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Trout and Salmon Movements in Two Idaho Streams as Related to Temperature, Food, Stream Flow, Cover, and Population Density[1]

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ABSTRACT

Many juvenile salmon and trout migrated from the Lemhi River drainage each fall–winter–spring period. Seaward migration of anadromous trout and salmon normally occurred in the spring but pre-smolt anadromous and non-anadromous fishes also left the stream usually beginning in the fall. I compared data on temperature, food abundance, stream flow, cover and population density with movements and conducted field and laboratory tests to determine reasons for the two types of movements.

Smolts of the anadromous species migrated for an obvious reason but none of the factors I examined appeared to "stimulate or release" their seaward migration. Movement frequently coincided with changes in water temperature and stream flow, but I could not establish a consistent causal relationship and concluded that photoperiod and perhaps growth must initiate the physiological and behavioral changes associated with seaward migration.

Non-anadromous and pre-smolt anadromous species emigrated from the streams for different reasons than the smolts. I postulated that fish found the stream environment unsuitable during the winter. Stream temperature declined in the fall as fish began moving from the streams but I could not induce more fish to stay in test troughs with 12 C water versus troughs with 0–10 C water. Fish emigrated before abundance of drift insects declined in winter. Emigration occurred in spite of the relatively stable flows in both streams. Population density modified the basic migration pattern by regulating the number and percentage of fish that emigrated and to a limited extent time of emigration.

Movements of non-smolt trout and salmon correlated best with the amount of cover provided by large rubble substrate. Subyearling trout emigrated from Big Springs Creek which contained no rubble substrate but remained in the Lemhi River which did. In both field and laboratory tests more fish remained in troughs or stream sections with large rubble substrate than in troughs or sections with gravel substrate. Trout and salmon in many Idaho streams enter the substrate when stream temperatures declined to 4–6 C. A suitable substrate providing adequate interstices appears necessary or the fish leave.

INTRODUCTION

Both anadromous and non-anadromous salmonids migrate extensively during the fall, winter and spring season in many Idaho streams. In addition to the normal seaward movement of smolts in the spring, many pre-smolt and non-anadromous fishes move downstream during the fall, winter and spring (Chapman and Bjornn, 1969) and some return upstream in the spring and early summer (Bjornn and Mallet, 1964). I compared data on movements of fish in the Lemhi River and Big Springs Creek (1962–1969) with various environmental factors and conducted field and laboratory tests to determine which factors caused or influenced the movements.

[1] Funds for these studies provided by Idaho Fish and Game Department through Federal Aid to Fish Restoration Project F-49-R and U. S. Bureau of Sport Fisheries and Wildlife.

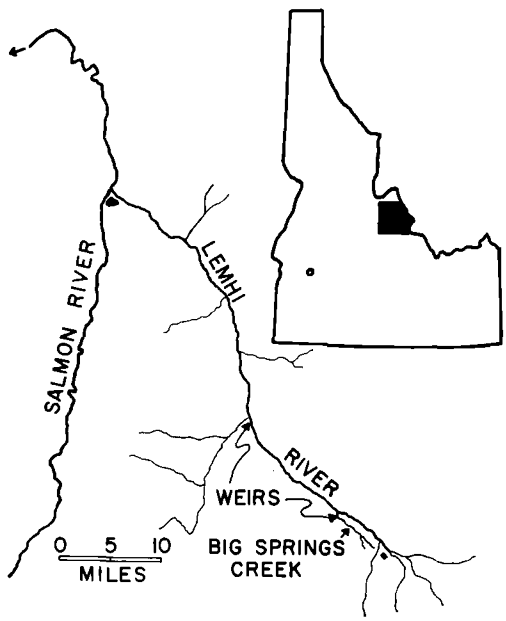

FIGURE 1.—Map of the Lemhi River drainage with location of fish weirs.

In the study streams behavior of salmonids changed from active feeding and territory occupation (or hierarchies) in the summer to "hiding or hibernation" in the winter. Few fish left the study streams during the summer but with the onset of fall, requirements of the fish apparently changed and an environment which fish found suitable in the summer became less suitable and they began to leave.

THE STUDY STREAMS

The Lemhi River (90.3 km long) flows through a broad mountain valley into the Salmon River at Salmon near the east central border of Idaho (Figure 1). Big Springs Creek (8.0 km in length) parallels and enters the Lemhi River 77 km from its junction with the Salmon River. The Lemhi River falls an average of 6.7 m/km.

I classify both streams as relatively productive on the basis of total dissolved solids (273 and 298 ppm) and bicarbonate alkalinity (134 and 160 ppm) in the water.

I found the following fish species in the study streams: non-anadromous rainbow trout (*Salmo gairdneri*), steelhead trout (anadromous rainbow trout), chinook salmon (*Oncorhynchus tshawytscha*), brook trout (*Salvelinus fontinalis*), Dolly Varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), sculpin (*Cottus* sp.), and dace (*Rhinichthys* sp.). Usually I could not distinguish between anadromous and non-anadromous rainbow trout and I used the term rainbow-steelhead trout when I believe both forms participated in the movements described.

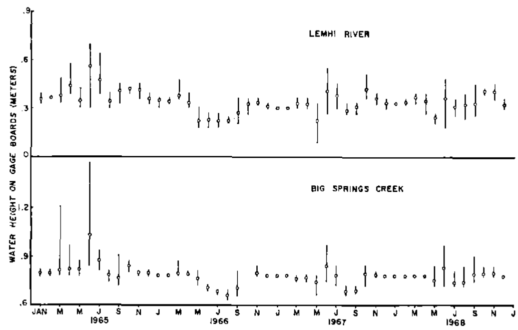

FIGURE 2.—Monthly range and mean height of water on gauge boards at Big Springs Creek and Lemhi River weir sites.

Stream Flow

The volume of flow in the study streams usually fluctuated within a narrow range (Figure 2). The water level in Big Springs Creek fluctuated a maximum of 0.85 m during 1965–68, and that in the Lemhi River 0.61 m, but levels changed less than 0.30 m most months. Big Springs Creek discharged 0.8–1.0 m^3/sec (0.79–0.82 m on gauge board) and the Lemhi River 3.4–5.0 m^3/sec (0.30–0.37 m on gauge board) during winter. I estimated the volume at 17.0 m^3/sec in the Lemhi River at the weir during peak discharge in June, 1965. Maximum flows exceeded minimum flows by less than 10:1 in all years and 2:1 in some years. Maximum discharges of many other Idaho streams frequently exceed minimum flows by ratios of 30–100:1.

Use of Lemhi drainage water 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 period that large scale use of water for irrigation began. Farmers withdrew water from both the study streams and their tributaries. Flow in the tributaries exceeded the needs for irrigation and entered the study streams in large quantities in years with deep snow pack in the surrounding mountains and abnormally large amounts of precipitation in the valleys during May and June (Figure 2—1965). Irrigation water spread on the alluvial fans in the valley, entered the study stream as ground water 2–6 months later, and increased the flow in the study streams during the late summer and fall. In Idaho drainages without irrigation, flows normally declined throughout the summer, fall and winter. The small amount of precipitation (less than 25 cm per year) which fell in the Lemhi valley also contributed to the small fluctuation in stream flow.

