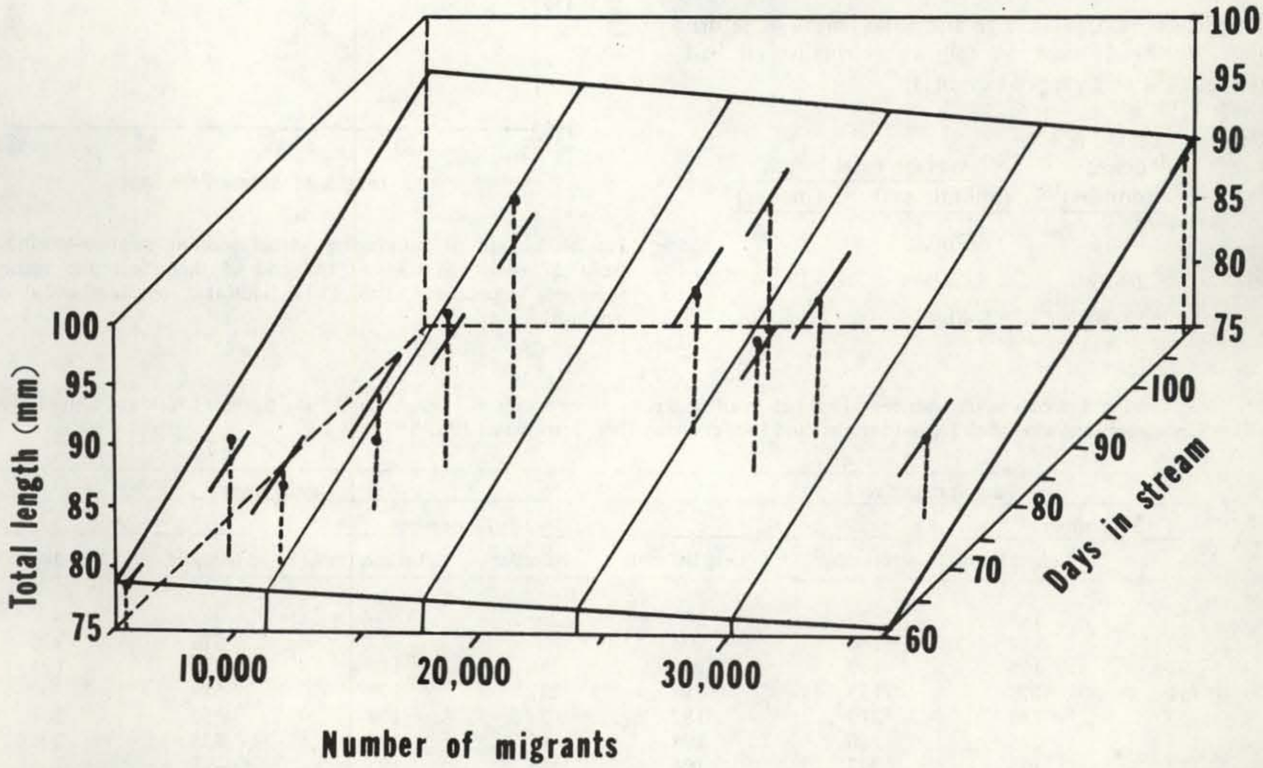

Fig. 22. Response surface for length (mm) of subyearling rainbow-steelhead trout versus days in stream by October 1 and number of subyearling migrants from Big Springs Creek.

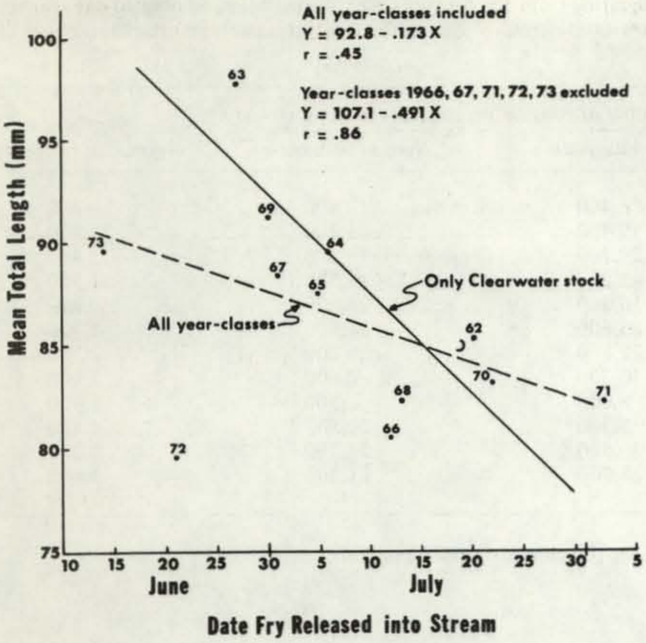

Fig. 23. Length of subyearling rainbow-steelhead migrants from Big Springs Creek in October as related to date fry of each year-class were released into stream as fry, 1962-1973 (indicated by numbers above symbols).

Columbia River biologists). Age and total length at return for adult steelhead were as follows (virtually all had migrated seaward as 2-year-old smolts):

Age	Period in ocean (months)	Average total length (millimeters)	Average total length (inches)
4_2	14-16	660-685	26-27
5_2	26-29	813-864	32-34
6_2	38-39	940-965	37-38

The Snake River stock of fry released into Big Springs Creek in 1966 and 1967 were primarily from a group of steelhead that passed Bonneville Dam during June through August (referred to as "A group" fish by Columbia River biologists). A fish that spent 1 year (12-13 months) in the ocean returned to spawn 2 years after the smolts migrated seaward, as an age 4_2 fish averaging 584 to 610 mm (23 to 24 inches) total length – 76 to 102 mm (3 to 4 inches) shorter than a B group fish of the same age. The greater length of the B group steelhead resulted from the additional 2 to 4 months of ocean rearing before they reentered fresh water. Steelhead of the A group that spent 2 years (24-25 months) in the ocean and returned to spawn 3 years after the smolts migrated seaward (age 5_2) had a mean length of 660 to 686 mm (26 to 27 inches) – again smaller than a B group steelhead of similar age.

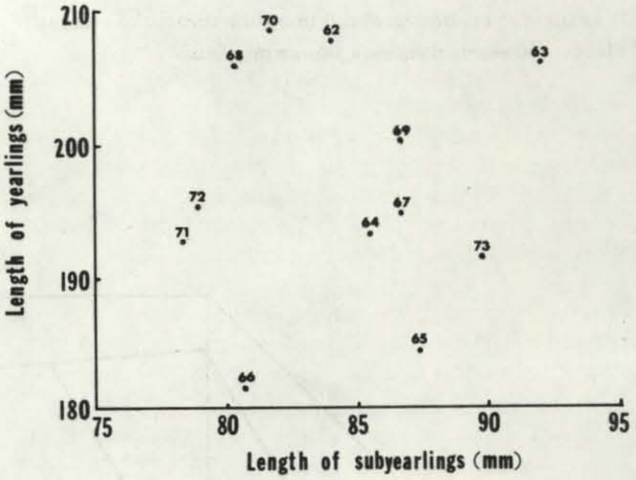

Fig. 24. Length of subyearling versus yearling rainbow-steelhead trout of each year-class at the end of their first and second summers, respectively, 1962-1973 (indicated by numbers above symbols).

Table 21. Mean total length of yearling rainbow-steelhead trout migrating downstream and caught in the Big Springs Creek and Lemhi River weirs during September following their second summer and the following May, year-classes 1962-1973.

Year-class	Big Springs Creek: September Number	September Length (mm)	May Number	May Length (mm)	Lemhi River: September Number	September Length (mm)	May Number	May Length (mm)
1962	27	188	73	208	–	–	–	–
1963	50	184	140	206	–	–	570	210
1964	382	176	140	189	750	177	880	194
1965	231	177	153	184	222	179	589	202
1966	3	188	219	187	37	179	350	201
1967	134	185	180	194	91	192	355	206
1968	179	173	332	194	385	193	415	204
1969	369	179	385	200	401	184	311	201
1970	229	174	183	205	112	180	102	206
1971	91	158	405	193	49	180	–	–
1972	76	168	995	195	1461	168	658	196
1973	315	175	803	192	751	166	1256	191

Steelhead entering the Lemhi River were assigned to a particular year-class on the basis of the stock of fish expected to return in any given year and the length of the returning fish. For example, in 1968 the steelhead trout adults trapped at the Lemhi River weir were of two distinct size groups (Fig. 27). The smaller fish, 559 to 635 mm (22 to 25 inches), were of the Snake River stock which had spent 1 year in the ocean. These fish originated from hatchery-reared smolts of the 1965 year-class released into the Lemhi River in the spring of 1966. The larger fish, 787 to 914 mm (31 to 36 inches) long, were age 5_2 fish of Clearwater River stock from the 1963 year-class of fry released into Big Springs Creek.

The large fish in 1969 and 1970 were also age 5_2 fish of the Clearwater River stock from the 1964 and 1965 releases of fry into Big Springs Creek. The largest fish, 965 mm (38 inches) long, might have been an age 6_2 fish of Clearwater stock (scales were not examined because of the large amount of reabsorption).

Separation of returning adult steelhead into various year-classes was sometimes difficult, as in 1972 when age 5_2 steelhead of Snake River stock from the 1967 year-class were expected to return along with age 4_2 steelhead of Clearwater stock from the 1968 year-class. The two groups of fish were of similar size, and scales were of little value in determining ocean age.

Once the returning adult steelhead had been assigned to a particular year-class, it was possible to calculate the approximate smolt-to-adult survival rate for each year-

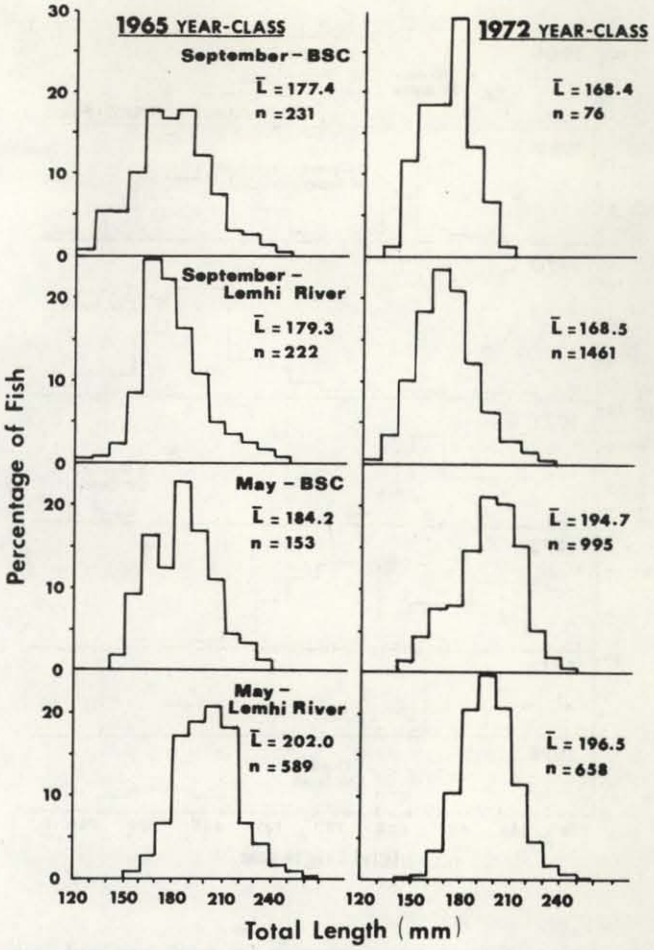

Fig. 25. Length-frequency distribution of yearling rainbow-steelhead trout collected at the Lemhi River and Big Springs Creek (BSC) weirs in September and the following May for the 1965 and 1972 year-classes ($\bar{L}$ = mean length).

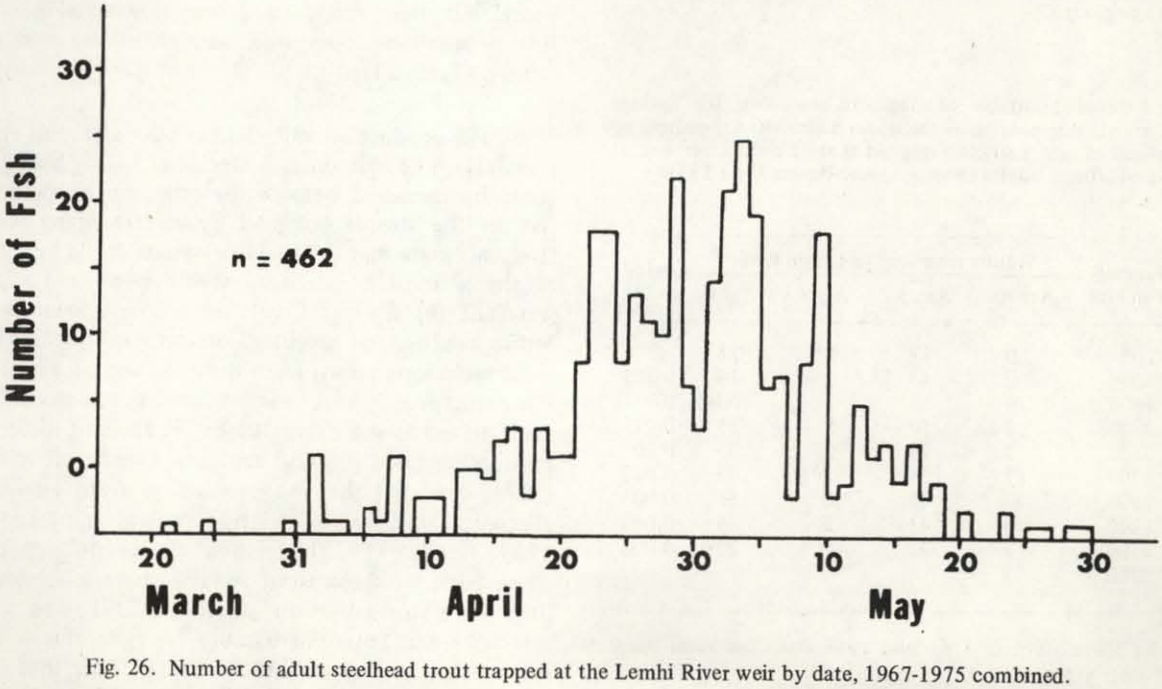

Fig. 26. Number of adult steelhead trout trapped at the Lemhi River weir by date, 1967-1975 combined.

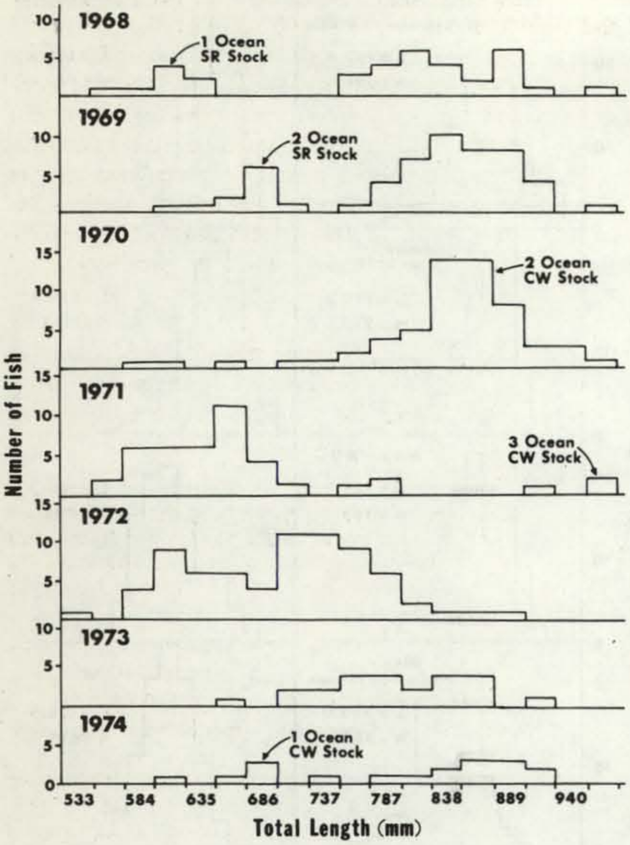

Fig. 27. Length-frequency distribution for adult steelhead trout trapped at the Lemhi River weir during years when length data were collected. 1, 2, or 3 ocean = years spent in the ocean; SR = Snake River stock and CW = Clearwater River stock of steelhead. Fish represented by labeled blocks were representative of the stocks and age groups.

