FILE COPY

RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A-038-IDA

WATER for IDAHO

Migration Response of Juvenile Chinook Salmon to Substrates and Temperatures

Project Investigator T.C. Bjornn
Research Assistant C.F. Morrill

Water Resources Research Institute
University of Idaho
Moscow, Idaho
June, 1972

RESEARCH TECHNICAL COMPLETION REPORT

PROJECT A-038-IDAHO

MIGRATION RESPONSE OF JUVENILE CHINOOK SALMON TO SUBSTRATES AND TEMPERATURES

PRINCIPAL INVESTIGATORS - C.F. Morrill
Research Assistant, Idaho Cooperative Fishery Unit
University of Idaho

T.C. Bjornn
Professor, Idaho Cooperative Fishery Unit
University of Idaho

PERIOD OF INVESTIGATION - September 1, 1970 to June 30, 1972

The work upon which this report is based was supported by funds provided by the United States Department of Interior, Office of Water Resources Research as authorized under the Water Resources Research Act of 1964.

Water Resources Research Institute
University of Idaho
June, 1972

ABSTRACT

I assessed downstream migration of age 0+ chinook salmon from stream channels with rock and rubble (good) or gravel or shale (poor) substrates and constant or declining water temperatures during the fall months of 1970 and 1971. As water temperatures declined, juvenile chinook left stream channels with gravel or shale substrates or moved into available hiding spaces in stream channels with rock and rubble substrate. Fish initially emigrated as temperatures declined below 10 C. I believe the number of emigrants reflects the holding capacity of the substrate and the density of the fish population. The migration response varied with size and race of fish. I attribute most of the response difference between races to differences in fish size. I contend that juvenile spring chinook find rock and rubble substrate an important component of their winter habitat.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Each fall as water temperatures decline, thousands of age 0+ spring chinook and steelhead trout move downstream from rearing areas in Idaho streams and rivers. Chapman and Bjornn (1969), Bjornn (1971), and Reingold (unpublished data)[1] observed downstream movements of salmonids throughout the fall, winter, and spring in the Salmon and Lemhi Rivers. The number of juvenile migrants peaked in the fall, usually during October. Bjornn (1971 b) estimated that an average of 141,000 juvenile chinook migrated from the upper Lemhi River each fall from 1963 to 1969. Fish migrated initially as water temperatures first declined below 10 C in September. Chapman and Bjornn (1969) tentatively concluded that water temperature controlled downstream movements of juvenile steelhead. The type of substrate present (quality of winter cover) modified the movement. After further tests, Bjornn (1971) found that temperature caused little difference in the number of salmon leaving test troughs with warm (10-12 C) or cold ($<$10 C) water, although significantly more salmon and steelhead remained in troughs with large rocks compared with troughs with gravel substrates. Bjornn stated that his test results regarding temperature and chinook movements were inconclusive. Bjornn (1971) found no evidence of correlation between fall migration of salmonids and food supply, water flow, or population density.

1/ Reingold, Melvin, Idaho Fish and Game Dept., Salmon, Idaho.

I assessed emigration of age 0+ spring chinook from stream channels with two water temperature regimes and substrate types from September through December in 1970 and 1971. As water temperatures declined, juvenile chinook left stream channels with gravel or shale (poor) substrates or in stream channels with rock and rubble (good) substrate, moved into available hiding spaces. Few chinook left stream channels with good substrate regardless of water temperatures. I rejected the hypothesis that juvenile chinook salmon exposed to declining water temperatures and poor substrate would not emigrate downstream. I conducted the experimental work at Hayden Creek Experimental Salmon and Steelhead Rearing Station, Lemhi, Idaho.