Water Temperature

Temperature of the study streams at the weirs followed a relatively constant seasonal pattern from year to year (Figure 3). Fluctuations in mean monthly temperatures between years did not exceed more than 1–2 C.

Maximum and mean temperatures of Big Springs Creek usually exceeded those of the Lemhi River at the weir, probably because more cool ground water entered the Lemhi River.

Daily fluctuations in temperature ranged from nothing in the winter when ice flowed in the streams to more than 25 F (14 C) in the summer. Maximum summer temperatures exceeded 75 F (23.9 C) in Big Springs Creek but only briefly each day. Daily minimum temperatures in summer ranged from 45–55 F (7–13 C) depending on the nighttime air temperatures.

Substrate

Gravel, sand and silt made up the bottom of Big Springs Creek and the Lemhi River upstream from the mouth of Big Springs Creek. Larger rock and rubble comprised more of the bottom materials in the Lemhi River downstream from the creek. Later in my paper I discuss the importance of substrate compositions and structure in relation to movement of fish.

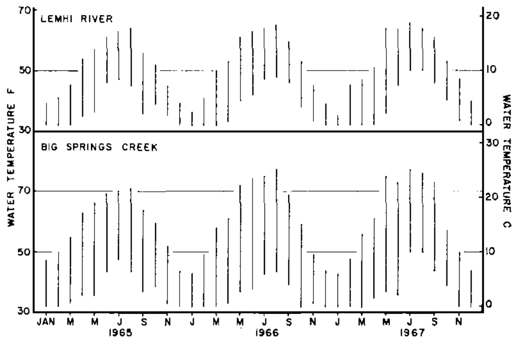

FIGURE 3.—Monthly range of maximum and minimum stream temperatures at the Lemhi River and Big Springs Creek weir sites.

Aquatic Vegetation

Horned pondweed (*Zannichellia palustris*) and buttercup (*Ranunculus aquatilus*) formed dense mats of vegetation in the upper Lemhi River and Big Springs Creek during the summer and fall months. The vegetation died and drifted from the streams during the fall and winter and the streams lacked vegetation from late winter to June when new plant growth began. The mats of vegetation filled the shallow stream channels, increased water depth, decreased velocity, and provided mid-stream cover for fish and invertebrates during the summer months.

Fish Weirs

I used two fish weirs to monitor downstream fish movements, one in Big Springs Creek near its mouth and one in the Lemhi River about 48 km upstream from its mouth (Figure 1). I attempted to monitor upstream movements of juveniles with 0.6 × 0.6 m box traps, each with a V opening facing downstream but few fish entered these traps. The two weirs restricted or blocked upstream movements of juvenile trout and salmon during some flow and operating conditions.

The weir at Big Springs Creek consisted initially of inclined screen traps. We later installed a large rotary drum screen with a bypass trap to reduce maintenance and pass the large amounts of vegetation drifting in the stream. The entire flow of the stream passed through the screens and fish moving downstream entered the traps. We usually

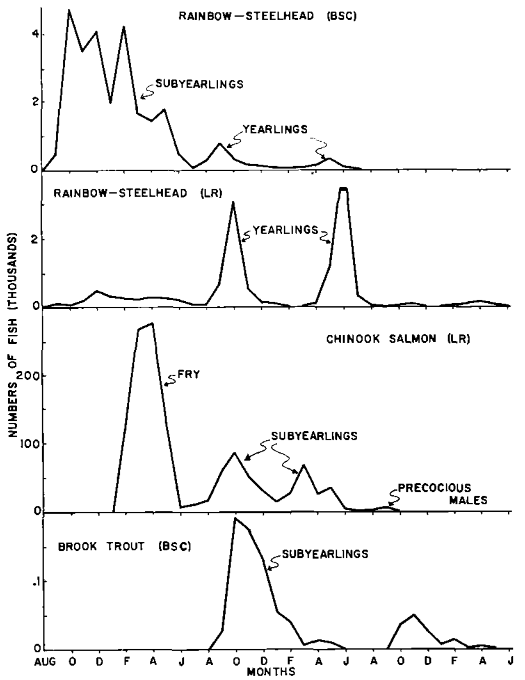

FIGURE 4.—Number of salmon and trout of 1964 year class which emigrated past Lemhi River (LR) and Big Springs Creek (BSC) weir sites. Fish of other year classes migrated in similar seasonal pattern.

operated the weir five days each week unless ice formation or equipment breakdown prevented operation. I estimated the total numbers of migrants by multiplying the monthly catch by the ratio of number of days in month over number of days of weir operation.

The downstream migrant trap in the Lemhi River consisted of a louver array which guided fish into a trap. The louvers strained approximately 10% of the river flow. The percentage of the downstream migrants that we captured in the louver trap depended on species, size and distribution of the fish across the stream. We released marked fish upstream from the weir to determine the percentage of migrants which passed the weir site and entered the louver trap and thereby we could estimate the total number of migrants. More detailed descriptions of both weir facilities and methods of operation appear in Bjornn (1966, 1968) and Holubetz (1967).

UPSTREAM MOVEMENTS

Some juvenile trout and salmon moved upstream in the study streams, but I did not obtain a quantitative measure of the magnitude or distance of such migrations. We caught few upstream migrants in box traps but I probably used inadequate traps.

I observed two situations which led me to believe that juveniles of certain species migrated upstream limited distances primarily during the summer months. I found large numbers of juvenile chinook salmon in screened irrigation ditches. The salmon probably entered the ditches by migrating upstream through the wasteways. At the weir in Big Springs Creek I recaptured a few marked juvenile trout which I had marked and released downstream from the weir. These fish probably returned upstream around the weir when the creek flowed through the bypass canal.

DOWNSTREAM MOVEMENTS

Juvenile trout and salmon entered downstream traps of the two weirs in all months of the year, but we caught most fish in fall and spring (Figure 4). Chinook salmon and steelhead trout smolts of appropriate age migrated to the sea only during the spring. Mains and Smith (1956) and Raymond[2] observed only one major downstream migration of juvenile salmon and trout in the Snake River and that in the spring months. Factors other than instinctual seaward migration caused the migration of non-smolt steelhead and salmon and non-anadromous rainbow and brook trout during the fall, winter and spring.

Chinook salmon migrated primarily as: (1) fry (less than 50 mm fork length) soon after emergence, (2) subyearlings (70–120 mm) in the fall-winter after their first summer, (3) smolts (80–130 mm) in the spring of their second year, and (4) precocious males after the spawning season at the end of their second summer (Figure 4). Migrants decreased in abundance from fry stage to precocious males in all year classes that we enumerated.