Table 22. Estimated number of steelhead smolts of Big Springs Creek origin that migrated from the upper Lemhi River; number of adult steelhead of each year-class trapped at the Lemhi River weir at different ages; ratio of adults to smolts, year-classes 1962-1971.

Year-class[a]	Number of smolts	Adults returning to Lemhi River				Adults/ smolts
		Age 4_2	Age 5_2	Age 6_2	Total	
1962	–	0	17	1	18	
1963	3000	0	13	1	14	0.005
1964	4800	0	50	3	53	0.011
1965	2900	2	50	3	55	0.019
1966	3100	3	24	2	29	0.009
1967	3300	17	54	2	73	0.022
1968	8300	20	46	0	66	0.008
1969	5700	2	41	2	45	0.008
1970	3300	7	20	–	27[b]	0.008
1971	2300	9	–	–		

[a] Mid-Snake River stock in 1966 and 1967 and Clearwater River stock in other years.

[b] Incomplete count; age 4_2 and 5_2 only.

class (Table 22). Smolt-to-returning-adult survival ranged from 0.5 to 2.2 percent and was similar for both Snake River and Clearwater River stocks. Much of the variability was caused by the varying survival of downstream migrants at the Snake and Columbia river dams.

Except for the 1965 year-class, adult steelhead returning to the Lemhi River weir did not provide enough eggs to replace the eggs used to stock the stream originally (Table 23). The primary reason the Big Springs Creek steelhead reintroduction program was not self-sustaining was the high mortality of the downstream migrants at the Columbia and Snake river dams. Most, if not all, wild stocks of salmon and steelhead in the Snake River drainage have been unable to replace themselves in recent years because of the high mortalities at the dams.

PRODUCTION AND YIELD OF SYMPATRIC AND ALLOPATRIC POPULATIONS OF SALMON AND STEELHEAD

I assessed the production and yield of allopatric populations of steelhead trout in Big Springs Creek during 1969 and 1973 and sympatric populations of chinook salmon and steelhead trout in 1971 and 1972. In 1969 and 1973, enough steelhead fry were released into the stream to make them the most abundant species in the stream during those years. In 1971 and 1972, large numbers of both chinook fingerlings and steelhead fry were released. Resident rainbow trout, brook trout, and mountain whitefish were present in the streams in all years, but they made up a relatively small part of the fish populations, compared with steelhead and chinook salmon (Table 24).

The production and yield of allopatric and sympatric populations of salmon and steelhead in Big Springs Creek could be measured because the estimates of abundance of fish in the stream obtained by electrofishing were relatively accurate and the yield of smolts could be monitored at the weir. The relatively stable flows and productive water of Big Springs Creek set it apart from other less fertile salmon and steelhead streams in Idaho. However, the conclusions drawn from these studies of allopatric and sympatric populations in Big Springs Creek might be applicable to other streams in Idaho, in spite of differences in productivity and physical features. Goodnight and Bjornn (1971) reported the fish production from an essentially allopatric steelhead population present in the stream in 1969. Bowler (1972) reported the production observed when both steelhead trout fry and chinook salmon fingerlings were stocked in the stream in 1971. The 1971 test was less than optimum because fewer steelhead fry were stocked in the stream, and at a later date, than in 1969. In 1972, adequate and equal numbers of steelhead trout

Table 23. Estimated number of steelhead eggs used to stock Big Springs Creek; adult steelhead returning to the Lemhi River weir; eggs available from returning females; percentage of original eggs replaced by returning adults, year-classes 1962-1970.

Year-class	Eggs used to stock stream[a]	Adults returning	Eggs available from adults[b]	Percentage of eggs replaced
1962	75,900	18	63,800	84
1963	227,400	14	49,600	22
1964	351,100	53	187,900	54
1965	178,200	55	195,000	109
1966	161,100	29	74,200	46
1967	251,300	73	186,900	74
1968	257,600	66	232,300	90
1969	379,300	45	158,400	42
1970	242,400	27	95,000	39

[a] Assuming 85% survival of green eggs to swim-up fry.

[b] Assuming 64% females and 4000 eggs per female for 1966 and 1967 year-classes and 5500 eggs per female for other year-classes.

and chinook salmon fingerlings were put in the stream at what I considered to be the optimum time of the year (1 June for chinook and late June for steelhead). In 1973, the allopatric steelhead test was replicated by releasing a large number of steelhead fry to evaluate the production from a steelhead trout population equal in number to the combined releases of steelhead fry and chinook salmon in the previous years.

Fish Production

The steelhead trout and chinook salmon released into Big Springs Creek contributed a large portion of the total tissue elaborated by all species (Table 25). In 1969, age 0 and I rainbow-steelhead trout accounted for 68 percent of the total production. Most (80-90%) of the age 0 and I rainbow-steelhead trout originated from steelhead fry released into the stream in 1968 and 1969. In 1971, steelhead trout and chinook salmon accounted for 88 percent of the production by all species combined. Age 0 rainbow-steelhead trout contributed a smaller proportion of the total production in 1971 than in 1969 because the number of steelhead released in the stream was small, release occurred late in the summer, and the production by chinook salmon was high.

The largest amount of tissue was produced when we released large numbers of steelhead trout and chinook salmon (651,000 fish of the two species) into the stream in 1972 (Table 26). The production of age 0 rainbow-steelhead and chinook salmon was 1128.7 kg (20.3 g/m^2). In 1973, when 854,000 steelhead fry (no salmon) were released into the stream, the production of age 0 steelhead was 536.3 kg (9.6 g/m^2). Production by age 0 rainbow-steelhead and chinook salmon living sympatrically in 1972 was 77 percent larger than that of steelhead alone in 1973.

Chinook salmon produced more tissue in both 1971 and 1972 than did rainbow-steelhead in any of the 4 years, whether they were stocked separately or together (Table 26). The larger amount of production by chinook salmon resulted from their lower rate of instantaneous mortality (Table 2). The instantaneous growth rate of chinook salmon was less than that for steelhead.

Table 24. Percentage species composition of fish in the main stem of Big Springs Creek when resident rainbow were the main fish species present (1962), when large number of steelhead fry were released (1973), and when large numbers of both steelhead and chinook salmon were released (1972).

	Percentage dominant fish present		
Species	Resident rainbow (1962)	Steelhead (1973)	Steelhead and salmon (1972)
Rainbow-steelhead	75.2	95.3	41.8
Age 0	–	83.8	37.6
Age I	–	9.6	3.8
Age II	–	1.9	0.4
Chinook salmon	6.2	1.6	57.3
Mountain whitefish	5.6	1.6	0.1
Brook trout	13.0	1.5	0.8
Fish in sample	537	7,628	13,224

Table 25. Fish production (kg) and percentage of total produced by each species of fish in Big Springs Creek during 1969 (Goodnight and Bjornn 1971) when only steelhead fry were stocked, and 1971 (Bowler 1972) when both steelhead fry and chinook fingerlings were stocked.

	Allopatric steelhead (1969)		Sympatric steelhead and salmon (1971)	
Species	Production (kg)	Percentage	Production (kg)	Percentage
Rainbow-steelhead	524.8	88.3	464.6	36.6
Age 0	304.8		133.0	
Age I	140.3		233.4	
Age II and older	79.7		98.2	
Chinook salmon	3.0	0.5	748.4	58.9
Mountain whitefish	–	–	23.0	1.8
Brook trout	24.6	4.1	35.0	2.8
Sculpins	42.2	7.2	–	–
Totals	594.6		1271.0	

Table 26. Number of steelhead trout fry and chinook salmon fingerlings released into Big Springs Creek; estimate of fall population of age 0 fish in main stem of creek; production of age 0 rainbow-steelhead trout and chinook salmon in the main stem; yield of age 0 migrants from the main stem and tributaries; proportion of production that left the stream as yield from allopatric (1969, 1973) or sympatric (1971, 1972) populations of the two species.

Test situation	Fry or fingerlings released	Fall population estimate	Production (only age 0) Total (kg)	Production (only age 0) Grams per m^2	Yield (only age 0) Number of migrants	Yield (only age 0) Number per 100 m^2	Yield (only age 0) Biomass (kg)	Yield (only age 0) Grams per m^2	Yield: production ratio
Allopatric steelhead									
1969	322,400	43,000[a]	304.8	5.5	20,200	36.3	137.4	2.5	0.45
1973	853,700	59,600[a]	536.3	9.6	37,700	67.7	248.8	4.5	0.47
Sympatric steelhead and salmon									
1971									
Steelhead	136,800	13,600[a]	133.0	2.4	5,300	9.5	29.2	0.5	0.21
Chinook	255,500	55,100[b]	748.4	13.4	55,100	98.9	556.5	10.0	0.75
1972									
Steelhead	358,900	39,200[a]	238.9	4.3	20,500	36.8	92.3	1.7	0.40
Chinook	291,600	75,400	889.8	16.0	62,800	112.7	596.6	10.7	0.67

[a] Includes wild rainbow trout which made up 10 to 20% of the rainbow-steelhead trout population.

[b] Minimum estimate based on counts of migrants at weir.

Production by age 0 steelhead was less when they were living with chinook salmon than when they were alone in the stream (Table 26). Similar numbers of steelhead fry were stocked in Big Springs Creek at about the same time in both 1969 and 1972, but the production in 1972 was 4.3 g/m^2 compared with 5.5 g/m^2 in 1969. At the end of the growing season, the age 0 rainbow-steelhead were 10 mm shorter and weighed 1.3 g less in 1972 than in 1969.

Yield of Fish

The maximum yield of age 0 migrant chinook salmon and rainbow-steelhead trout, expressed either as number or biomass, occurred in 1972 when the two species lived together in Big Springs Creek (Table 26). The yield was 83,300 migrants (149.5 fish/100 m^2, or 12.4 g/m^2). The maximum yield of rainbow-steelhead trout in an allopatric situation occurred in 1973, when 37,700 age 0 migrants left the stream (67.7 fish/100 m^2 or 4.5 g/m^2). The yield of age 0 rainbow-steelhead trout was less in 1969 than in 1973 and the yield from the sympatric populations of the two species in 1971 was less than in 1972 because fewer fry of one or both species were released in 1969 and 1971 than in 1972 and 1973.

The yield of age 0 rainbow-steelhead trout was less when both species were released into the stream than when only steelhead trout fry were released. The number of age 0 rainbow-steelhead trout migrants produced in 1971 and 1972 was less than might be expected from similar numbers of fry released in earlier years with essentially allopatric steelhead populations in the stream (Fig. 16). On the basis of the curve in Fig. 16, the yield (number of migrants per 100 m^2) of rainbow-steelhead subyearlings for the 1971 year-class should have been 15 to 20 rather than the 9.5 observed; and the yield for the 1972 year-class should have been 45 to 50 if only steelhead had been in the stream, rather than the 36.8 observed.

The yield of rainbow-steelhead trout expressed as biomass of age 0 migrants was less in 1972 than in 1969, despite the nearly equal numbers of migrants, because the migrants were smaller in 1972 (Table 26). The large number of chinook salmon in the stream in 1972 appears to have reduced the growth of steelhead. Steelhead were released into the stream 10 days earlier in 1972 than in 1969, but at the end of the summer had a shorter mean length (Fig. 23) and a lighter mean weight (Table 26).

Up to three-fourths of the production by age 0 chinook salmon and rainbow-steelhead trout in Big Springs Creek eventually migrated from the stream in the form of subyearlings (Table 26). Of the fish tissue produced by age 0 chinook salmon, 67 percent in 1971 and 75 percent in 1972 left the stream in the form of migrants. The proportion of tissue produced by age 0 rainbow-steelhead trout represented in the trout migrants ranged from 21 percent in 1971 to 47 percent in 1973. I expected fewer of the rainbow-steelhead trout than chinook salmon to leave the stream as age 0 migrants because some of the production was by resident rainbow trout, which might never leave the stream, and some was by steelhead that remained in the stream for a second summer before they left the stream as yearlings. The proportion of the rainbow-steelhead production leaving the stream in the form of age 0 migrants was largest in 1973, when the largest production occurred, and smallest in 1971, when the smallest rainbow-steelhead production occurred. When relatively few rainbow-steelhead lived in the stream during the summer, a smaller proportion of the age 0 fish left the stream than when a large number were in the stream in the summer.

The yield of yearling rainbow-steelhead from Big Springs Creek appeared to be unaffected by the release of chinook salmon along with the steelhead trout. The number of yearling migrants from the 1971 year-class was relatively small (1400 fish, Table 27), whereas the number from the 1972 year-class (3200) was the second largest observed in the 12 years of study. For both year-classes, the number of yearling migrants exceeded the number observed for other year-classes when only steelhead fry were released in similar numbers (Fig. 16).

Table 27. Estimated number of yearling rainbow-steelhead that lived in Big Springs Creek for two summers before leaving the stream, year-classes 1962-1973.

Year-class	Number of migrants	Year-class	Number of migrants
1962	800	1968	2300
1963	1100	1969	1900
1964	2400	1970	1400
1965	1500	1971	1400
1966	800	1972	3200
1967	1700	1973	3500

EFFECTS OF STEELHEAD FRY RELEASES ON THE RESIDENT FISH IN BIG SPRINGS CREEK

The studies of steelhead trout and chinook salmon in Big Springs Creek provided unique opportunity to assess the impact of introduced steelhead trout on self-sustaining resident trout populations. The steelhead trout fry released into Big Springs Creek were potential competitors of the resident trout – particularly rainbow trout. The resident rainbow trout originated as residual steelhead trout or from hatchery-reared rainbow trout released into the stream in earlier years. Brook trout were introduced into the stream many years before the steelhead trout fry were released and had established a small but self-sustaining population.

I evaluated the effects of the steelhead fry releases on resident rainbow trout primarily by comparing 1) the number of downstream migrants at the Big Springs Creek weir before and after steelhead fry were present in the stream and 2) the abundance of age II and older trout in our electrofishing samples taken each year. The first steelhead trout fry were released into Big Springs Creek in June 1962 and began migrating downstream as subyearlings in the fall of 1962. The first yearling steelhead trout migrants left Big Springs Creek in the fall of 1963. Since operation of the Big Springs Creek weir began in April 1962, subyearlings and yearlings counted during the spring of 1962 and yearlings counted during the fall-winter-spring of 1962-1963 were resident trout. The subyearling rainbow-steelhead migrants in the fall of 1962 and the yearlings in the fall of 1963 and later years, were either resident rainbow or steelhead trout, and the age II and older trout were all resident rainbow trout.