MATERIALS AND METHODS

I assessed juvenile chinook emigration from four different temperature-substrate types in twelve experimental stream channels (Figure 1). I placed 25 to 30 fish in each stream channel and counted the number of emigrants from each channel during each experimental run. The four temperature-substrate types included constant temperature-poor substrate (CP), constant temperature-good substrate (CG), declining temperature-good substrate (DG), and declining temperature-poor substrate (DP), with three replicates of each or twelve experimental units. I used spring water (10-12 C) for constant temperatures and mixed cold water from Hayden Creek ($<$10 C) with spring water to obtain the declining water temperature regime. A system of pipes supplied six channels

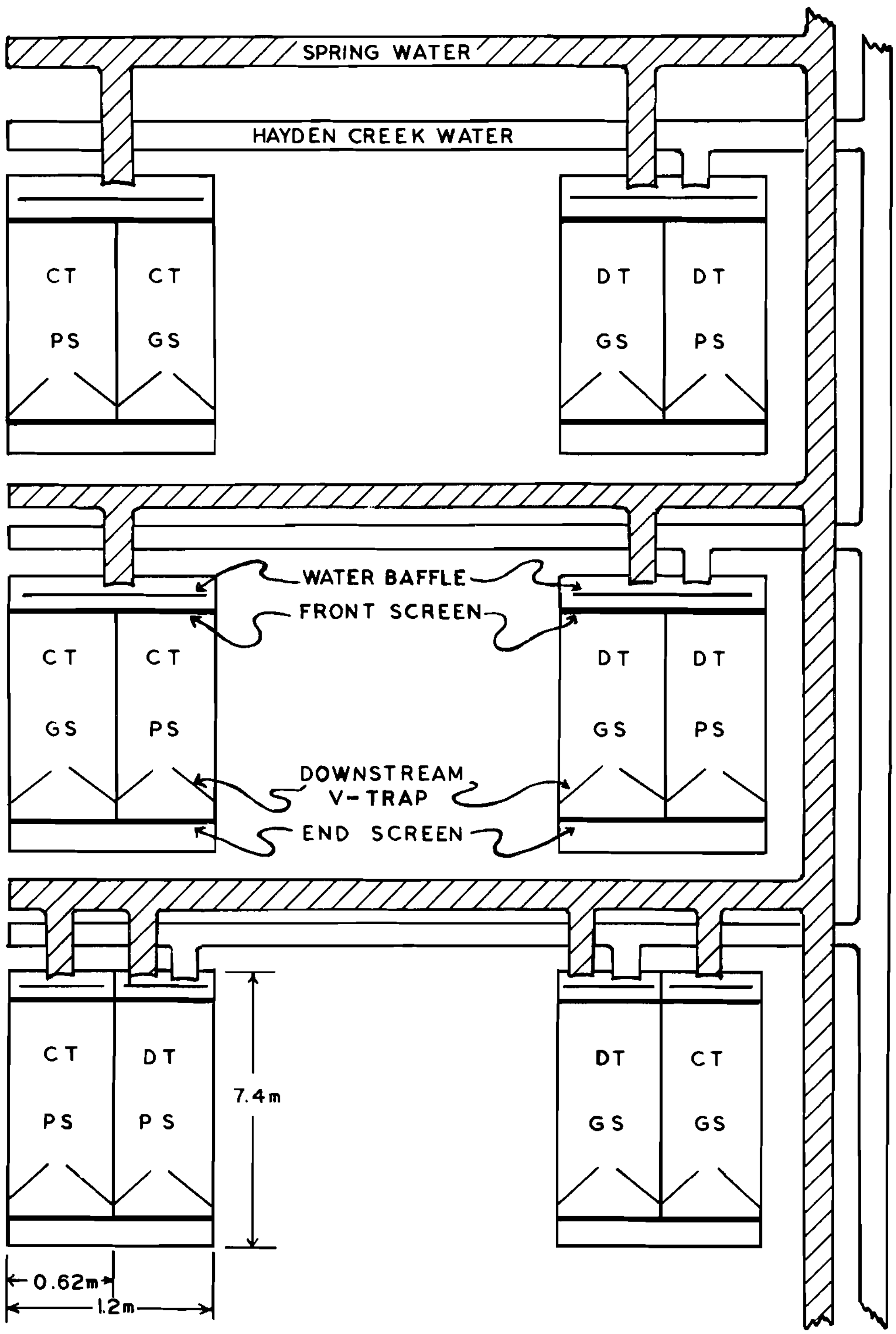

Figure 1. A schematic diagram of the experimental stream channels used to test the response of age 0+ chinook to constant and declining water temperatures (CT and DT) and to good and poor substrate (GS and PS).