Rainbow–steelhead trout did not migrate as

[2] Personal communication: Howard Raymond, National Marine Fisheries Service, Seattle, Washington.

newly-emerged fry in mid-summer but primarily as: (1) subyearlings (60–120 mm total length) in the fall, winter, or spring after their first summer, (2) yearlings (140–210 mm) in the fall after their second summer, and (3) smolts (160–240 mm) in the spring of their third year (Figure 4). A few steelhead trout remained an additional year before migrating to the sea. In Big Springs Creek subyearlings outnumbered the other age groups of migrants while at the Lemhi weir site smolts migrating in the spring outnumbered all other age groups (Figure 4). In the Lemhi River few subyearlings migrated downstream past the weir site even though relatively large numbers (up to 25,000) entered the river from Big Springs Creek each fall.

From the fall of 1962 through 1969 both anadromous (steelhead) and non-anadromous rainbow trout migrated from Big Springs Creek so that I could not determine if the migration pattern described above applied to both forms. However, rainbow trout of the 1960 and 1961 year classes entered the weir trap during 1962 as subyearlings and yearlings and thus provided evidence that non-anadromous rainbow trout migrated in a manner similar to that of steelhead trout (Figure 5). I believe fewer rainbow than steelhead trout migrated especially during years when I released large numbers of steelhead trout fry into the creek.

The largest rainbow–steelhead subyearlings appeared to migrate first from Big Springs Creek. I analyzed the 1962–1964 data and found statistically significant (.05 level) differences in lengths of fish migrating the first half of October versus late November or December as follows: 1962, 90.2 versus 84.3 mm total length; 1963, 100.3 versus 92.0 mm; 1964, 91.0 versus 83.5 mm.

Brook trout migrated from Big Springs Creek primarily as: (1) subyearlings (80–170 mm total length) in the fall, winter, or spring after their first summer, and (2) as yearlings (110–270 mm) in the fall, winter, or spring after their second summer (Figure 4). Brook trout fry emerged during February–March but did not migrate as fry. Although small numbers of brook trout migrated each year, they migrated in a manner similar to that of other trout.

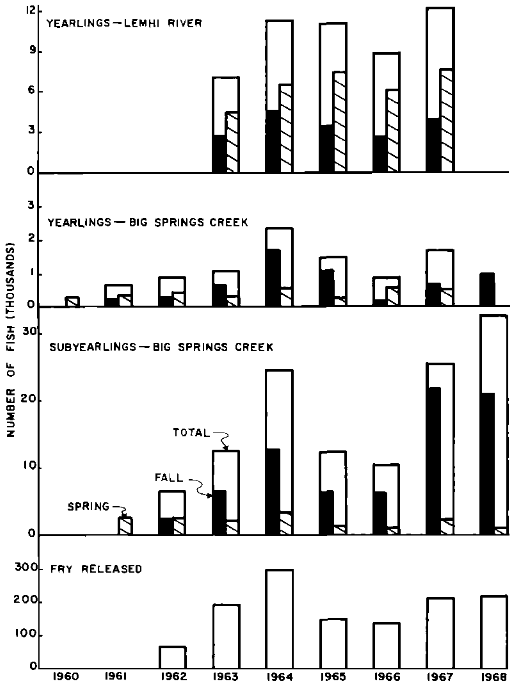

FIGURE 5.—Number of steelhead trout fry released into Big Springs Creek and number of rainbow–steelhead of each year class emigrating past Big Springs Creek and Lemhi weir site during fall (August–December), spring (April–July), and total (August–July) emigration season.

Movement Versus Water Temperature

Juvenile salmon and trout commenced migration from both study streams in the fall as stream temperatures declined (Figure 6). Yearling rainbow–steelhead migrated in largest numbers during September while the largest number of subyearling salmon and trout migrated in October and November.

The number of fish migrating normally declined in winter as stream temperatures reached their annual lows. In the spring, as temperatures increased, larger numbers of yearling rainbow–steelhead and chinook salmon migrated, but fewer subyearling rainbow–steelhead and brook trout migrated (Figures 4 and 6). Seaward-bound smolts comprised a large part of the May peak in numbers of yearling (age II) rainbow–steelhead trout and all of the March–June peak of chinook salmon. Large decreases in stream temperature appeared to cause increased numbers of fish to