The fish population in Big Springs Creek was sampled with electrofishing gear in the same sections of the stream at approximately the same time of the year (late July or August) from 1962 to 1968. From these electrofishing samples, I assessed changes in abundance of rainbow-steelhead trout of various age-classes and in species composition of the other fish in the stream. In 1969, the location of the sample sections in Big Springs Creek was changed to better suit estimation of fish production. In 1970, the same sample sections were electrofished as in 1962 to 1968. In 1971 to 1975 new sample sections were used to facilitate production estimates. Both the absolute and relative abundance of fish in the electrofishing samples for the years 1962 to 1968 and 1970 can be compared directly. The electrofishing samples collected in 1969 and 1971 to 1975 provide comparable relative abundance information for various age-classes and species, but the absolute abundances of fish in the samples are not comparable between the early years and those after 1971 because we sampled different sections and amounts of stream.

No steelhead trout fry were released into the stream in 1975; thus all of the age 0 rainbow trout collected by electrofishing and at the Big Springs Creek weir that year were resident rainbow trout rather than steelhead trout. By comparing the abundance of subyearling trout in the 1975 electrofishing samples and estimates of fish passing the Big Springs Creek weir with equivalent data for earlier years, an estimate was obtained of the abundance of resident rainbow trout after they had been subjected to many years of competition with steelhead trout.

Resident Trout Populations Before Steelhead Fry Releases

Resident rainbow trout were the most abundant salmonid in Big Springs Creek before steelhead trout fry were released in the stream. In the 1962 electrofishing

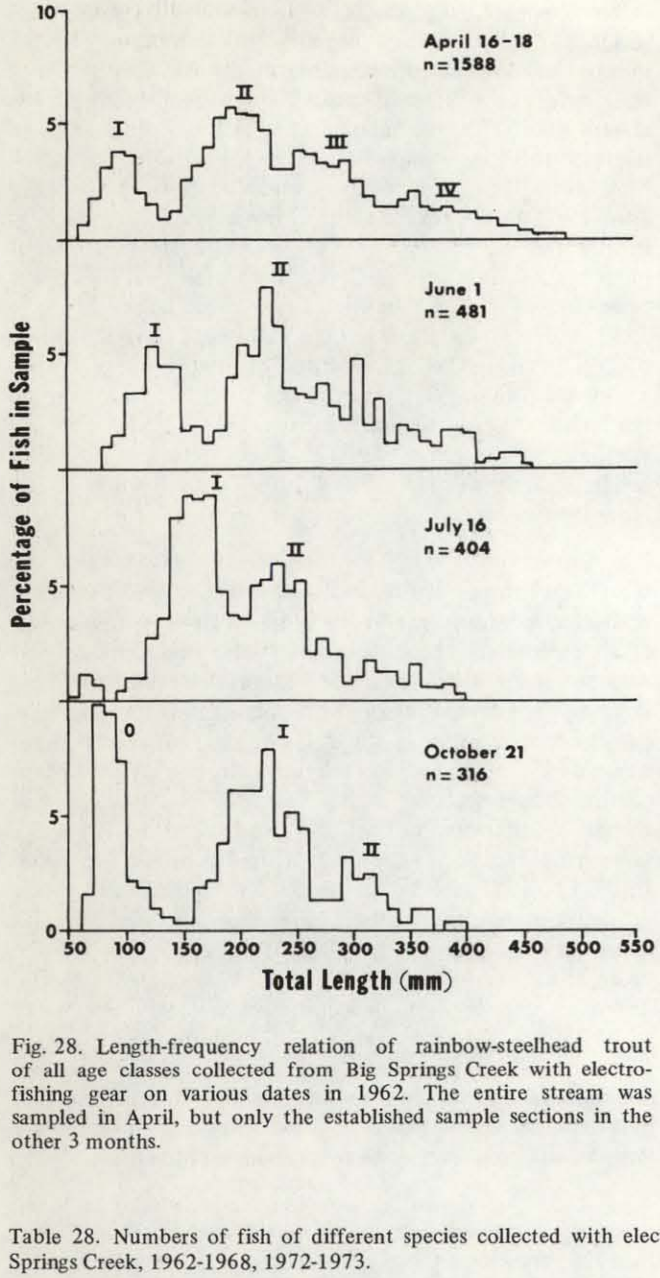

Fig. 28. Length-frequency relation of rainbow-steelhead trout of all age classes collected from Big Springs Creek with electrofishing gear on various dates in 1962. The entire stream was sampled in April, but only the established sample sections in the other 3 months.

samples, which contained no steelhead trout, resident rainbow trout made up 75 percent of the total number of fish collected, chinook salmon 6 percent, brook trout 13 percent, and mountain whitefish 6 percent (Table 28).

The age structure of the rainbow trout collected in the electrofishing samples of July 1962 was typical of a resident population (Fig. 28). The newly emerged rainbow trout fry were not easily caught with electrofishing gear in midsummer, and no special attempt was made to collect them. Age I rainbow trout were the youngest rainbow trout fully vulnerable to electrofishing in midsummer and thus they were the most abundant in the sample. A substantial number of age II fish, and some age III and IV fish up to 400 mm long were also collected. In the mid-summer electrofishing sample, chinook salmon were mostly age 0, brook trout were age I and II, and whitefish were mostly age III and older.

Age II and older fish made up 44 percent of all rainbow trout 1 year and older in the 1962 samples from Big Springs Creek (Table 29). Although 1962 was the only year in which the rainbow trout population was sampled before it was affected by the steelhead fry releases, the 1962 data were representative of the moderately fished rainbow trout population.

Rainbow trout moved into Big Springs Creek from the Lemhi River to spawn and some of the resulting juvenile trout left Big Springs Creek and entered the Lemhi River. During April and May of 1962 and 1963, 200 yearlings of the 1960 and 1961 year-classes, respectively, migrated downstream out of Big Springs Creek. These yearling rainbow trout left the stream at an age and time of the year when steelhead smolts left in later years. An estimated 2700 subyearling rainbow trout of the 1961 year-class left Big Springs Creek during the period April through July 1962 and 700 yearlings left the creek during the fall-winter-spring of 1962-1963 (Table 6).

Table 28. Numbers of fish of different species collected with electrofishing gear and percentage of the total catch made up by each, Big Springs Creek, 1962-1968, 1972-1973.

	Rainbow-steelhead		Chinook salmon		Brook trout		Mountain whitefish	
Year	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1962	404	75.2	33	6.2	70	13.0	30	5.6
1963	786	81.0	40	4.1	138	14.2	6	0.1
1964	537	74.4	24	3.3	122	16.9	39	5.4
1965	829	85.2	18	1.9	126	14.0	–[a]	–
1966	460	81.3	3	0.1	102	18.0	1	0.2
1067	325	80.7	14	3.5	52	12.9	12	3.0
1968	1285	83.9	41	2.7	123	8.0	82	5.4
1972[b]	5532	41.8	7579	57.3	101	0.8	12	0.1
1973[b]	7266	95.3	123	1.6	115	1.5	124	1.6

[a] Whitefish were not counted in 1965.

[b] No special effort was made to collect age 0 fish in 1962-1968 but they were collecteed in 1972 and 1973. Both steelhead fry and chinook fingerlings were released in 1972 but only steelhead fry in other years.

Table 29. Number and percentage of age I and age II and older rainbow-steelhead trout collected from the sample sections of Big Springs Creek with electrofishing gear during late summer, 1962-1970.

Year	Age I fish		Age II and older fish[a]	
	Number	Percentage	Number	Percentage
1962[a]	222	56	173	44
1963	617	80	153	20
1964	427	83	91	17
1965	741	94	45	6
1966	394	88	52	12
1967	272	84	53	16
1968	1188	94	78	6
1970	622	93	47	7

[a] All fish collected in 1962 and most of the age II and older fish in other years were resident rainbow trout.

In 1962, 430 rainbow trout longer than 300 mm migrated downstream out of Big Springs Creek during the period April through July (Table 30). Most of these fish were spawners that had entered Big Springs Creek earlier, spawned, and were returning to the Lemhi River. Most brook trout that left Big Springs Creek did so during the fall from September to December 1962.

Resident Trout Populations After Steelhead Fry Releases

After steelhead fry were released into Big Springs Creek, rainbow-steelhead trout made up an even larger proportion of the fish in the stream than when steelhead were not present. More rainbow-steelhead trout were collected from the sample sections of Big Springs Creek each year from 1963 through 1968 (except 1967) than in 1962. Rainbow-steelhead trout made up 74 to 85 percent of all species collected from 1962 through 1968 (not including age 0 trout; Table 28).

In 1972 and 1973, the fish populations were sampled by electrofishing in late summer and a special effort was made to collect all age 0 rainbow-steelhead trout as well as all age-classes of other species. In 1972, a year when chinook salmon fingerlings were also released in the stream, rainbow-steelhead trout (including age 0 fish) made up 42 percent of the fish collected, chinook salmon 57 percent, and brook trout and whitefish the rest. In 1973, when only steelhead fry were released into the stream, rainbow-steelhead trout (including age 0 fish) made up 95 percent of the fish collected (Table 28).

Except in 1971 and 1972, when chinook salmon fingerlings were released into Big Springs Creek, juvenile chinook salmon were not abundant in the stream. Chinook salmon contributed only 6.2 percent of the fish collected in electrofishing samples in 1962 and a smaller percentage in later years (Table 28). The number of juvenile chinook salmon reared in Big Springs Creek depended, in part, on the number of adult salmon that spawned in the stream.

The brook trout population in Big Springs Creek was not noticeably affected by the steelhead trout fry released into the stream. In 1962, the electrofishing crew collected 70 brook trout from the sample sections and in later years (except 1967) they collected more than 70. Brook trout made up 10 to 20 percent of the age I and older fish collected from the stream in 1962 to 1968. In 1972 and 1973, when all age 0 fish were included in the electrofishing sample, brook trout made up less than 2 percent of the fish collected (Table 28). Since age 0 brook trout were large enough to be regularly collected by electrofishing, the 1973 sample most accurately represents the relative abundance of brook trout in the main stem of Big Springs Creek. Brook trout normally made up less than 10 percent of the age I and older rainbow-steelhead and brook trout collected from the stream (Table 31). The number of whitefish collected from the sample sections varied but was always small – less than 6 percent of all fish collected (Table 28).

Although steelhead trout fry releases did not appear to adversely affect brook trout, they did affect the rainbow trout population. After 4 years of fry releases, age I rainbow-steelhead trout were more abundant than in 1962 and yearlings made up a much larger percentage of the rainbow-steelhead trout collected from Big Springs Creek (Table 29). In 1962, age I fish contributed only 56 percent of the age I and older fish collected, whereas in later years this percentage was nearly 90 percent. Both the number and percentage of age II and older

Table 30. Estimated number of rainbow trout spawners (longer than 300 mm) that migrated downstream out of Big Springs Creek each year during March-July and the number of brook trout that left during September-December, 1962-1973.

Year	Number of rainbow trout spawners	Number of brook trout
1962	430	147
1963	265	449
1964	79	633
1965	174	422
1966	248	302
1967	73	361
1968	56	417
1969	163	–
1970	79	247
1971	66	294
1972	–[a]	102
1973	128	272

[a] Adult rainbow trout not counted in 1972.

fish in the electrofishing samples declined as a result of the introduction of fry into Big Springs Creek. In 1962, the 173 age II and older fish collected from the electrofishing sections made up 44 percent of the age I and older rainbow trout collected. In later years, only one-third as many age II and older rainbow trout were collected and they composed only 6 to 16 percent of the fish collected (Table 29). By 1965, after steelhead fry releases in the previous 3 years, the rainbow-steelhead trout population in Big Springs Creek consisted almost exclusively of age 0 (which were not collected in the electrofishing samples) and age I fish; relatively few age II and older rainbow trout were collected (Fig. 29).

After 10 years of steelhead fry releases, the rainbow trout population in Big Springs Creek had been reduced and made up only 10 to 20 percent of the rainbow-steelhead trout population in the stream in years when approximately 300,000 steelhead fry were released. In 1975, when no steelhead fry were released, we collected 868 subyearling

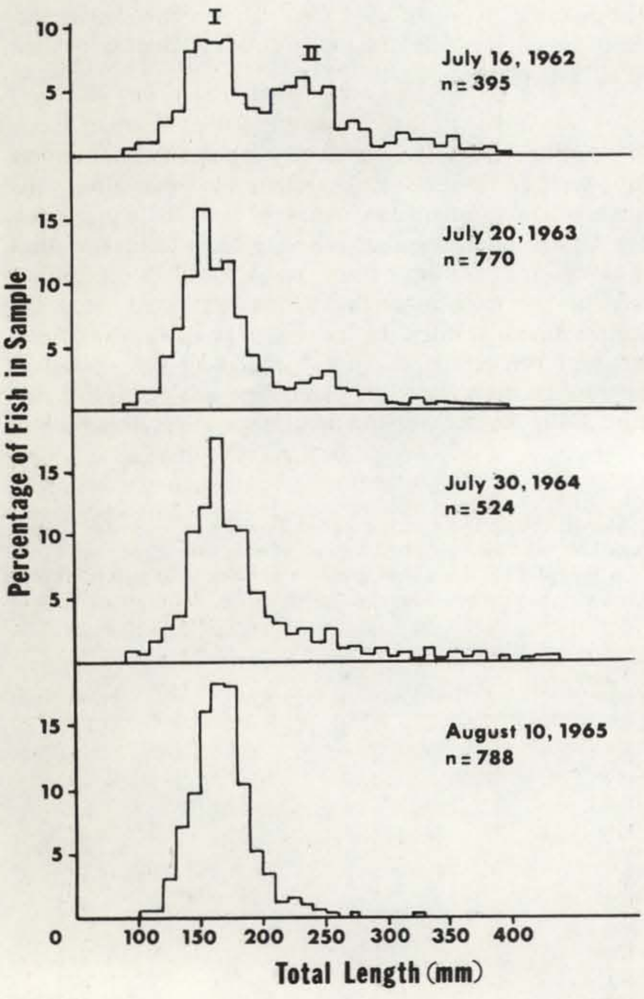

Fig. 29. Length-frequency distribution of rainbow-steelhead trout (age I or older) collected from Big Springs Creek sample sections with electrofishing gear during midsummer, 1962-1965.

Table 31. Number of age I and older rainbow-steelhead trout and brook trout collected from sample sections of Big Springs Creek during summer or early fall, 1962-1974, and the percentage made up of rainbow-steelhead trout.

Year	Number of rainbow-steelhead and brook trout collected	Percentage made up of rainbow-steelhead trout
1962	426	92.7
1963	830	92.8
1964	577	90.7
1965	833	94.6
1966	488	91.4
1967	377	86.2
1968	1389	91.1
1969	901	97.1
1970	741	95.7
1971	649	93.7
1972	589	93.4
1973	912	95.8
1974	1067	86.6

rainbow trout from the sample sections of Big Springs Creek. In the 3 preceding years, when steelhead trout were released, we collected 4117 to 7976 subyearling rainbow-steelhead trout from these same sections (Table 14). If rainbow trout subyearlings were no more abundant in 1972 to 1974 than in 1975, they made up no more than 10 to 20 percent of the subyearling rainbow-steelhead trout populations in the stream during those 3 years. The increased number of subyearling and yearling migrants from Big Springs Creek was additional evidence that steelhead trout were abundant in Big Springs Creek and probably provided substantial competition for the resident rainbow trout (Table 6).