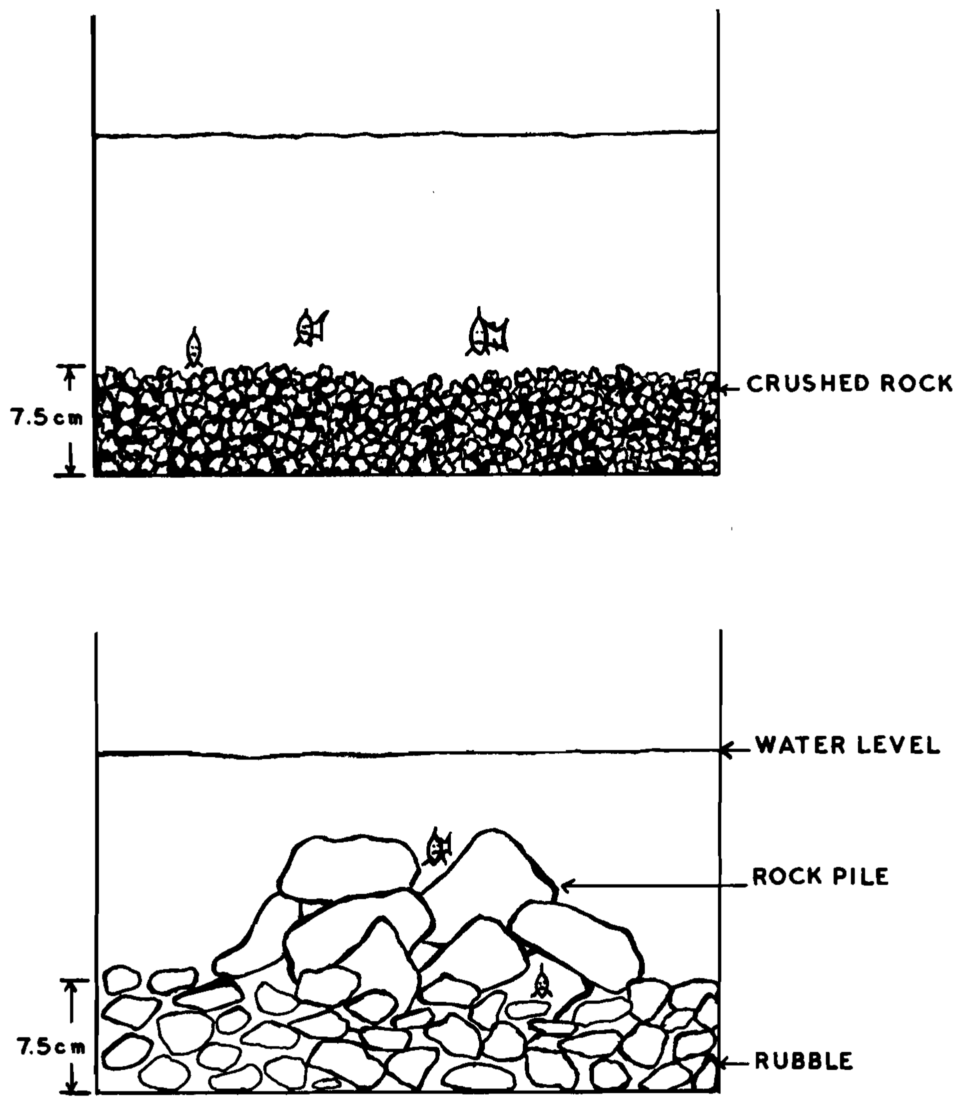

Figure 2. A schematic diagram of good and poor substrates used in the experimental stream channels.