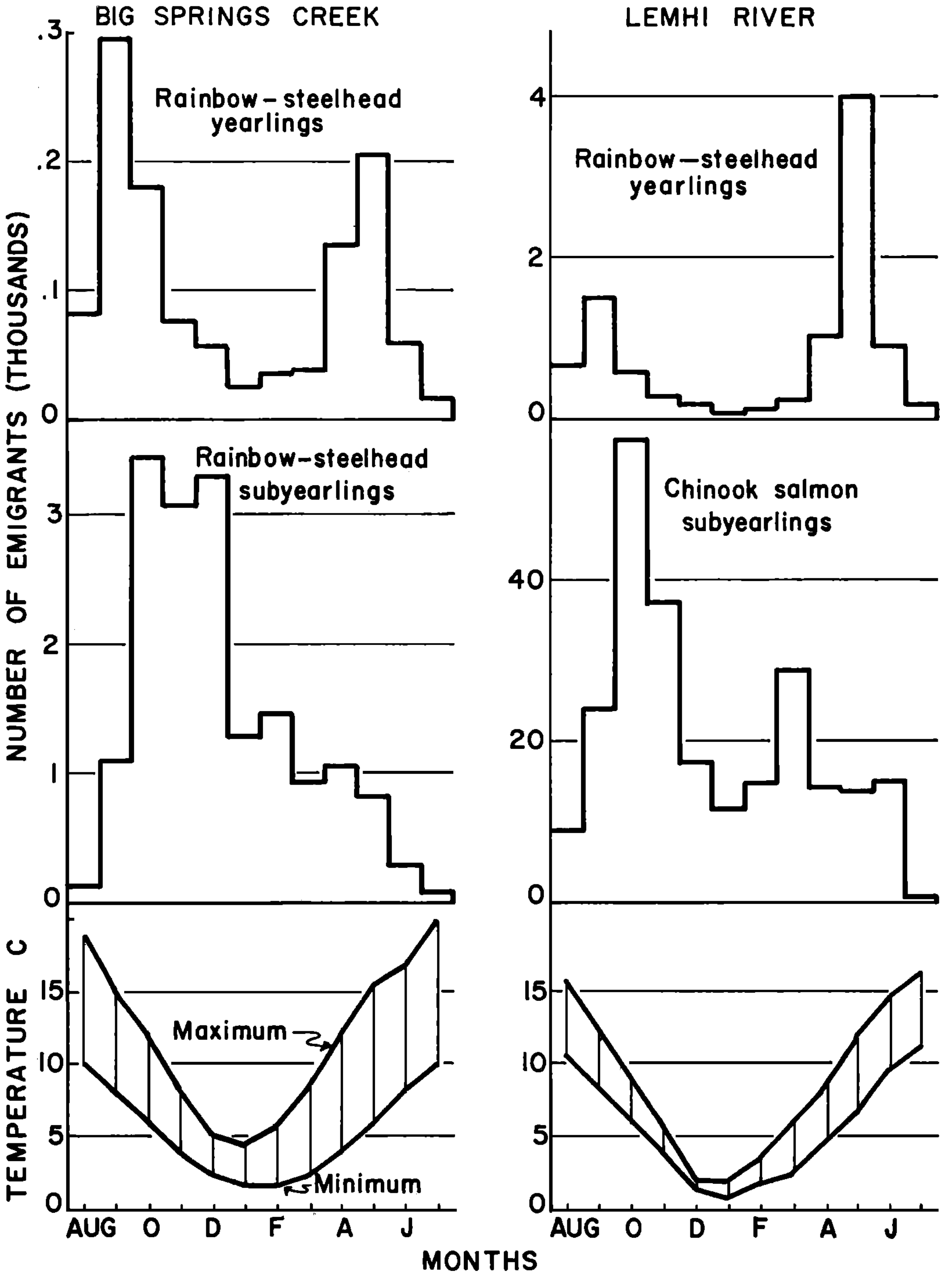

FIGURE 6.—Mean monthly temperatures of Lemhi River and Big Springs Creek and mean number of fish emigrating from each stream each month for 1964–1968 and 1962–1968 periods respectively.

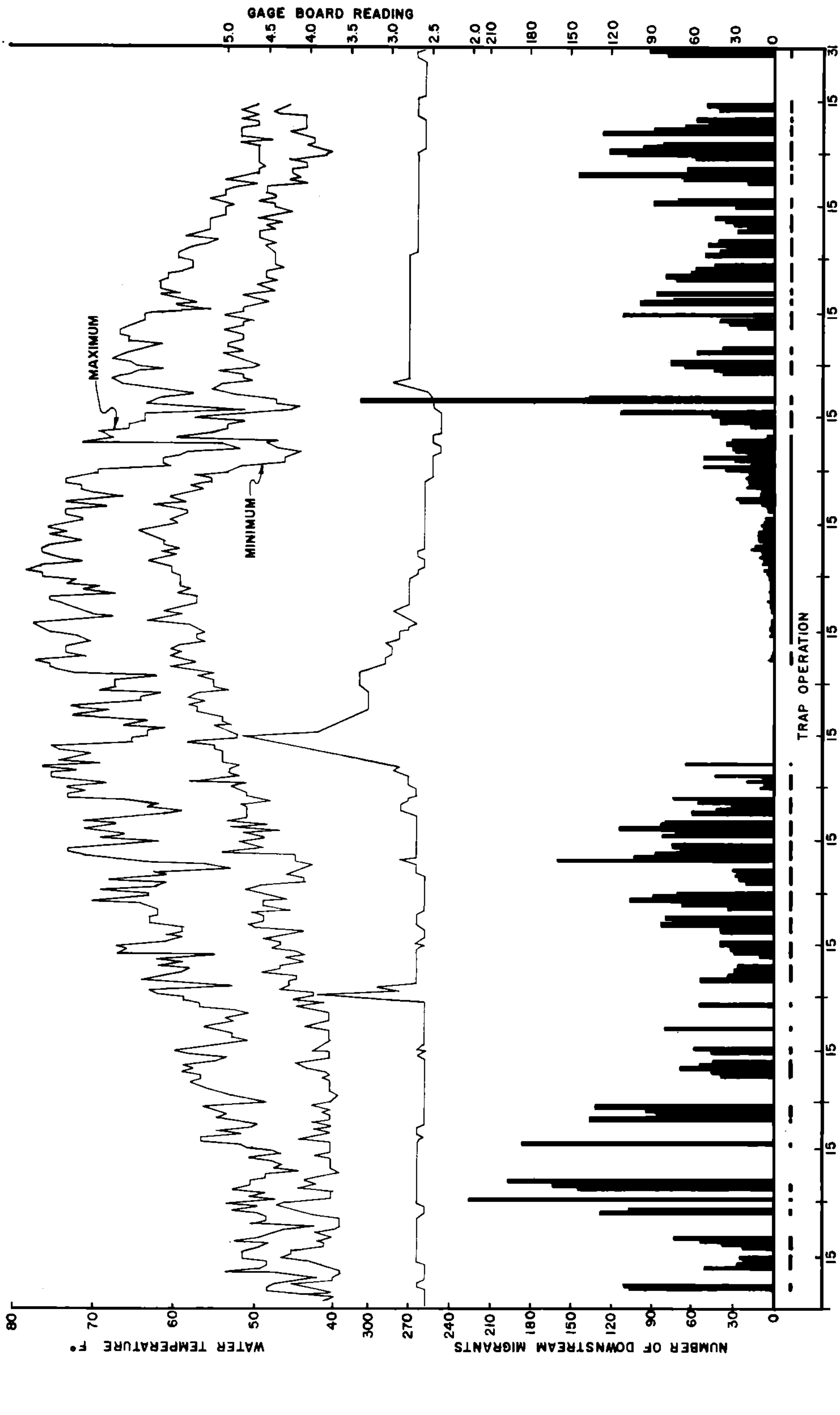

FIGURE 7.—Water temperature, water level (on gauge board), days of trap operation and daily catch of rainbow-steelhead downstream migrants at Big Springs Creek weir during 1965.

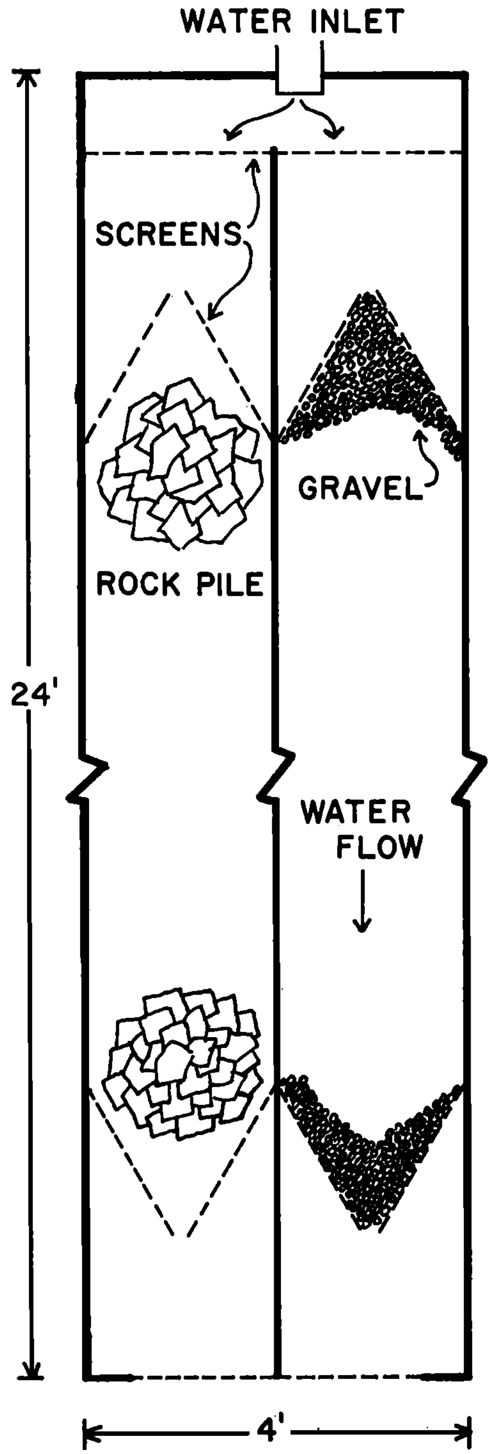

FIGURE 8.—Diagram of troughs used in temperature-substrate tests during 1967 and 1968.

migrate as illustrated on May 10 and September 18, 1965 in Big Springs Creek (Figure 7). Similar increases in movement coincided with sudden declines in temperature in other years and with other species (Bjornn, 1966).