Inasmuch as steelhead fry were released into the stream during the first year of weir operation, I was unable to determine the number of rainbow trout subyearlings that left Big Springs Creek after their first summer before the resident trout population was affected by the steelhead. The number of rainbow trout of the 1961 year-class trapped in the spring of 1962 – nearly 2500 during April, May, and June (Table 13) – was an indication that a substantial number of subyearling rainbow trout probably left the creek each year. In later years, similar numbers of subyearlings (rainbow and steelhead trout) left Big Springs Creek during the same 3 months, but the proportion which were steelhead trout undoubtedly increased. Thus, the abundance of resident rainbow trout must have decreased.

Differences between years in the number of fall migrants provided additional evidence of the decrease in abundance of rainbow trout. In 1975, when steelhead fry were not released, the number of rainbow trout subyearlings that migrated from Big Springs Creek during the fall was much smaller than the number that migrated in any of the preceding years when fry were released (Table 15). The number of subyearlings that left the stream during September, October, and November in 1962 was four times the number migrating in 1975. Although steelhead fry were released into the stream in 1962, the number was relatively small; the rainbow trout population was larger than in any other year, and many of the migrants were rainbow trout.

The number of rainbow trout spawners (longer than 300 mm) that migrated downstream out of Big Springs Creek from March through July after spawning was largest in 1962 (Table 30). The number was reduced thereafter because 1) entry into the stream might have been restricted in some years by operation of the downstream migrant trap and 2) competition with steelhead trout reduced the number of the rainbow trout juveniles in Big Springs Creek, ultimately resulting in a reduction in numbers of spawners. Probably the second reason was the more important. Rainbow trout spawned in Big Springs Creek beginning in late March, and thus some spawners entered the stream during late February and March. Since the downstream migrant weir in Big Springs Creek was operated only about half the time during February and March in most years, and little more during April, resident rainbow trout spawners had access to Big Springs Creek.

CHINOOK SALMON SPAWNING ESCAPEMENT, SMOLT YIELD, AND ADULT RETURN

In this section, my assessments of the summer and winter capacity of the upper Lemhi River for juvenile chinook salmon and the number of natural spawners needed to fully seed the rearing area are presented.

Adult Salmon Entering the Lemhi River

Timing of Migration

Adult chinook salmon entered the upper Lemhi River during the summer. The first adult chinook salmon entered the weir trap as early as mid-May in years when the spring runoff was small and the water was relatively clear, and as late as mid-June in years when the runoff was large and the water turbid (Fig. 30). Although fish were delayed in their arrival to the upper Lemhi River in some years, they were not delayed in spawning.

The timing of adult chinook salmon migration into the upper Lemhi River was bimodal; a large group of fish passed the weir site soon after entering the Lemhi River and a second group just before spawning, in late August (Fig. 30). Although this bimodal migration at first raised the question of two separate stocks of fish – spring and summer chinook – in the upper Lemhi River, I later concluded that only spring chinook entered the Lemhi River. Some of the fish spent the summer in the Lemhi River downstream from the weir and then moved up to the spawning area, past the weir, just before spawning. The conclusion that summer chinook were not present in the Lemhi River was based on the following observations: 1) the timing of spawning was unimodal, rather than the bimodal timing that has been observed in streams with known populations of both spring and summer chinook; 2) no chinook tagged at Bonneville Dam during the time summer chinook were passing through the lower Columbia River have been recovered in the Lemhi River; 3) a no-longer-existing diversion dam in the lower end of the Lemhi River diverted all the Lemhi River flow to a powerhouse on the Salmon River during the months when summer chinook would have arrived at the mouth of the Lemhi River, and probably eliminated the stock; 4) in some recent years when flows were low in the Lemhi River, irrigation diversion dams placed across the river by mid-July would have blocked the migration of summer chinook if they were present – nevertheless, the timing of migration into the upper Lemhi River was bimodal; and 5) the adult chinook salmon migration into the upper Lemhi River ended earlier than the migration of salmon into the Pahsimeroi River, a stream which contains both spring and summer chinook salmon (Fig. 31).

Age Structure of Adult Salmon at the Weir

Chinook salmon that spawned in the upper Lemhi River were mostly 3, 4, or 5 years old. Eggs deposited in the redds in early September incubated during the fall and winter and the fry emerged in February and March. The juvenile salmon then stayed in the Lemhi River or a downstream area for 1 year before migrating to the ocean in the spring, about 18 months after the eggs were deposited. A few fish – only 4 percent of the salmon examined at the Lemhi River weir in 1965-1974 (Table 32) – re-entered fresh water after 1 year in the ocean and spawned at the end of their third year of life (here designated as age 3_2) at a length of less than 610 mm. Salmon that spent 2 years in the ocean spawned at the end of their fourth year of life (age 4_2; length, 610-813 mm) and fish that spent 3 years in the ocean spawned at the end of their fifth year of life (age 5_2; longer than 813 mm). Age groups 4_2 and 5_2 fluctuated in relative abundance from year to year, but together made up nearly equal proportions of the fish examined at the Lemhi River weir over the 10-year period (Table 32).

Sex Ratio of Adult Salmon at the Weir

In 1965 and 1966, random samples of fish trapped at the Lemhi River weir were examined to determine length, age, and sex. None of the fish in the 1965 sample of 188 fish, and only 11 in the sample of 309 in 1966, were age 3_2. All of the age 3_2 fish were males (Table 33), as was normally true for adults returning after 1 year in the ocean. In both 1965 and 1966, males slightly outnumbered females among the age 4_2 fish, but were outnumbered by females among age 5_2 fish.

Number of Chinook Salmon Counted at the Weir

The number of adult salmon captured at the Lemhi River weir ranged from 428 in 1974 to 1943 in 1968 (Table 34). The 1964 run might have been larger than that in any other year, but we counted fish in only the latter part of the run because the weir was not completed until 23 June. The estimated number of females available to spawn in the upper Lemhi River (weir count minus harvest, times proportion which were females) ranged from 206 in 1974 to 808 in 1968 (Table 34). The correlations between the count of salmon at the weir and the number of female salmon available to spawn (Fig. 32) and estimated egg deposition (based on number and size of females, Fig. 33) were high, as would be expected.

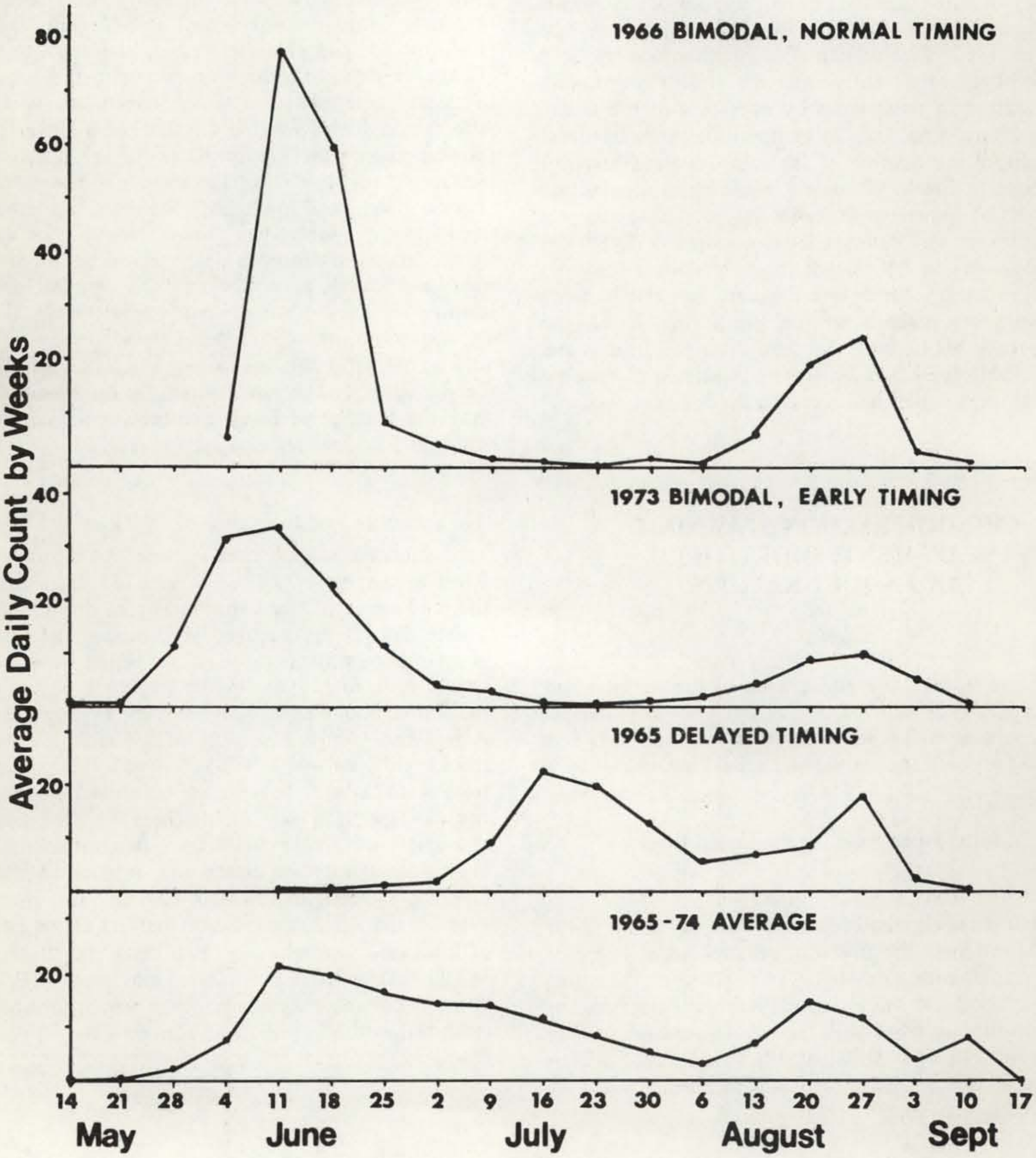

Fig. 30. Timing of capture of returning adult chinook salmon at the Lemhi River weir in 1966, a year with normal, bimodal timing; in 1973, a year with early arrival because of small, non-turbid spring runoff; in 1965, a year with delayed arrival because of large, turbid spring runoff; and the 1965-1974 average.

Table 32. Percentage age composition of adult chinook salmon caught in the upstream trap of the Lemhi River weir, 1965-1974.

Year	Number of fish in sample	Percentage age group 3_2	4_2	5_2
1965	188	0	51	49
1966	309	4	65	31
1967	1807	4	49	47
1968	1972	2	38	60
1969	755	5	68	27
1970	1217	2	56	43
1971	832	4	77	19
1972	1185	3	44	53
1973	1039	2	32	67
1974	428	4	57	39
Average		3.0	53.5	43.5

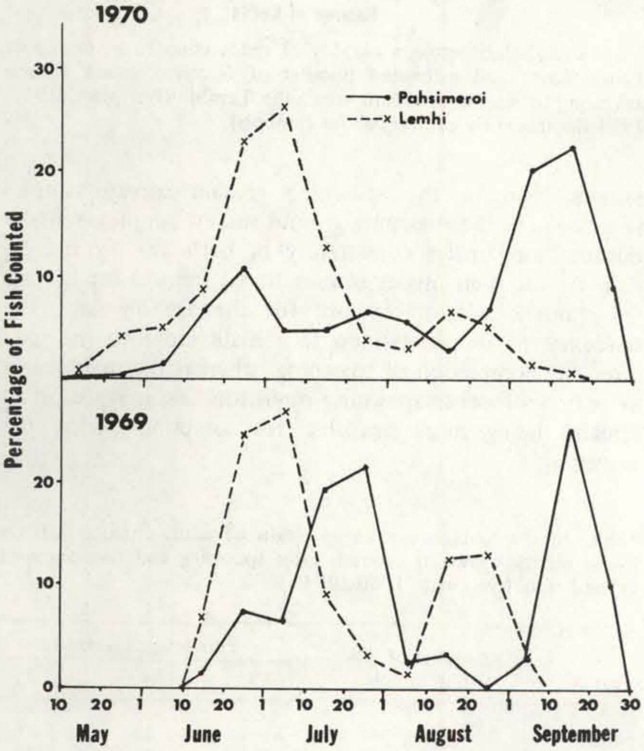

Fig. 31. The timing of adult chinook salmon returning past the Lemhi and Pahsimeroi River fish weirs, 1969 and 1970.

Table 33. Percentage of adult chinook salmon in a random sample removed from the upstream trap of the Lemhi weir classified as males and females in each age group, 1965 and 1966.

Age group	1965 Number of fish in sample	1965 Percentage males	1966 Number of fish in sample	1966 Percentage males
Age 3_2	0	–	11	100
Age 4_2	96	54	201	55
Age 5_2	92	38	97	47

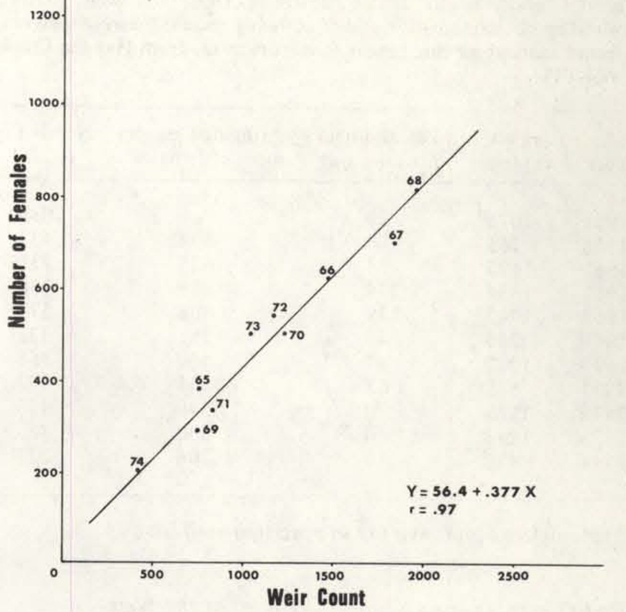

Fig. 32. Relation between number of adult salmon counted at the Lemhi River weir and estimated number of female salmon available to spawn, based on age, sex, and harvest data, 1965-1974 (indicated by figures above symbols).

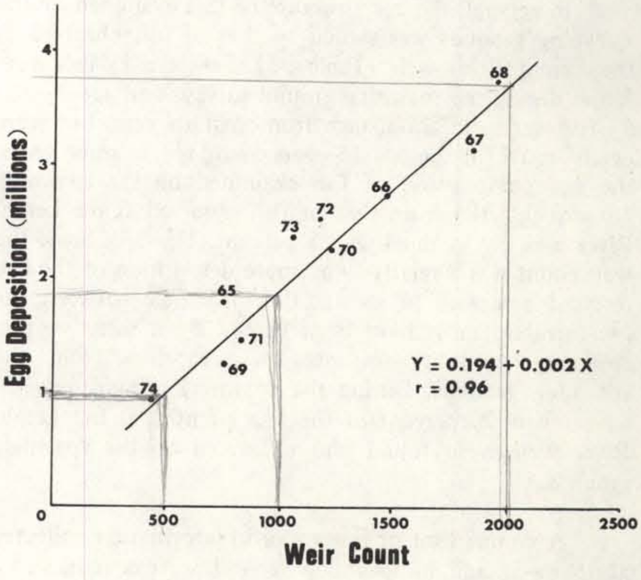

Fig. 33. Relation between number of adult chinook salmon counted at the Lemhi River weir and estimated number of eggs available for deposition, 1965-1974 (indicated by numbers above symbols).

Table 34. Number of adult salmon captured at the Lemhi River weir; number removed for artificial spawning; estimated number of females available to spawn upstream from the weir (natural mortality not included); number of redds counted during spawning ground surveys in the Lemhi River upstream from Hayden Creek, 1964-1974.