with spring water and six channels with both spring and creek water. In six channels I constructed three rock piles on a bed of rubble 2.5-7.5 cm deep to simulate good substrate (Figure 2). In the remaining six channels I used fine shale 2.5-7.5 cm deep supplemented with four rocks to simulate poor substrate in 1970. In 1971, I replaced the shale and rocks with 1.6 cm crushed rock 2.5-7.5 cm deep. The large rocks I used ranged from 15 to 45 cm across. Each channel was 7.4 m long, 0.62 m wide, and 0.62 m deep with a water baffle, one V-trap, and two end screens (Figure 1). The channels rested on a cement slab about 180 feet long and 10 feet wide enclosed on three sides and covered with a translucent fiberglass roof which protected the slab and the stream channels from inclement weather and direct light. I controlled water flows for each channel with butterfly valves and regulated water flow at 76 liters/min per channel. Water depth averaged between 38 and 40 cm.

In August, 1970, I tested the hypothesis that spring and creek water caused differential emigration of juvenile chinook from the experimental stream channels. At 6 PM I placed 25 fish in each of three channels, one with all spring water, a second with 50 percent spring and 50 percent creek water, and a third with all creek water. Water temperatures remained nearly constant among the three channels. Acclimation proceeded for the next 48 hours. I then removed the blocks from the V-traps allowing fish to emigrate freely during the next twelve hours. The next morning I recorded the number of fish present in the V-traps. Water sources did not cause differential emigration of juvenile chinook (Table 1).

Table 1. The number of fish leaving the experimental stream channels with different water sources.

Water source	Fish leaving Test 1	Test 2
100% Spring	3	3
50% Spring - 50% Creek	4	3
100% Creek	3	2

In 1970 I completed five experimental runs each with chinook from Lemhi River and Valley Creek. I re-examined the response of chinook from Valley Creek (three tests) and Lemhi River (one test) in 1971 and tested for differences between and within races and sizes. Each experimental run with sample populations from each race lasted eight days. Initially I recorded water temperatures with two thermographs and six minimum-maximum thermometers. In 1971 I eliminated the minimum-maximum thermometers. In 1970 I used the standard operating procedures explained below.

First day: Fill channels with spring water, adjust water flows to 76 liters/min. Block entrance to V-traps. Set minimum-maximum thermometers. Introduce test fish in channels near 6 PM. Cover channels with chicken wire (to prevent avian and mammalian predation).

Second day: Acclimation.

Third day: Remove trap blocks around 6 PM after 48 hours acclimation.

Fourth morning: Remove and record the number of fish in each V-trap near 8 AM. Record water temperatures. Change water flows to 75 percent spring - 25 percent creek water in the six channels designated for declining water temperatures. Check and adjust all water flows to 76 liters/min as necessary. Complete work as early as possible.

Fifth morning: Repeat procedure as above. Change water flows to 50 percent spring - 50 percent creek in channels with declining water temperature regimes.

Sixth morning: Repeat basic procedure. Change water flows to 25 percent spring - 75 percent creek in channels with declining water temperature regimes.

Seventh morning: Repeat basic procedure. Change water flows to 100 percent creek water in channels with declining water temperature regimes.

Eighth morning: Repeat basic procedure. No change in water flow composition.

Ninth morning: Disregard water flows and repeat procedure as before. Remove and account for all remaining fish in each channel. Clean channels as necessary. Fill all channels with spring water and prepare for next run.

I evaluated the data graphically and statistically in assessing the effects of temperature and substrate upon the observed emigration from the channels. I used a random block factorial design to evaluate the effects of temperature, substrate, and temperature-substrate interaction on fish emigration.