Although migrations coincided with seasonal temperature changes, I could not establish any causal relationship from the data on temperature and weir counts. In 1967–68 I conducted tests during the fall–winter periods to more clearly define the role of temperature in the fall migrations. In 1967, I used troughs 24 ft (7.5 m) long, 2 ft (0.6 m) deep and 4 ft (1.3 m) wide with large rock and gravel substrates to determine the effect of water temperature and substrate rock size on downstream movements. In 1968 we divided the troughs lengthwise to provide for replication in the tests and also added an upstream trap used in some of the tests (Figure 8). I used spring water (11–12 C) in half the troughs and Hayden Creek water (0–10 C) in the other half. We placed gravel (1.5 cm diameter) in half the troughs and piles of larger rock (15–45 cm) in the others.

For these tests we used age 0 rainbow–steelhead trout and chinook salmon taken from traps in the study streams. After acclimating the fish 24 hours we removed the barriers to the traps, began the tests, and removed and counted fish from the traps daily. Most fish leaving the troughs did so in 2–3 days and during the nighttime. We fed the fish dry meal once daily.

Chapman and Bjornn (1969) reported the results of the 1967 tests (Table 1) and tentatively concluded that primarily low temperature caused the downstream movement of rainbow–steelhead trout and quality of the winter cover (substrate) modified the movement. We were less sure of the influence of temperature.

After completing the 1968 tests (Table 1) I must revise our conclusion concerning the causal role of temperature in downstream movement. In many of the 1968 tests, fish placed in the warmer spring water left the troughs at least as readily as fish placed in the colder water troughs.

When I used both upstream and downstream traps in the 1968 tests (tests 1, 2, 3, 4 and 5, Table 1), most fish left the troughs regardless

TABLE 1.—*Percentage of subyearling rainbow–steelhead trout and chinook salmon leaving test troughs with: (1) rainbow–steelhead only present, (2) chinook salmon only present, (3) both species present, (4) spring water versus colder creek water, and (5) large rock versus gravel substrate*

Year and test number		Date of test	Number of fish/ trough	Temperature of Hayden Creek C		Hayden Creek water		Spring water (12 C)	
						Rock	Gravel	Rock	Gravel
			Rainbow–steelhead trout only						
1967	1	October 16–31	100	1–9		41	81	2	0
	2	November 1–30	100	0–6		33	67	13	6
					Means	37.0	74.0	7.5	3.0
					Means	55.5		5.3	
1968	1[1]	September 20–27	25	4–10		47,40	100,95	–	–
	2[1]	September 27–October 4	25	3–10		95,79	100,100	82,100	89,96
	4[1]	October 11–18	25	4–9		33,48	68,52	57,56	100,96
	5[1]	October 18–25	25	2–8		52,21	83,96	92,79	100,100
					Means	51.9	86.8	77.7	96.8
					Means	69.4		87.3	
	6	October 25–November 1	25	1–7		53,5	65,56	0,12	96,42
	9	November 15–22	15	0–8		7,0	100,87	29,27	73,60
	11	November 29–December 6	25	0–7		0,4	100,71	24,8	56,72
	13	December 13–20	25	0–5		0,16	96,92	12,8	12,20
					Means	10.6	83.4	15.0	53.9
					Means	47.0		34.5	
			Rainbow–steelhead trout with chinook salmon present						
	8	November 8–15	15–15	0–8		0,14	80,47	67,64	77,40
	10	November 22–29	10–10	0–8		0,0	40,0	10,10	22,33
					Means	3.5	41.8	37.8	43.8
					Means	22.7		40.4	
			Chinook salmon only						
1967	3	December 6–13	100	0–5		45	91	27	65
	4	December 14–20	28	0–4		68	82	7	57
					Means	56.5	86.5	17.0	61.0
					Means	71.5		39.0	
1968	3[1]	October 4–11	25	3–9		76,84	100,100	60,100	100 –
					Means	80.0	100.0	80.0	100.0
					Means	90.0		86.7	
	7	November 1–8	25	1–8		4,0	48,40	21,8	48,36
	12	December 6–13	10	0–9		0,20	100,90	10,10	90,10
					Means	6.0	69.5	12.3	46.0
					Means	37.8		29.2	
			Chinook salmon with rainbow–steelhead trout present						
1968	8	November 8–15	15–15	0–8		20,38	73,73	13,27	100,47
	10	November 22–29	10–10	0–8		0,0	0,0	80,0	40,60
					Means	14.5	36.5	30.0	61.8
					Means	25.5		45.9	

[1] Both upstream and downstream traps used in these tests. Only downstream traps operated in remainder of tests.

of water source (temperature) and usually a majority entered the upstream traps. Operating under the hypothesis that colder temperatures cause fish to move downstream I expected fish in creek water to enter the downstream trap if they left the troughs and fish in spring water to remain in the troughs or enter upstream traps.

Tests 6, 9, 11 and 13 (rainbow–steelhead trout) and 7 and 12 (chinook salmon) in 1968 compare most readily with the 1967 tests because I used only downstream traps in both years. In 1968, as in 1967, fewer salmon and trout entered the downstream traps of troughs with spring water (34.5%) than with creek water (47.0%), but I found a smaller and statistically insignificant difference in 1968 (Table 1).