Year	Fish captured	Females held for spawning	Estimated escapement of females	Number of redds
1964	1075[a]	27	–	1038
1965	765	0	394	433
1966	1473	13	625	738
1967	1834	234	969	786
1968	1943	139	808	572
1969	743	46	281	328
1970	1217	47	502	358
1971	832	65	334	392
1972	1185	0	549	473
1973	1043	0	502	433
1974	428	0	206	237

[a] Incomplete count; weir not in operation until June 24.

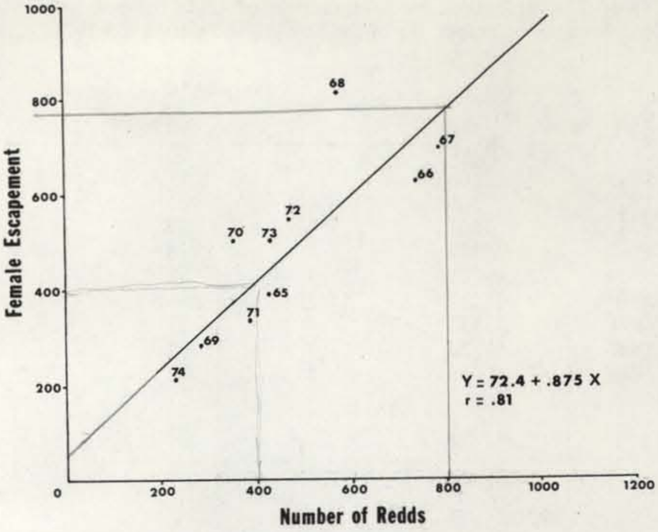

Fig. 34. Relation between number of redds counted in the upper Lemhi River and estimated number of female chinook salmon available to spawn upstream from the Lemhi River weir, 1965-1974 (indicated by numbers above symbols).

Redd Counts versus Salmon Counted at the Weir

The number of redds counted in the Lemhi River upstream from the weir ranged from 1038 in 1964 to 237 in 1974 (Table 34). There was a high degree of correlation between female escapement and number of redds counted in spawning ground surveys (Fig. 34). The correlation between redds counted and the estimated number of chinook salmon eggs available for deposition (Fig. 35) was not as high as for redds and the number of females, but was significantly different from zero (0.95 confidence level).

In general, the age structure of fish examined on the spawning grounds was similar to that of fish observed at the Lemhi River weir (Table 35). Few age 3_2 fish were found during the spawning ground surveys and age 4_2 and 5_2 fish varied in abundance from year to year, but were nearly equal for the last 15 years combined. In some years, the age composition of fish examined on the spawning grounds differed from that of fish observed at the Lemhi River weir by as much as 25 percent (Fig. 36). Since the weir count was a relatively accurate description of the fish released upstream to spawn, the difference between the two samples must have been caused by a selective prespawning mortality or post-spawning loss from the spawning grounds. During the spawning ground surveys, fewer than 20 percent of the fish counted at the Lemhi River weir were found and examined on the spawning grounds.

A comparison of the sex ratio information collected at the weir and in spawning ground surveys indicated a trend toward fewer males in the spawning ground surveys than at the Lemhi River weir. Sex information was collected at the Lemhi River weir in only 2 years, but in both those years and for both age 4_2 and 5_2 fish, the percentage of females was consistently smaller in the weir sample than in the spawning ground survey samples (Fig. 37). In the spawning ground survey samples, females outnumbered males consistently in both age 4_2 and 5_2 fish. At the weir, males outnumbered females for the age 4_2 chinook salmon but not for the age 5_2 fish. The tendency of female salmon to remain close to the redd after the completion of spawning, whereas the male leaves in search of other spawning opportunities, may result in females being more available for sampling during the survey.

Table 35. Percentage age composition of adult chinook salmon found on the spawning grounds after spawning and fish observed at the Lemhi River weir, 1960-1974.

Year	Number of fish in sample	Percentage age group		
		3_2	4_2	5_2
1960	150	4	49	47
1961	358	3	54	43
1962	304	0	68	32
1963	96	2	34	64
1964	214	0	72	28
1965	26	0	65	35
1966	176	0	66	34
1967	170	1	30	69
1968	103	0	67	33
1969	44	0	68	32
1970	87	1	41	57
1971	104	2	73	25
1972	161	0	27	73
1973	129	0	16	84
1974	33	0	21	79
Average, spawning grounds (1965-1974)		0.4	47.5	52.1
Average, Lemhi weir (1965-1974)		3.0	53.5	43.5

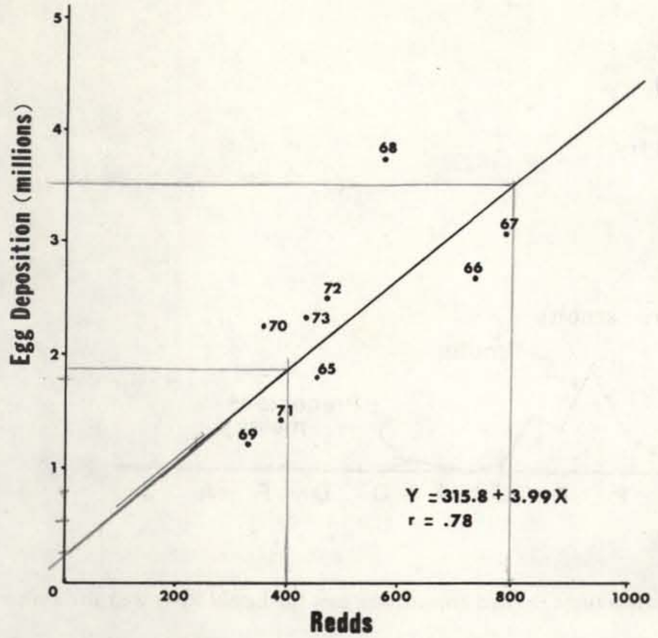

Fig. 35. Number of redds counted in the upper Lemhi River versus estimated number of chinook salmon eggs available for deposition for each year-class, 1965-1973 (indicated by numbers above symbols).

Smolt Yields from Natural Spawning

Timing of Juvenile Migration

Chinook salmon adults spawned in the upper Lemhi River in late August and early September. The fry began emerging from the gravel in late January or February, and many moved downstream past the Lemhi River weir site in a migration that peaked in March and April and had ceased by late May (Fig. 38). Comparatively few of the young-of-the-year chinook salmon migrated downstream during June, July, and August. Beginning in late September, the young-of-the-year, which had grown to smolt size, began moving downstream out of the upper Lemhi River. Large numbers of the juvenile salmon that had lived in the upper Lemhi River during the summer moved downstream during September, October, and November. Small numbers of juvenile salmon moved downstream during the winter months, but the numbers increased again in late February and peaked during March; the true seaward migration of smolts was during the spring. The newly emerged fry and smolt-sized young-of-the-year fish that migrated during the fall were not smolts and were not migrating to the sea.

After the spring migration of yearling smolts, the only juvenile salmon of the year-class that remained in the stream were precocious males. These yearlings remained in the upper Lemhi River until the fall spawning season, when they ripened and had the appearance of adult males, even to the extent of body deterioration as the spawning season progressed. A relatively small number (usually less than 10,000) of the precocious males moved downstream during the fall spawning season (Fig. 38).

Juvenile salmon migrated downstream out of the upper Lemhi River during every month of the year, but there were three distinct peaks: 1) soon after emergence in early spring, 2) in the fall after the fish had grown to smolt size, and 3) during the following spring as yearling smolts (Fig. 38). Yearling smolts were the least abundant of the three groups of migrating fish, and newly emerged fry the most abundant. The number of young-of-the-year salmon migrating downstream during the fall usually exceeded the number of yearlings migrating downstream the following spring.

Similar patterns of downstream migration of chinook salmon occurred in the Lemhi River and Big Springs Creek (Fig. 39). In both streams, young-of-the-year fall migrants were more abundant than smolts migrating the next spring.

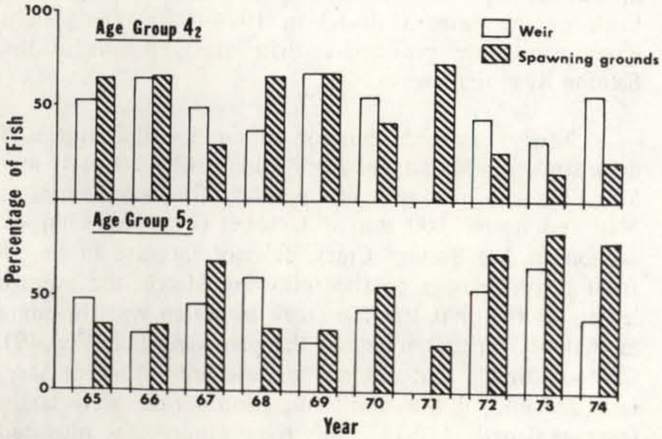

Fig. 36. Percentage of adult chinook salmon observed during spawning ground surveys in the upper Lemhi River or at the Lemhi weir, classified by age groups 4_2 or 5_2, 1965-1974.

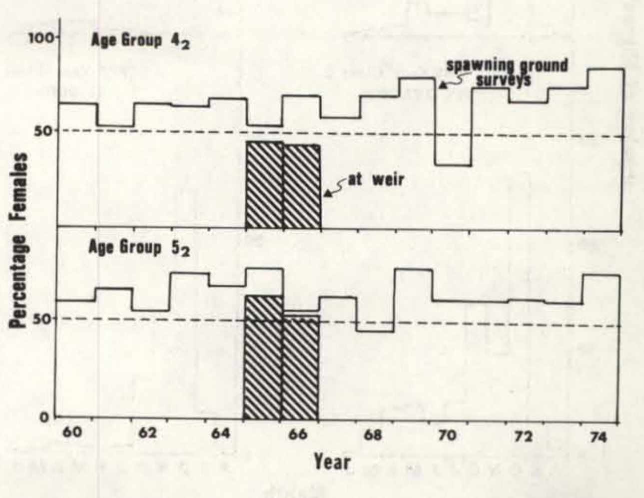

Fig. 37. Percentage of adult chinook salmon observed during spawning ground surveys (1960-1974) or at Lemhi weir (1965 and 1966), in age groups 4_2 and 5_2, that were classified as females.

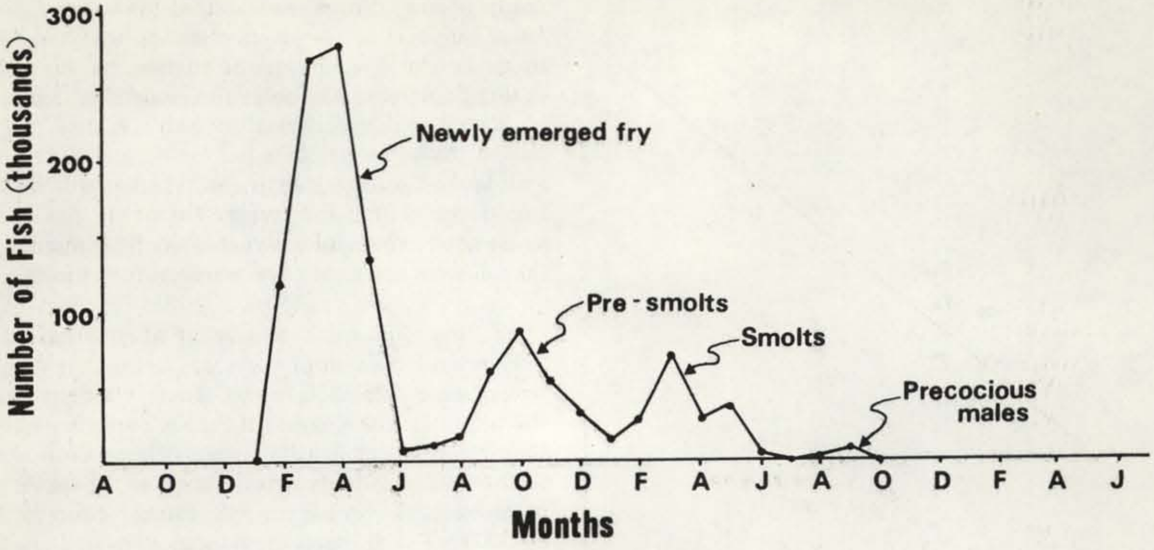

Fig. 38. Estimated number of juvenile chinook salmon of the 1964 year-class that migrated downstream past the Lemhi River weir site during each month they were present in the river.

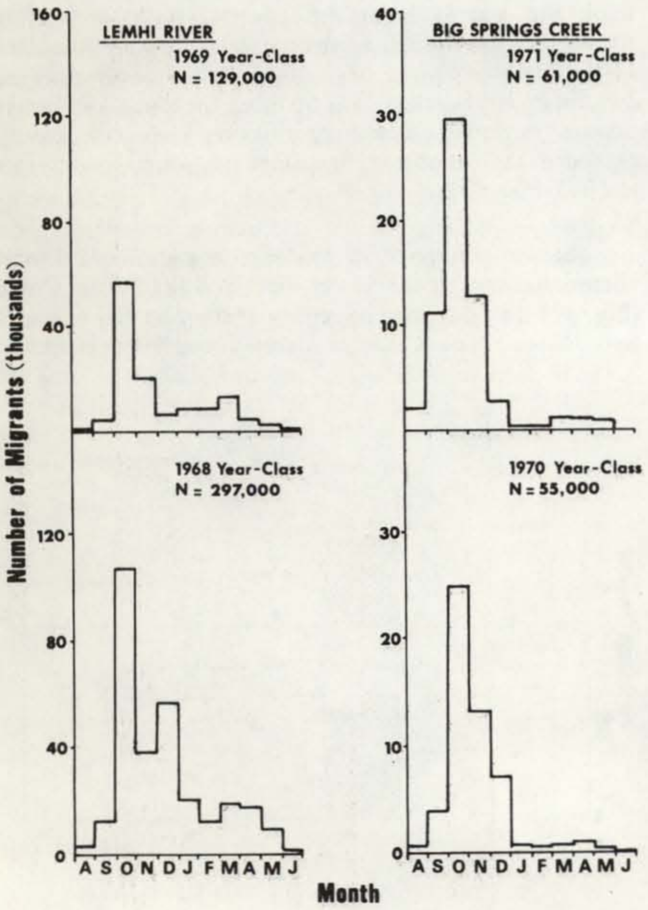

Fig. 39. Number of yearling rainbow-steelhead that migrated downstream past the Lemhi River (1968-1969) and Big Springs Creek (1970-1971) weir sites during each month starting in August.

In Big Springs Creek, however, few of the juvenile salmon present in the stream during the summer remained overwinter and migrated as yearling smolts, whereas in the Lemhi River, 25 to 45 percent of the smolt-size migrants left during the spring as smolts (Fig. 40). Few juvenile salmon overwintered in Big Springs Creek because the stream had relatively little of the large rubble used by small salmon as winter habitat.

Size of Migrants

The growth rate of juvenile chinook salmon in the upper Lemhi River was inversely related to their density (Fig. 41). The chinook salmon smolts produced in the Lemhi River were among the largest produced in the Salmon River drainage. In the Lemhi River, fork length of juvenile chinook in the fall averaged 95 to 103 mm, compared with 64 to 82 mm for chinook salmon produced in the Marsh Creek drainage (a tributary of the Middle Fork of the Salmon River) in 1974-1976. The Lemhi River was more productive than most streams in the Salmon River drainage.

Newly emerged chinook salmon fry that migrated downstream in March and April were mostly 30 to 39 mm long. The modal length of migrating fish was 55 mm in May and nearly 100 mm in October (Fig. 42). Chinook salmon in Big Springs Creek did not increase in length from early October to the following March; the average length of fish that left the creek in March was the same as that of fish that migrated the preceding fall (Fig. 42). Chinook smolts that did not migrate until April or May, near the end of the smolt migration season, were larger (average length 110-115 mm) than smolts that migrated in March. Precocious male salmon that remained in the upper Lemhi River a second summer grew to an average size of 135-mm fork length by late August.

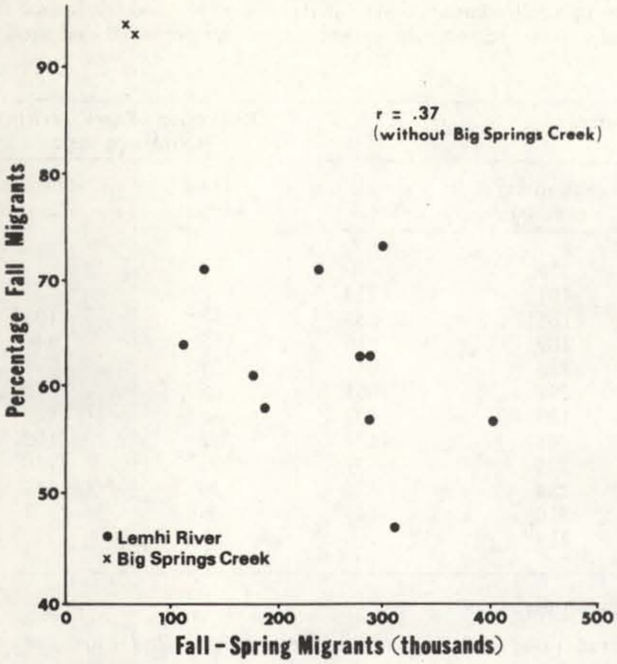

Fig. 40. Number of smolt-sized chinook salmon that migrated downstream past the Lemhi River and Big Springs Creek weir sites during the fall-winter-spring versus the percentage that migrated during the fall (September-December), 1964-1974.

Number of Migrants

The estimated number of juvenile salmon (both fry and smolt-sized fish) that migrated downstream past the Lemhi River weir site ranged from 0.3 to 1.2 million. The number of smolt-sized salmon that migrated downstream during the fall-winter-spring ranged from slightly over 100,000 to 400,000 for the year-classes studied (Table 36).

The number of chinook salmon fry or smolt-sized fish that migrated downstream out of the upper Lemhi River was a function of the number of eggs deposited by adult salmon (Figs. 43 and 44). For the range of spawning escapements and egg depositions (1 to 4 million) studied (Table 36), the relation between eggs deposited and numbers of fry or smolt-sized migrants produced appeared to be linear. Fifty percent of the variation in number of fry migrants (Fig. 43) and 79 percent of the variation in number of smolt-sized migrants (Fig. 44) could be explained by variation in egg deposition. The spawning escapement (egg deposition) at which proportional increases of fry or smolt migrants were no longer detectable was not observed during the years of our study and thus must have been in excess of 4 million eggs.

The percentage of the total juvenile salmon migrants that migrated either as fry or as smolt-sized fish in the fall was nearly constant for each of the spawning escapements (expressed as eggs deposited, Fig. 45). About 65 to 70 percent of the total chinook migrants were fry, regardless of the number of eggs deposited. Smolt-sized fish that migrated in the fall made up 10 to 20 percent of the total migrants, irrespective of the number of eggs deposited. Juvenile salmon that migrated as smolts (not plotted in Fig. 45) also made up a nearly constant percentage of the total migrants at all levels of egg deposition.

The percentage of the total migrants that left the Lemhi River as fry, subyearlings in the fall and winter, or smolts in the spring was also nearly constant (Fig. 46). Of the total chinook salmon migrants for each year-class, fry made up 60 to 70 percent, subyearlings in the fall 16 to 22 percent, and smolts in the spring 9 to 21 percent.

The percentage of smolt-sized migrants that left the upper Lemhi River during the fall months was not strongly correlated with the total number of smolt-sized migrants (Fig. 40). The percentage migrating in the fall ranged from 56 to 73 percent for all year-classes except one in the Lemhi River. More than 90 percent of the smolt-sized migrants left Big Springs Creek during the fall; few overwintered in the stream.

The number of smolt-sized chinook salmon that overwintered in the upper Lemhi River and then migrated as smolts during March, April, and May ranged from 26,000 to 126,000 during the years of study. For some year-classes the total number of smolt-sized chinook salmon present in the stream at the end of the summer (roughly equal to the number that migrated during fall-winter-spring) was as large as the number of fish (126,000) of the 1964 year-class that overwintered in the upper Lemhi River and then migrated in the spring. If the amount of suitable winter habitat was the only factor that caused juvenile chinook salmon to migrate downstream during the fall and winter, few fish would be expected to migrate when fewer than 150,000 fish were present at the end of the summer. Since 126,000 juveniles of the 1964 year-class overwintered in the upper Lemhi River and migrated as smolts during the spring, it would seem that at least that many juvenile salmon could overwinter in the upper Lemhi River each year. However, there were only 106,000 smolt-sized

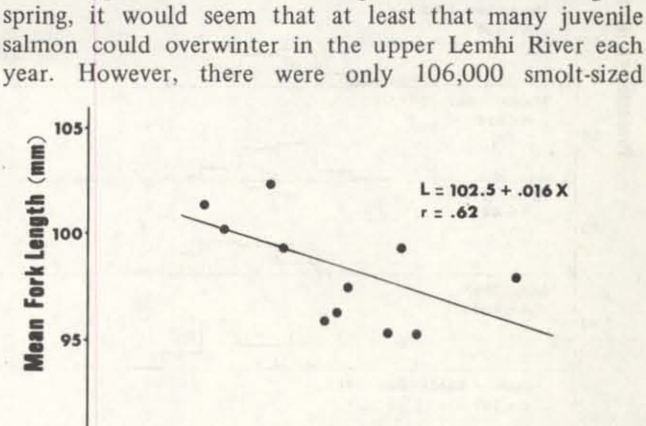

Fig. 41. Number of smolt-sized chinook salmon that migrated downstream past the Lemhi River weir site during the fall-winter-spring (as an index of juvenile abundance) versus mean fork length (mm) of migrants in October, 1964-1974.

Table 36. Estimated number of eggs deposited in the upper Lemhi River by adult salmon; number of fry, fingerlings, and smolt-sized fish migrating downstream past the Lemhi Weir in spring, summer, or fall-winter-spring, respectively; proportion of eggs deposited that survived to migrant stage, year-classes 1963-1974.

Year-class	Estimated egg deposition (thousands)	Downstream migrants (thousands)				Proportion of eggs surviving to migrant stage	
		Spring (fry)	Summer (fingerlings)	Fall-spring (smolts)	Total	Total migrants	Fall-spring migrants
1963	–	–	33	174	–		
1964	–	794	35	401	1230		
1965	1794	389	11	185	585	.33	.103
1966	2738	301	6	109	416	.15	.040
1967	3169	591	12	238	841	.27	.075
1968	3774	759	5	297	1061	.28	.079
1969	1219	267	11	129	407	.33	.106
1970	2258	910	19	245	1174	.52	.109
1971	1417	103	3	225	331	.23	.159
1972	2530	577	15	284	876	.35	.112
1973	2375	527	8	310[a]	845[a]	.36[a]	.131
1974	921	266	10	219[b]	–		.238[b]

[a] Includes smolts produced from 900,000 chinook fingerlings released in spring 1974.

[b] Includes smolts from 1,140,300 fingerlings released in spring 1975. The fall-spring smolt estimate was incomplete because it included only the fall 1975 migrants.

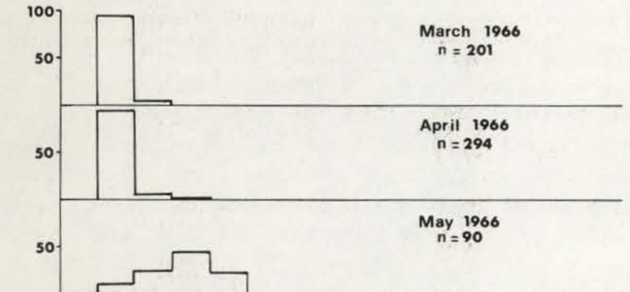

Fig. 42. Length-frequency distribution of juvenile chinook salmon of the 1965 year-class that migrated downstream past the Lemhi River weir site.

migrants of the 1966 year-class and 80 percent of them migrated during the fall and winter (before March). Theoretically all of the migrants of the 1966 year-class could have remained in the upper Lemhi River and migrated during the normal smolt migration season of March, April, and May if they had so desired.

The proportion of the estimated number of eggs deposited by spawners in the upper Lemhi River that survived to migrate from the river ranged from 0.15 to 0.52 (Table 36), and the proportion of the eggs that survived to migrate as smolt-sized juveniles ranged from 0.04 to 0.16. The proportion of eggs represented by migrating juveniles appears high, especially for the total migrants, which included fry. The proportion of the egg deposition that survived to migrate as subyearling, smolt-sized fish was similar to the survival rate for steelhead trout fry released into Big Springs Creek (Table 10). The estimated number of downstream migrants could be inflated – especially the number of fry – if all the marked fish did not return downstream past the weir or if they were not as readily caught as unmarked fish. Failure to meet either of these conditions for mark-recapture population estimates was more likely for fry than for the smolt-sized migrants.

Smolt Yield with Hatchery Supplementation

After the first few years of study, it became obvious that the upper Lemhi River was not producing the maximum possible number of juvenile salmon because spawning escapements were inadequate. At first, I attempted to supplement natural spawning by placing eyed chinook

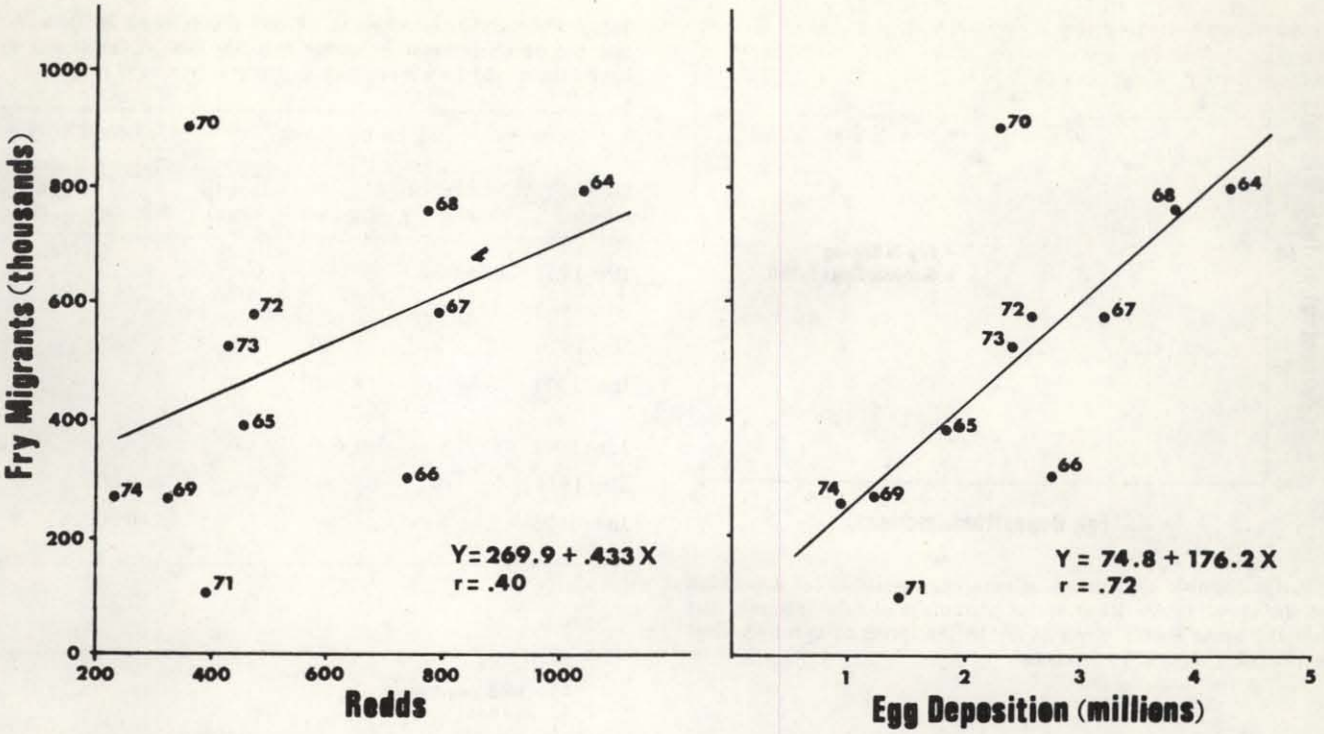

Fig. 43. Number of chinook salmon redds counted in the upper Lemhi River and the number of chinook eggs available for deposition versus the number of chinook salmon fry that migrated downstream past the weir site, 1964-1974 year-classes (indicated by numbers above symbols).

salmon eggs in the Big Springs Creek incubation channel. Few of the eggs placed in the channel survived, however, because of the large amounts of organic debris that clogged the interstitial spaces in the gravel and reduced dissolved oxygen levels to near zero in water flowing through the gravel. In 1967 and 1968, eggs were kept in the hatchery until the swim-up fry stage and then released into Big Springs Creek in early December. This was earlier than the normal date of fry emergence because water was warmer in the hatchery than in the study streams, where fry normally did not begin emerging until late January or February.

Releasing chinook salmon fry into Big Springs Creek in December did not increase the number of smolt-sized migrants the following fall-winter-spring; the number was no different in 1967 and 1968, when fry were released, than in 1966 when no fry were released (Fig. 47). Many of the fry left the creek soon after release.

The juvenile salmon were thereafter held in the hatchery until the downstream migration of naturally emerged fry had decreased to a minimum (Fig. 38). In May 1970, 21,100 chinook fingerlings of the 1969 year-class, reared at Kooskia National Fish Hatchery, were released into Big Springs Creek (Table 37). They averaged 75 mm in fork length when released. A large number of the fingerlings migrated downstream out of Big Springs Creek immediately after release and the rest migrated during July (Fig. 47). None of the fingerlings released in 1970 remained in Big Springs Creek for the entire summer.

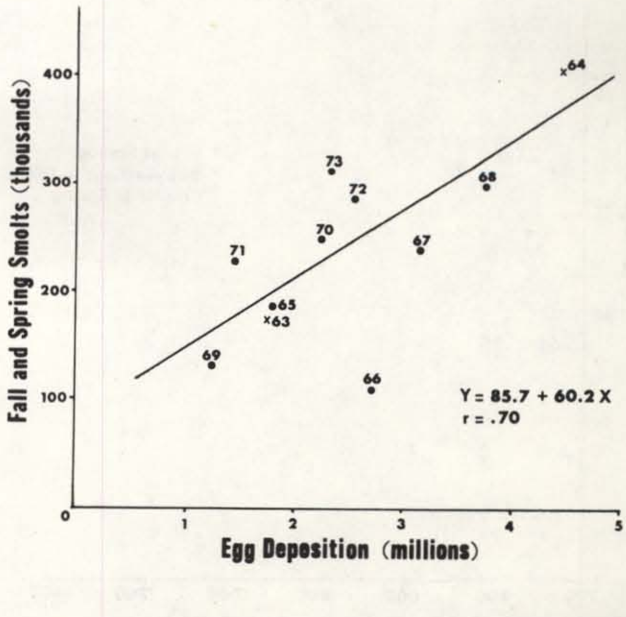

Fig. 44. Egg deposition by adult chinook salmon in the upper Lemhi River and number of smolt-sized migrants that later migrated past the Lemhi River weir site during the fall-winter-spring, 1963-1973 (indicated by numbers over symbols). Egg deposition for the 1963 and 1964 year-classes (X) estimated from Fig. 35.