I ran tests with both trout and salmon in the troughs concurrently in 1968 to see if one

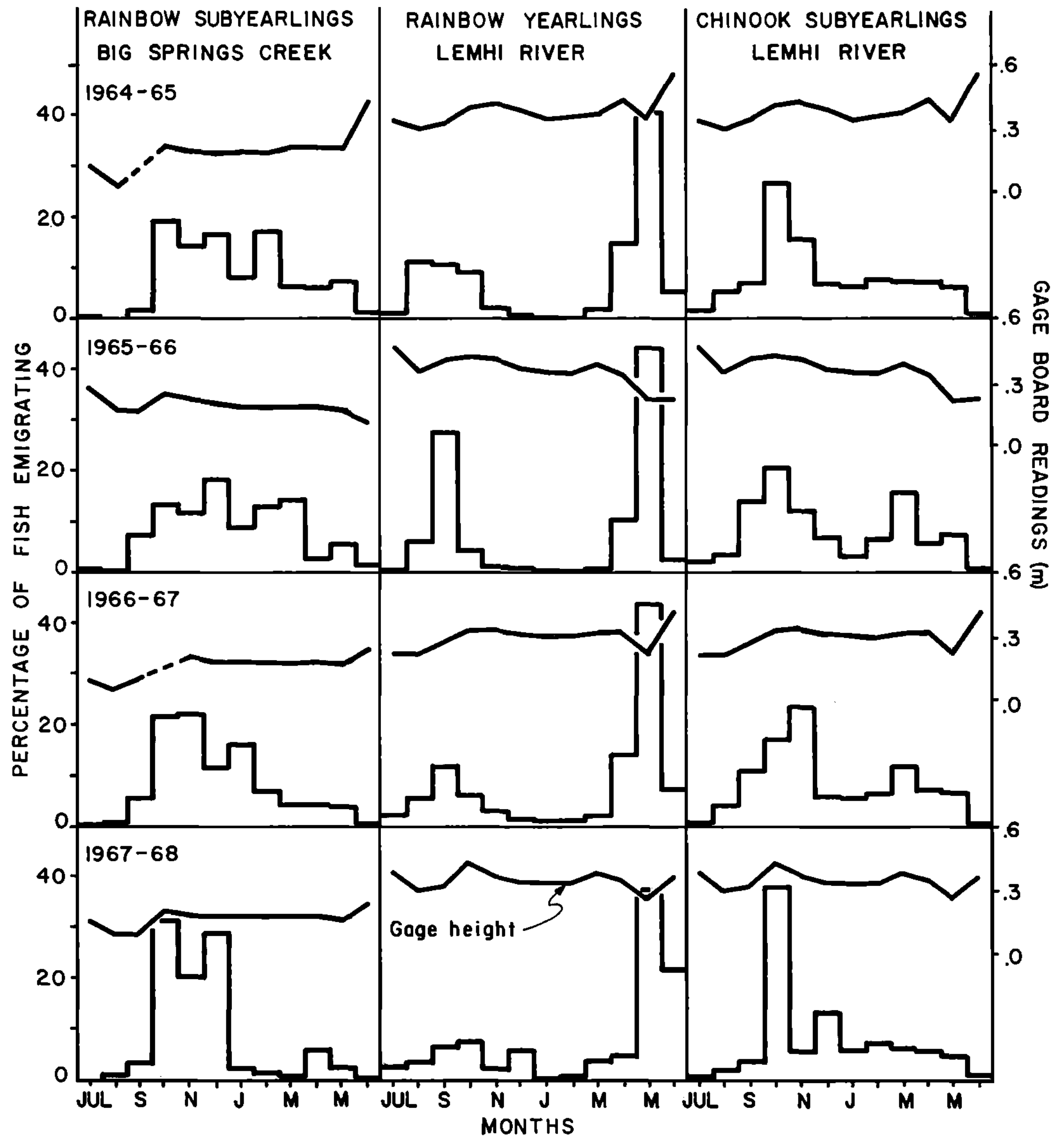

FIGURE 9.—Mean monthly stream height (flow) of Lemhi River and Big Springs Creek and percentage of total fish which migrated past weir sites each month.

species might affect the movements of the other. Nearly identical percentages of both species left the troughs but larger numbers left the troughs with spring water (Table 1).

From the inconsistent and variable results of the 1968 tests, I must conclude that I used unsuitable test apparatus or procedures, or that temperature did not affect movements under the conditions tested.

Movement Versus Streamflow

In general, migration of trout and salmon coincided with more or less consistent seasonal fluctuations in streamflow (Figure 9). Few fish migrated during the summer when streamflow reached a minimum. As withdrawals of water for irrigation declined, flow in the streams increased in late September and October and the fall migration began during those months. Streamflow remained relatively constant during winter while the number of fish migrating declined from the fall peak. In spring, the migration of yearling trout appeared to coincide with a reduced flow in May resulting from irrigation withdrawals prior to snow-melt run-off. Subyearling trout and salmon migrated in the spring also but with less well defined peaks of movement. Few fish moved downstream in June and July when peak flows occurred.

Although some of the major migrations coincided with seasonal changes in streamflow, I do not believe fluctuations in stream flow caused the migrations. Usually the fall migration of trout and salmon began in late August or September before streamflow increased and continued during stable flows (Figures 7 and 9).

Movement Versus Food Abundance

We collected samples of drifting insects and stomachs from 10 juvenile steelhead trout monthly during 1966 and 1967 at Big Springs Creek to determine if the fish migrated because of reduced food abundance. Hartman (1963) and Waters (1962) found drift food less abundant in winter in the streams they studied. We collected drift insect samples in five nets, each 30 cm wide and spaced across a uniform riffle, at two-hour intervals during a 24-hour period. The monthly mean number of drifting insects (Figure 10) was determined from 60 samples each collected for 15 minutes.

Fewer insects entered our nets during the winter months, but the decline in abundance of insects occurred after trout began migrating from the stream (Figure 10). Many trout began migrating in September and October but the number of insects entering our nets did not decline until December.

Trout stomachs contained more insects during the winter months (Figure 10), but reduced digestion rates during winter may account for the increased number of insects (Reimers, 1957).

Movement Versus Cover

Cover in Big Springs Creek and the upper Lemhi River consists primarily of: (1) mats

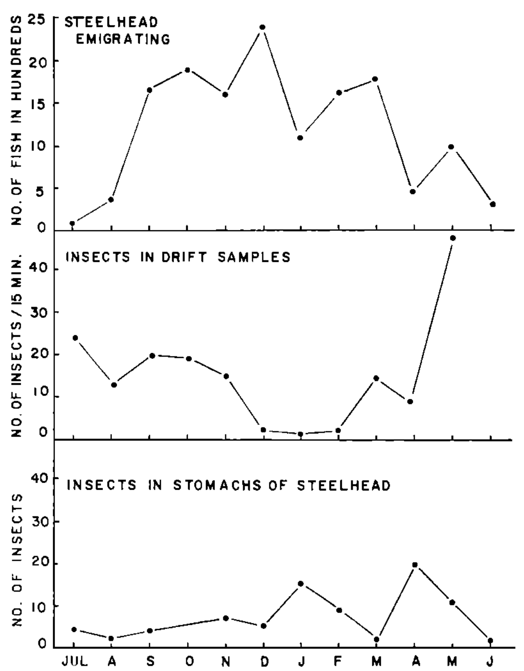

FIGURE 10.—Estimated number of rainbow–steelhead trout which left Big Springs Creek, mean number of insects collected in drift nets per 15 minutes, and mean number of aquatic insects in trout stomachs collected during 1966–1967.

of vegetation during summer and fall, (2) undercut banks, and (3) pools. I found large rubble substrate and the cover it provides primarily in the Lemhi River downstream from Big Springs Creek.