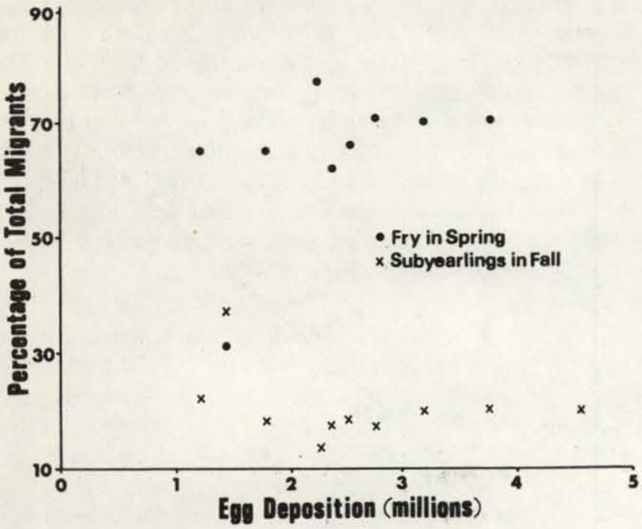

Fig. 45. Number of chinook salmon eggs available for deposition in the upper Lemhi River versus percentage of total migrants that left the upper Lemhi River as fry in the spring or as subyearlings in the fall, 1965-1974 year-classes.

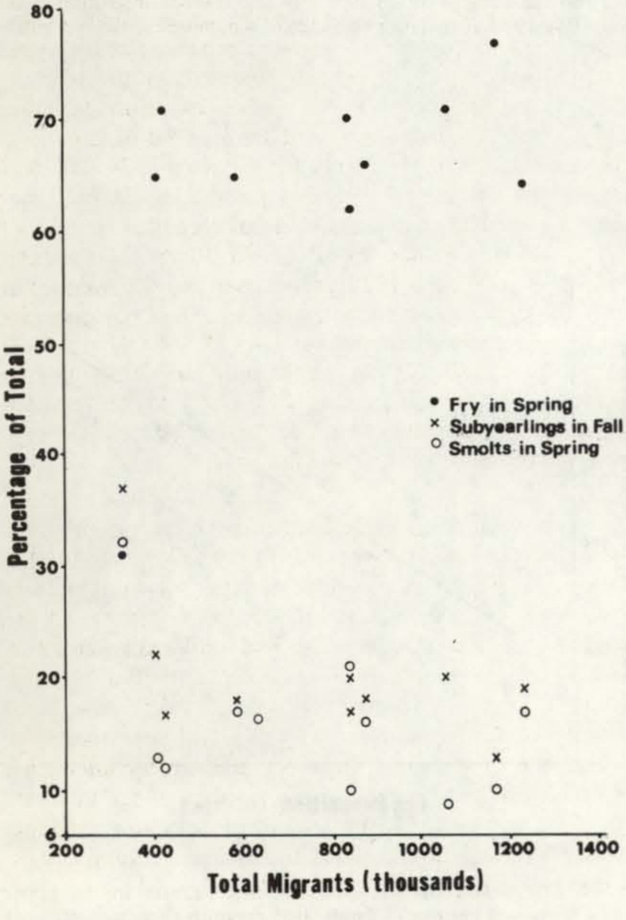

Fig. 46. Percentage of total juvenile chinook salmon migrants that left the upper Lemhi River as fry in the spring, subyearlings in the fall, or smolts in the spring, 1964-1973 year-classes.

Table 37. Number of chinook salmon fry released in December and fingerlings released in spring into Big Springs Creek and the Lemhi River, and their mean fork length at release, 1967-1975.

	Big Springs Creek			Lemhi River	
		Chinook fingerlings		Chinook fingerlings	
Date of release	Number of chinook fry	Number	Length (mm)	Number	Length (mm)
Dec. 1967	156,000	–	–	–	–
Dec. 1968	171,000	–	–	–	–
May 1970	–	21,100	75	–	–
June 1971	–	8,900	88	–	–
		255,500	55		
June 1972	–	291,600	60	–	–
May 1974	–	–	–	900,000	60
June 1975	–	–	–	1,140,300	56

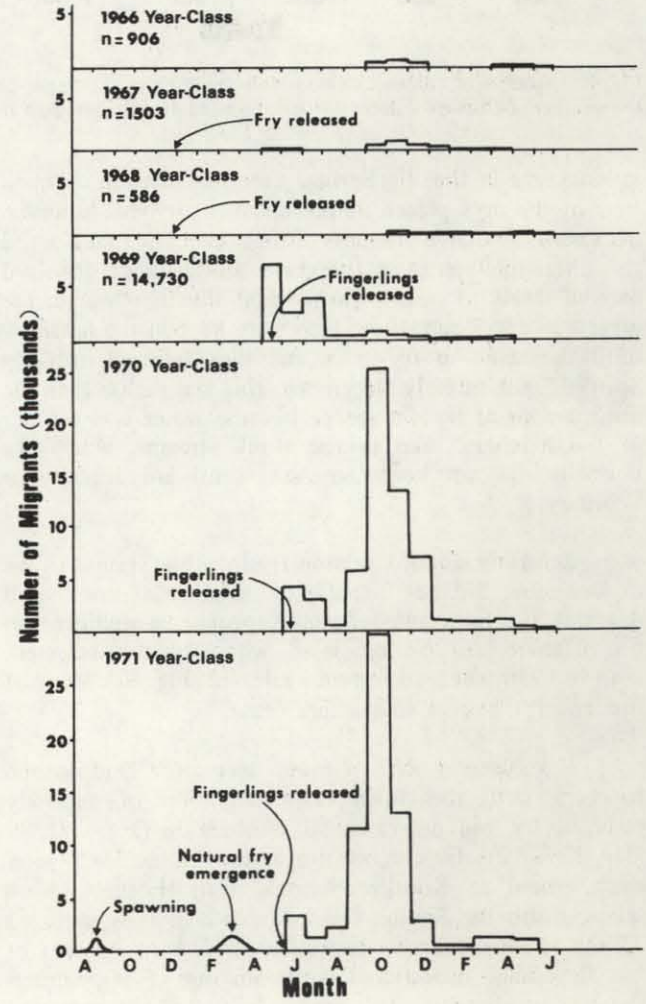

Fig. 47. Number of chinook salmon that migrated from Big Springs Creek each month for the 1966-1971 year-classes.

In early June 1971, 264,400 chinook salmon fingerlings of the 1970 year-class were released into Big Springs Creek (Table 37). One group of 8900 fish, from Lemhi River adults that had been reared at Kooskia National Fish Hatchery, averaged 88-mm fork length when released. The rest of the fingerlings were either of Lemhi River origin and raised at the Hayden Creek hatchery, or of Rapid River origin and raised at Rapid River. The fish from both hatcheries averaged 55-mm fork length when released.

As occurred in 1970 when fish of the 1969 year-class were released, some of the fingerlings released in early June 1971 migrated downstream out of Big Springs Creek immediately after release. Another group migrated during late June and early July and a third group remained in the stream until the normal fall migration period (Fig. 47). The group of larger salmon from Kooskia National Fish Hatchery left Big Springs Creek during June soon after release and during late June and July (Table 38). These fish had the appearance of smolts and continued migrating downstream after they left Big Springs Creek. Fish marked at Big Springs Creek were recaptured within the next 2 days at the Lemhi River weir, 40 km downstream. Although the mid-summer migrants seemed to be actively migrating to the sea, I doubt they completed their migration successfully because of the high water temperatures in the lower Snake and Columbia rivers during midsummer.

In 1972, 291,600 chinook fingerlings of the 1971 year-class that averaged 60-mm fork length were released into Big Springs Creek. Most of these smaller fingerlings remained in the stream for the entire summer and migrated downstream during the fall (Fig. 47).

Table 38. Number of chinook salmon fingerlings released into Big Springs Creek, number captured at the weir, and mean length of migrants during June and July 1971.

	Fish released		Fish counted at weir	
Date	Number	Mean fork length (mm)	Number	Mean fork length (mm)
June 4	52,223	55	0	62
June 5-6	141,600	55	1,091	63
June 7-9	61,700 8,900	55 88	35	–
June 10-11	–	–	2,350	89
June 12-18	–	–	15	–
June 19-30	–	–	163	–
July 1-14	–	–	2,418	97

In 1970 and 1971, 21 percent of the chinook salmon fingerlings released into Big Springs Creek survived the summer to migrate during the fall-winter-spring (Table 39). Smolt-sized migrants resulting from fingerlings released in Big Springs Creek made up 11 percent of the total number of smolt-sized fish produced in the upper Lemhi River in 1970 and 21 percent in 1971 (Table 39). Thus, many of the chinook salmon fingerlings released into Big Springs Creek survived the summer, grew well, and added significantly to the number of smolts produced.

A large number of chinook salmon fingerlings were released into the upper Lemhi River in 1974 and 1975. Idaho Department of Fish and Game personnel released 900,000 chinook fingerlings of the 1973 year-class (average length 60 mm) into the upper Lemhi River in May 1974, and 1,140,300 (average length 56 mm) in early June 1975 (Table 37). Few, if any, of these fish moved downstream past the Lemhi River weir during the summer. Since the natural spawning escapements in 1973 and 1974 were relatively small, these efforts to supplement natural spawning had a reasonable chance of adding significantly to the production of smolts from the upper Lemhi River.

To evaluate the yield of smolts resulting from chinook fingerlings released into the upper Lemhi River, I compared the number of migrants produced in the upper Lemhi River by year-classes supplemented by the addition of hatchery fingerlings (1973 and 1974) with all other year-classes. The first measure of the survival of fingerlings released into the upper Lemhi River during 1974 and 1975 was the number of fall migrants passing the Lemhi River weir. A close correlation existed between the number of eggs deposited in the upper Lemhi River by spawners of the 1963 through 1972 year-classes and the number of smolt-sized juvenile chinook that migrated downstream past the Lemhi weir during the fall (Fig. 48). If the 1966 year-class, which had an abnormally small number of smolts, is omitted, 94 percent ($r = 0.97$) of the variation in number of migrants was due to the number of eggs deposited in the upper Lemhi River.

The number of smolt-sized chinook salmon migrants counted at the Lemhi River weir in the fall of 1974 (1973 year-class) was no larger than I expected from natural spawning alone. The release of 900,000 fingerlings in the upper Lemhi River apparently had not increased smolt yield, unless the survival of naturally produced chinook salmon of the 1973 year-class was unusually low, as it was for the 1966 year-class (Fig. 48). Although there was no evidence of increased yield of smolt-sized chinook for the 1973 year-class based on the number of fall migrants (Fig. 48), the total number of fall-winter-spring migrants was larger than might be expected from the natural spawning escapement in 1973 (Fig. 44).

During the fall of 1975, the number of smolt-sized migrants of the 1974 year-class was unusually large (Fig.

Table 39. Number of chinook salmon smolts from hatchery fingerlings that left Big Springs Creek and passed the Lemhi River weir site, 1970 and 1971 year-classes.

Year-class	Fingerlings released in Big Springs Creek	Fall and spring smolts from Big Springs Creek			Estimated number of wild smolts from the upper Lemhi River	Percentage of total smolts from Big Springs Creek
		Number leaving creek	Percentage of number stocked	Number passing Lemhi River weir		
1970	255,500[a]	55,100	21.6	33,000	245,000	11.9
1971	291,600	60,800	20.9	61,000	225,000	21.3

[a] Does not include 8900 large fingerlings that migrated downstream in midsummer.

48). An estimated 219,000 smolt-sized chinook salmon of the 1974 year-class migrated downstream past the Lemhi River weir site during the fall. Only about 83,000 fall migrants would have been expected from the less than 1 million eggs deposited by spawners in the upper Lemhi River in 1974 (Fig. 48). Operation of the Lemhi River weir was discontinued after the fall migration season in 1975; consequently no estimate of the total number of fall-winter-spring migrants for the 1974 year-class is available. The number of fall migrants counted in 1975, however, is an indication that the fingerlings released in the upper Lemhi River during the early summer of 1975 made a substantial contribution to the yield of smolts.

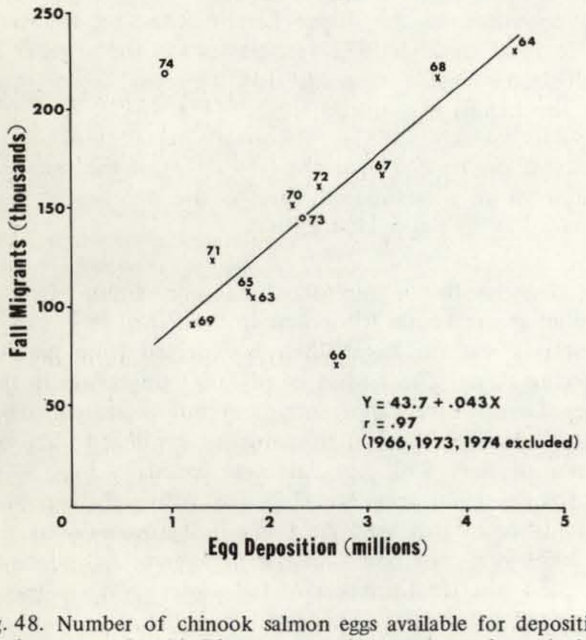

Fig. 48. Number of chinook salmon eggs available for deposition in the upper Lemhi River versus the number of smolt-sized migrants that passed the weir site in the fall, 1963-1974 year-classes (indicated by numbers above symbols). Migrants of the 1973 and 1974 year-classes (o) included fingerlings released in the river from a hatchery.

Adult Returns from Chinook Smolts

The number of adult salmon returning to the upper Lemhi River ranged from an estimated 513 fish of the 1971 year-class to 2123 fish of the 1963 year-class (Table 40). Survival of chinook salmon smolts (smolt-sized fish that migrated in the fall-winter-spring) from the time they left the upper Lemhi River until they returned as adults ranged from 0.18 percent for the 1971 year-class to 1.22 percent for the 1963 year-class (Table 40).

Smolt-sized migrants of the 1963 year-class left the upper Lemhi River during the fall-winter-spring of 1964-1965 and were the first complete year-class of salmon counted at the Lemhi River weir. The 1963 year-class smolts entered the ocean in the spring of 1965 and returned to the Lemhi River in 1966 as age 3_2 adults, in 1967 as age 4_2, and in 1968 as age 5_2.

Survival of smolts to adults decreased in recent years as more and more dams were completed in the lower Snake and Columbia rivers (Table 40). Among the year-classes studied, survival was highest for the chinook smolts of the 1963 year-class. These smolts migrated to the sea in 1965, a year when only four dams were in the lower Snake and Columbia rivers and when flows during the migration season were large so that many fish went over the spillways rather than through the turbines. The smolts of the 1964 and 1971 year-classes had the lowest survival rates (Table 40). Smolts of these year-classes migrated to the sea in 1966 and 1973, years when the spring runoffs were small, and many of the fish had to pass the dams through the turbines.

The smolt-to-adult survival rates calculated from adults that returned to the Lemhi River weir did not take into account the differential harvest from each year-class as the adults passed through the lower Columbia River. Harvest of the upriver spring chinook runs in the lower Columbia River by the sport, commercial, and Indian fisheries ranged from 56 percent of the run in 1973 to nil in 1975 and 1976. To make the survival rates

Table 40. Estimated number of chinook salmon adults of each year-class that spawned; number of smolts leaving the upper Lemhi River; adults returning by age group; percentage survival from smolt to returning adult with and without adjustment of adult returns for the percentage of the spring chinook run harvested in the Columbia River, year-classes 1963-1973.

Year-class	Count of adults at Lemhi River weir[a]	Smolts produced	Number of returning adults				Percentage survival	Adult returns adjusted for harvest in Columbia River	
			Age 3_2	Age 4_2	Age 5_2	Total		Number of adults	Percentage survival
1963		174,000	59	899	1165	2123	1.22	3818	2.19
1964	1075	401,000	73	738	205	1016	0.25	1664	0.41
1965	765	185,000	39	516	519	1074	0.58	1879	1.02
1966	1473	109,000	34	680	156	870	0.81	1582	1.45
1967	1844	238,000	18	642	628	1288	0.54	2279	0.96
1968	1943	297,000	33	521	696	1254	0.42	2668	0.90
1969	755	129,000	36	334	167	537	0.42	1099	0.85
1970	1217	278,000[b]	21	244	675[c]	940	0.34	1116	0.40
1971	831	286,000[b]	13	198[c]	302[c]	513	0.18	521	0.18
1972	1185	284,000	27[c]	309[c]	–	–	–	–	–
1973	1043	310,000[d]	19[c]	–	–	–	–	–	–

a Adults not counted in 1963 and count incomplete in 1964.
b Includes smolts from Big Springs Creek.
c Estimated from redd counts in 1975 and 1976 and the relation between redds and female escapement in previous years (Fig. 34).
d Includes some smolts from hatchery fingerling releases.

more comparable, I adjusted the number of adults returning to the Lemhi River each year to the number that would have been expected if none had been harvested downriver. The major differences in survival rates between year-classes of salmon, then, were those caused by losses at the dams.

Without a harvest of upriver spring chinook salmon in the lower Columbia River, I estimated 3818 adults of the 1963 year-class would have returned to the Lemhi River weir rather than the actual return of 2123 fish (Table 40). The smolt-to-adult survival rate would then have been 2.19 percent for the 1963 year-class, rather than 1.22 percent.

Even with the adjustment for downriver harvest, the 1964 and 1971 year-classes survived poorly compared with other year-classes. The trend toward reduced survival as more dams were added to the rivers was also clearly evident (Table 40).

The Lemhi River chinook salmon run has not been a self-sustaining run in recent years. The number of returning adults was large enough to replace the parent run in only 1 of 8 years (Table 40). Even without any harvest in 1975 and 1976, the adults of the 1970 and 1971 year-classes were too few to replace the parent run.

With average egg deposition and egg-to-smolt survival, 0.56 percent of the smolts that leave the upper Lemhi River must return as adults for the Lemhi River chinook salmon run to be self-sustaining. With a run of 1350 adults counted at the weir, I would expect deposition of 2.5 million eggs (Fig. 33), an egg-to-smolt survival of 9.7 percent to produce 242,000 smolts (Fig. 44), and a smolt-to-adult survival of 0.56 percent to give 1350 returning adults.

DISCUSSION

Fish production and yield of migrants from sympatric populations of chinook salmon and steelhead trout exceeded that observed from allopatric steelhead populations. The production and yield of an allopatric rainbow-steelhead trout population was less than half that observed for sympatric populations, even when more steelhead fry were released than the combined total of steelhead fry and chinook salmon fingerlings.

Of all the factors that exert some control on fish production, managers can influence only three: 1) the number of fry entering the stream, 2) the amount of food consumed by an individual fish, perhaps by manipulating the number and species of fish in the stream, and 3) perhaps the survival rate, by reducing the number of predators. In these studies, I varied the number of fry entering the stream and manipulated the abundance and species of fish present that might compete for the available food supply.

The number of migrants from allopatric steelhead trout populations in Big Springs Creek was directly related to the number of fry released (up to about 500,000 fry), but growth of steelhead in allopatric populations was more closely correlated with number of days in the stream than with number of fry released. Since growth was little affected by the densities of steelhead tested in Big Springs Creek, production was primarily a function of the biomass in the stream at the start of the summer (i.e., the number of fry released).

Steelhead production and yield were reduced, but not drastically (5.5 versus 4.3 g/m^2), when large numbers of chinook salmon fingerlings were added to Big Springs Creek. The larger chinook salmon fingerlings apparently provided some competition for the steelhead fry, even though the habitat requirements of the chinook probably differed from those of steelhead (Everest and Chapman 1972). The production (tissue elaboration) by chinook salmon more than compensated for the reduced production of steelhead trout when both species occupied the stream.

Fish production in Big Springs Creek is in the upper part of the range observed for salmonids in cold-water streams. Chapman (1978) reported production of up to 18 g/m^2 per year for most cold-water streams. The production by all species of fish in Big Springs Creek was about 16 g/m^2 in years such as 1973, when the maximum allopatric steelhead trout population was present (Table 41). In 1973, age 0 rainbow-steelhead trout produced 536 kg of tissue. I did not estimate the production of the other age classes of rainbow-steelhead or other species of fish, but if an average of the estimates from the 1969 and 1971 studies is used, the total production would be near 900 kg. More than half the production would be contributed by the age 0 rainbow-steelhead trout.

Table 41. Estimated total fish production in Big Springs Creek by fish other than age 0 chinook salmon or rainbow-steelhead trout[a], by all fish when the maximum allopatric steelhead population was present (1973), and by all fish when both steelhead and chinook were present (1972).

	Production (kg)		
Species	By fish other than age 0 chinook or rainbow-steelhead	Allopatric steelhead at 1973 levels	Sympatric steelhead and chinook at 1972 levels
Rainbow-steelhead			
Age 0		536	239
Age I	185	185	185
Age II and older	90	90	90
Chinook salmon		3	890
Sculpins	42	42	42
Brook trout	30	30	30
Mountain whitefish	23	23	23
Total		909	1499
g/m^2		16.3	26.9

[a] Based on 1969 and 1971 data.

With sympatric steelhead and chinook populations in Big Springs Creek similar to those observed in 1972, the production of all species would approach 1500 kg per year (27 g/m^2), assuming that production by the older age classes of rainbow-steelhead and the other species of fish would remain relatively constant. Production by age 0 rainbow-steelhead would amount to 16 percent of the total and production by chinook salmon to about 60 percent of the total (Table 41).

Production by salmonids in Big Springs Creek would approach 900 to 1500 kg only with intensive management and manipulation of the fish populations. Without the annual addition of steelhead fry and chinook salmon fingerlings, the stream would be dominated by resident rainbow trout and mountain whitefish. Both the resident trout and whitefish populations would contain a large proportion of large, slow-growing individuals, and thus production would be reduced. In pristine times, the production of salmonids in Big Springs Creek might have approached the levels obtained with intensive management because the seeding by chinook salmon and steelhead trout through natural spawning might approach the densities developed by releasing fish. In addition, the summer chinook, which were absent from the Lemhi River drainage after the early 1900s, may have been the most productive portion of the chinook salmon run.

Steelhead trout fry appear to have outnumbered, if not outcompeted, resident rainbow trout fry in Big Springs Creek and caused a reduction in the abundance of resident rainbow trout. The steelhead trout fry released into Big Springs Creek appear to have been at least as viable as the wild rainbow trout fry and, because of the larger number of steelhead fry, changed the rainbow-steelhead population in Big Springs Creek from one containing a substantial number of older and larger rainbow trout to one composed primarily of subyearling and yearling steelhead with few age II and older rainbow trout. Resident rainbow trout were the most abundant fish in Big Springs Creek before the release of steelhead trout fry (at least 75% of the total number of salmonids in the stream) but after 13 years of releasing steelhead fry into the stream, resident rainbow trout made up only 10 to 20 percent of the rainbow-steelhead trout population. There was little, if any, measurable impact of the steelhead fry on the brook trout population.

Although Big Springs Creek produced much fish tissue and a large number of age 0 migrants, the stream was not a complete habitat unit for the anadromous fish species, especially the large numbers that resulted from the fry and fingerlings added to the stream. A large proportion of the juvenile salmon and steelhead that spent their first summer in Big Springs Creek left the stream during their first winter and found new stream areas to complete their freshwater life before migrating to the ocean. Chinook salmon needed only a place to overwinter before migrating to the ocean the following spring. Steelhead, on the other hand, needed a place to overwinter and then spend an additional summer and winter before migrating to the ocean. For the 1973 year-class, only 1200 steelhead smolts had spent 2 years in the stream and then migrated during the normal spring migration period. These fish made up only 3 percent of the total number of migrants for the 1973 year-class. The chinook salmon overwintered in the Lemhi River and Salmon River after they left Big Springs Creek, whereas most of the subyearling rainbow-steelhead trout remained in the upper Lemhi River another 12 to 18 months before starting their journey to the ocean.

The summer holding capacity of Big Springs Creek for fish was much larger than the winter capacity. When only steelhead trout fry were released into the stream (1973), the summer capacity was about 60,000 subyearling and 3500 yearling rainbow-steelhead trout (1.1 fish/m^2 and 10.8 g/m^2; Table 42). During the following fall, winter, and early spring 39,000 of the rainbow-steelhead trout (5.7 g/m^2) left the stream, leaving 24,500 fish to overwinter in Big Springs Creek (5.1 g/m^2). For rainbow-steelhead trout, the overwinter capacity of Big Springs Creek appeared to be less than half the summer capacity (0.44 fish/m^2 in winter vs. 1.14 fish/m^2 in summer, or 5.1 g/m^2 vs. 10.8 g/m^2; Table 42).

With both steelhead and chinook present, Big Springs Creek supported 116,000 fish (2.08 fish/m^2) in 1972 with a biomass at the end of the summer of 18.0 g/m^2. During the following fall and winter, 77,900 of the fish left the stream (12.5 g/m^2), leaving 38,100 fish (5.5 g/m^2) to overwinter in the stream. Again, the number of chinook salmon and steelhead trout that overwintered was less than half the number present in the summer (Table 42).

The same relationship between summer and winter capacity seems to apply to the upper Lemhi River, including Big Springs Creek. In 1973, there were an estimated 617,000 juvenile salmon and steelhead trout (1.29 fish/m^2 and 21.4 g/m^2) in the upper Lemhi River and Big Springs Creek at the end of the summer. During the following fall and winter, 290,100 fish (14.2 g/m^2) left the upper

Table 42. Estimated number and biomass of fish in Big Springs Creek and the upper Lemhi River at the end of summer (an estimate of summer rearing capacity) and the number and biomass leaving the streams during the following fall, winter and early spring. The difference between the number or biomass at end of summer and the number or biomass leaving is accepted as an estimate of winter capacity, assuming all fish not leaving survive the winter, 1972-1973.

			Fish in stream at end of summer				Fish leaving stream during winter			Difference		
			Number		Biomass			Biomass			Biomass	
Year	Species	Age	Total	Fish/m^2	kg	g/m^2	Number	kg	g/m^2	Number	kg	g/m^2
Big Springs Creek												
1973	Rainbow-	0	60,000	1.08	342.0	6.1	37,700	214.9	3.9	22,300	0.40	2.2
	steelhead	I	3,200[a]	0.06	240.0	4.3	1,300	97.5	1.8	1,900	0.03	2.5
			63,500	1.14		10.4	39,000		5.7	24,200	0.43	4.7
1972	Rainbow-	0	39,200	0.70	176.4	3.2	20,500	92.3	1.7	18,700	0.34	1.5
	steelhead	I	1,400[a]	0.03	105.0	1.9	800	60.0	1.1	600	0.01	0.8
			40,600	0.73		5.1	21,300		2.8	19,300	0.35	2.3
	Chinook	0	75,400	1.35	716.3	12.9	56,600	537.7	9.7	18,800	0.34	3.2
			116,000	2.08		18.0	77,900		12.5	38,100	0.68	5.5
Upper Lemhi River and Big Springs Creek												
1973	Rainbow-	0	250,000[b]	0.52	1,425.0	3.0	3,200	18.2	0.3	246,800	0.52	2.7
	steelhead	I	83,000[a]	0.17	6,225.0	13.0	61,000	4,575.0	9.6	22,000	0.05	3.4
			333,000	0.70		16.0	64,200		9.9	268,800	0.56	6.1
	Chinook	0	284,000[a]	0.59	2,556.0	5.4	225,900	2,003.0	4.3	58,100	0.12	1.1
			617,000	1.29		21.4	290,100		14.2	326,900	0.68	7.2

[a] Minimum estimate, as this number was the actual number of eventual migrants; some fish may not have survived to migrate or been destined to migrate.

[b] Estimate based on survival rates observed in Big Springs Creek and a release of 2.5 million fry.

Lemhi River, leaving 327,000 fish (7.2 g/m^2) to overwinter in the upper Lemhi River and Big Springs Creek. The winter population density (7.2 g/m^2) was less than half the estimated summer density (21.4 g/m^2).

There was a difference, however, in the fish that used the winter capacity in the Lemhi River and Big Springs Creek. Few of the subyearling rainbow-steelhead trout left the upper Lemhi River, whereas more than half the subyearlings left Big Springs Creek during the winter. The winter habitat in Big Springs Creek was apparently not adequate to support the large number of subyearling rainbow-steelhead present during the summer, but in the Lemhi River the winter habitat was adequate. A large proportion of the yearling steelhead trout and subyearling chinook salmon left the upper Lemhi River – an indication that the winter habitat in the upper Lemhi River was not adequate for those fish (Table 42).

To produce the maximum number of steelhead trout smolts in the upper Lemhi River drainage, about 2.5 million steelhead fry (5.2 fry/m^2) should be released to produce an expected 75,000 yearling steelhead (0.16 migrant/m^2). The number of returning adults produced from the 75,000 steelhead smolts depends in large part on the mortality of the downstream migrants passing the Snake and Columbia river dams. If most of the migrants were collected at the first two dams and transported to the lower river, 1.5 to 2.0 percent of the smolts might be expected to return as adults to the Lemhi River (1125 to 1500 adults) if no fish were removed between Lower Granite Dam and the Lemhi River. Only 950 adults would be needed to provide enough eggs to release 2.5 million fry each year (females 64% of the run, 5500 eggs per female, 75% survival from green egg to swim-up fry).

If survival rates were less than projected, then fewer adults would return and the run might not be self-sustaining. For example, if the returning adults were allowed to spawn naturally, and 50 percent of the deposited eggs survived to the swim-up fry stage and survival from fry to returning adult was similar to that projected for fry released from a hatchery, then we might expect 1000 returning adults, most of which would be needed for spawning. If only 2 percent of the fry entering the stream survived to smolt stage and only 1.5 percent of the smolts returned as adults, the 750 expected adult returns from a release of 2.5 million fry would not provide enough eggs to sustain the stock. If fry were available to perpetuate the run from some source other than adults returning to the Lemhi River, then most of the returning adults could be harvested in a fishery and it would not matter if the run were self-sustaining.

The situation described for the Lemhi River steelhead trout population is similar to that facing all of the wild salmon and steelhead stocks throughout the Salmon and Clearwater drainages. The stocks may not be able to sustain themselves if intensive fisheries that harvest excess fish destined for fish hatcheries also harvest the wild fish.

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