Vegetation began to die and drift from the streams in September, about the time fish began migrating. Since other streams where similar downstream migration occurs did not contain the mats of vegetation (Chapman and Bjornn, 1969, Figure 8), I believe the loss of vegetation was a secondary (if any) cause of the migration.

Chapman and Bjornn (1969) theorized that salmon and trout in Idaho streams need winter cover in which to hide. Large numbers of fish left the upper Lemhi and Big Springs Creek and thus I believe many fish found the habitat unsuitable. Since few trout which left Big Springs Creek as subyearlings continued migrating past the Lemhi Weir site they must have found suitable habitat. The lower Lemhi River differed from upper portions of the

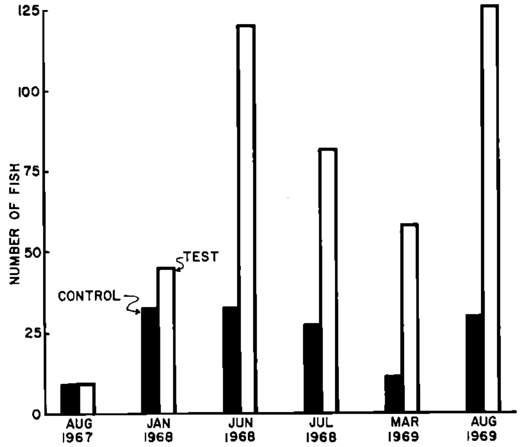

FIGURE 11.—Number of rainbow–steelhead yearlings collected from control and test (rock piles added) sections of Big Springs Creek. Rock piles added after sampling in August 1967.

study streams primarily in that it contained some rubble substrate.

To test the hypothesis that substrate made no difference to migrating fish we conducted: (1) the trough tests mentioned previously (Table 1), and (2) we placed piles of large rock in two 100 ft (30.5 m) long sections of Big Springs Creek during August of 1967. Two control sections 100 ft (30.5 m) in length adjacent to the test section contained no rock. In both test situations we wanted to see if larger numbers of trout and salmon remained in the troughs or stream sections with large rubble substrate.

Fewer trout and salmon left the troughs with rock substrate than with gravel substrate with exceptions in only a few tests (Table 1). With all tests averaged, 32% of the rainbow–steelhead trout left the troughs with rock compared with 68% from the troughs with gravel. Thirty percent of the chinook salmon left the troughs with rock compared with 63% from troughs with gravel substrate.

We found a larger number of age I+ rainbow–steelhead trout in the sections of Big Springs Creek where we added piles of rock than in the sections without rock (Figure 11). Fish in the sections with added rock occupied a variety of stations in the stream during summer but in winter nearly all fish lived in or near rock piles. Fish in sections without rock also occupied a variety of stations in summer, but we found them primarily under cut banks in the winter. Without vegetation or rocks in the stream channel fish avoided the shallow depth and faster velocity of the open riffle sections in the stream.

Movement Versus Population Density

The number of subyearling and yearling rainbow–steelhead trout which migrated from the study streams fluctuated with the number of steelhead trout fry released into Big Springs Creek (Figure 5). The number of fry released regulated the number of rainbow–steelhead juveniles which reared and migrated from Big Springs Creek. Subyearlings of the 1967–68 year classes which migrated from Big Springs Creek represented a higher proportion of the fry released than in previous years perhaps because steelhead had more completely replaced rainbow trout in the stream (Bjornn, unpublished data).

The number of fish rearing in Big Springs Creek (as measured by the number of migrants) regulated somewhat the time when fish left the stream (Figure 12). When large numbers of subyearlings and yearlings migrated from the stream a higher percentage left during the early August to December part of the migration season.

In the Lemhi River, a relatively constant percentage of rainbow–steelhead yearlings and chinook salmon subyearlings migrated in the fall regardless of the total number migrating (Figure 12).

The fraction of the population of subyearling rainbow–steelhead rearing in Big Springs Creek that migrates may also vary with population density. A relatively constant number of subyearlings migrated from Big Springs Creek during the spring (April–July) each year (Figure 5). I believe all but a relatively constant number of subyearlings leave Big Springs Creek each year by spring. Goodnight and Bjornn[3] (unpublished data) estimated the population of rainbow–steelhead subyearlings in Big Springs Creek in the spring of 1969 at 3,000 to 7,000 fish. Their estimate seems reasonable when compared with the number

[3] W. Goodnight and T. C. Bjornn, University of Idaho, Moscow, Idaho.

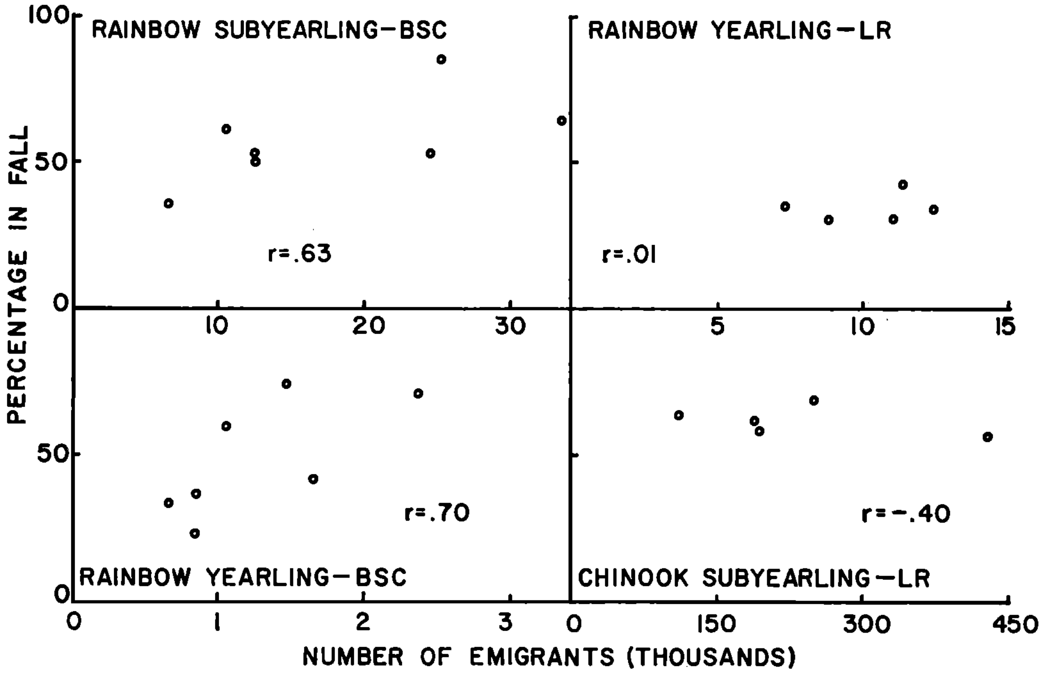

FIGURE 12.—Correlation (r) between number of emigrants which passed the Lemhi River (LR) or Big Springs Creek (BSC) weir sites (1962–1968 year classes) and percentages which emigrated in fall.

of yearlings which reared and migrated from the stream. Approximately 20–40% of the subyearlings must survive to yield the 800–2,400 yearlings which migrated from the creek.

Assuming about 5,000 subyearlings remain in Big Springs Creek each year to rear a second summer, then the total number of subyearlings produced in the stream ranged from 11,000 to 30,000 fish. The percentage of the estimated total number produced which migrated as subyearlings ranged from 55 to 83%.

DISCUSSION

Two types of downstream movement occurred among juvenile trout and salmon in the study streams: (1) seaward migration in the spring months by age I chinook salmon and age II or III steelhead trout, and (2) downstream movements primarily in the fall, winter and spring by pre-smolt and non-anadromous fish. Smolts of the anadromous species obviously sought the ocean in their downstream movements but what did the pre-smolts or non-anadromous fish seek? What stimulated or released movements in each case?

Water temperatures, streamflow, and photoperiod could stimulate or release the seaward migration of chinook salmon and steelhead trout smolts. Peak movements of steelhead trout smolts occurred in May when Lemhi streamflow decreased (Figure 9), but I do not believe the changing stream flows caused the downstream movements. Steelhead began migrating from the Lemhi River in late March and April when streamflow increased or remained constant in most years. Steelhead smolts migrated from Big Springs Creek also in April and May and streamflow remained relatively constant throughout the migration period (Figure 9). Chinook salmon smolts migrated from the Lemhi River throughout the spring months (with a peak occurring in March some years) and during relatively stable streamflows (Figure 9).

The smolt migration of both salmon and trout in the study streams coincided with increasing stream temperatures in the spring (Figure 6), but the increasing temperatures seemed coincidental since steelhead trout reared in a spring-fed pond on a tributary of the Lemhi River migrated from the relatively constant temperature pond at the normal time in April or May.[4] Osterdahl (1969) observed that timing of seaward migration of Atlantic salmon (*Salmo salar*) frequently, but not always, coincided with an increase in stream temperature and he concluded temperature did not cause the migration. Bjornn, Craddock, and Corley (1968) found sockeye salmon (*Oncorhynchus nerka*) left Redfish Lake regardless of temperature at the lake outlet.

I could not establish a causal relationship between stream temperature and the seaward migration of salmon and trout smolts with the data I collected. Eales (1965), however, found that increased thyroid activity in steelhead trout smolts depended on both increasing temperature and photoperiod. Johnston and Eales (1968) found that deposition of guanine and hypoxanthine (silvering) in the skin and scales of Atlantic salmon also depended on temperature but was not affected appreciably by lengthening photoperiod. Canadian workers (Fisheries Research Board of Canada, 1966) reported that coho salmon (*Oncorhynchus kisutch*) held in 8.5 C water underwent changes in both guanine deposition and coefficient of condition with change in photoperiod. For fish held in 2.5 C water the coefficient of condition changed little, if any, under any photoperiod regime tested and guanine level increased slightly by the end of the experiment.

Water temperatures in the Lemhi River increased during the spring and thus would not inhibit the parr-smolt transformation in the manner listed above. At Redfish Lake, however, we (Bjornn *et al.*, 1968) observed sockeye salmon smolts leaving an ice-covered lake in which water temperatures had not exceeded 4 C for 3–4 months.

Baggerman (1960) concluded that daily length of photoperiod controlled timing of maturation of the mechanism for marine osmoregulation and probably migration-disposition of juvenile salmon. She found thyroid activity increased prior to the migration season and declined as it ended. Wagner, Conte, and Fessler (1969) suggested that marine osmoregulation developed independent of the parr-smolt transformation[5] in coho salmon and development of the euryhaline state did not result in an immediate change in migration disposition.

The role of photoperiod and temperature as stimulators, or releasers, in the seaward migration of salmon and trout smolts is unclear and should be better defined. Growth also plays a role since some fish do not migrate until they reach a threshold size and pass through one or two photoperiod-temperature cycles before migrating to the sea (steelhead trout for example).

Since pre-smolts and non-anadromous fish migrated primarily during the period September–May each year, I theorized that the fish found some aspect of the environment unsuitable during that period. Chapman and Bjornn (1969) proposed that fish in most Idaho streams required winter cover and that low water temperatures triggered the winter hiding behavior observed by them (Hartman, 1965; Everest, 1969).

In my experiments with substrate and temperature, I induced more fish to remain in test troughs or test sections of Big Springs Creek by providing my concept of a more suitable substrate in terms of winter cover (Table 2 and Figure 11). I believe the amount of suitable winter cover in a stream plays a major role in regulating the number of fish that overwinter in streams with winter temperatures below 4–5 C. Hunt (1969) found reduced loss of brook trout in a Wisconsin stream due to mortality and migration after habitat improvement. He believed the improvement in "space-refuge" factors (protective cover, depth, pool area) accounted for the larger overwinter populations.

The role, if any, of temperature in the fall–winter migrations remained unclear, perhaps because of inadequate test troughs. A slightly larger number (not statistically significant) of salmon and trout left the troughs with gravel substrate and cold water compared to gravel

[4] Unpublished data, Idaho Fish and Game Department, Salmon, Idaho.

[5] I consider the parr-smolt transformation to include both the changes in appearance (silveriness and coefficient of condition) and behavior (migration disposition).

TABLE 2.—*Percentage of fish leaving troughs during tests conducted in 1967 and 1968 (Table 1), all tests combined*

	Substrate	
	Rock	Gravel
Steelhead trout		
Creek water (0–10 C)	26.7	76.2
Spring water (11–12 C)	41.3	62.9
Chinook salmon		
Creek water	29.6	66.4
Spring water	30.3	62.8

substrate and warmer water (Table 2). In the troughs with rock substrate equal numbers of salmon remained in the two water temperatures and fewer trout remained in the trough with warmer spring water.

Temperature appeared to cause little if any change in the behavior of fish moving downstream, but Chapman and Bjornn (1969) presented some convincing evidence that lower water temperatures triggered winter hiding behavior of fish. A fish induced to hide by low water temperatures may move downstream if unable to locate suitable cover and thus temperatures may trigger downstream movement indirectly.

I found no evidence that food or stream flow induced the movements observed in the study streams. Small freshets during the usual migration period occasionally coincided with temporary increases in the number of migrants but such occurrences only modified the basic migration pattern.

Population density also appeared to only modify the basic migration patterns rather than cause the movement. The number of salmon and rainbow–steelhead trout that migrated and the time of migration correlated with population density in some instances, but some fish moved downstream at all population densities encountered. Because some fish migrated regardless of population density, inherited traits or photoperiod could also play a role in the movement. Lack of movement of brook trout fry leads me to recognize the possibility that no fish would migrate if populations did not exceed the winter capacity of the streams, perhaps in terms of winter cover.

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