In 1971 I tested the hypothesis that chinook emigrated from each temperature-substrate type independently of race and size of fish. I altered the operating procedure described earlier due to time limitations imposed by construction work undertaken at the hatchery in late September and early October, 1971. Each experimental run lasted seven days. I changed the rate of temperature decline by adjusting water flows to 65 percent spring - 35 percent creek on the fourth morning, 35 percent spring - 65 percent creek on the fifth morning, and 100 percent creek on the sixth morning, thus completing the run on the morning of the eighth day. Except for these changes, the standard operating procedure remained unchanged. I evaluated the results of these tests with a G-test (Sokal and Rohlf, 1969).

We collected juvenile chinook by electrofishing from Marsh and Valley Creeks in Stanley Basin in 1970 and from the upper Salmon River in 1971. In both years we collected more than 80 percent of the chinook from Valley Creek. We collected fish from the upper Lemhi River in August of 1970 and 1971 by electrofishing. I also took juvenile chinook from the fish traps at the Lemhi River weir in October and November of 1970 as they migrated from the upper Lemhi River. I identified these fish as "movers" to distinguish them from other Lemhi chinook, "pre-movers", collected from the river prior to any downstream emigration.

I held the test fish in fiberglass vats with water temperatures of 10-12 C prior to placing them into the experimental stream channels. I fed them dry hatchery diets and frozen shrimp, but did not feed fish in experimental channels during the tests.

When selecting fish for each test I avoided fish which exhibited abnormal physical appearance or behavior.

RESULTS

I found that few fish left channels with good substrate regardless of water temperatures. Declining water temperatures stimulated fish emigration from channels with poor substrate and hiding behavior in those with good substrate.

Lemhi chinook, 1970 and 1971

Few chinook from the Lemhi River left channels with good substrate in all tests regardless of water temperatures (Table 2). Fourteen percent of the fish left channels with constant temperature-good substrate versus twelve percent from channels with declining temperature-good substrate (Figure 3). The largest percentage of chinook which emigrated from channels with declining temperature-good substrate left the first night temperatures declined below 10 C. As temperatures continued to decline emigration decreased and virtually ceased at temperatures below 5 C. Channels with good substrate supported mean densities of five fish/m^2 for both temperature regimes (Table 3).

More fish left channels with poor substrate than good substrate and emigration from channels with constant temperature-poor substrate and declining temperature-poor substrate differed significantly (Figure 3). Emigration from channels with constant temperature-poor substrate averaged 37 percent versus 62 percent from channels with declining temperature-poor substrate. Emigration from channels with constant temperature-poor substrate peaked the first night and declined steadily thereafter. Emigration from channels with declining temperature-poor substrate peaked the first night with initial temperature decline below 10 C and decreased thereafter as temperatures declined to 5 C. As temperatures declined further, emigration increased from three to twelve percent per night. Channels with poor substrate supported mean densities of two and three fish/m^2, respectively, in declining and constant water temperatures.

In the first test with pre-movers from the Lemhi River, similar percentages of chinook emigrated from channels with each temperature-substrate combination. I attribute this lack of differential response to warmer than average declining water temperatures. Minimum temperatures never declined below 5 C and maximum temperatures exceeded 7.2 C each day.

Lemhi chinook: Movers versus pre-movers

Pre-movers, chinook collected prior to fall emigration, and movers, chinook collected while actively emigrating, emigrated similarly from channels with good substrate at the end of acclimation (Table 4). Water temperatures ranged between 10 and 12 C during acclimation. Twelve percent of the pre-movers versus fourteen percent of the movers left channels with good substrate. Significantly more movers (46%) than pre-movers (16%) left channels with poor substrate.

Stanley Basin chinook, 1970

In the 1970 tests chinook from Stanley Basin emigrated from channels with each temperature-substrate type in a pattern similar to that of Lemhi chinook. Twenty-three and 54 percent

Table 2. The percentage of chinook from the Lemhi River which remained in each channel in each test conducted with pre-movers and movers (see text for explanation).

Pre-movers

Temperature	Substrate	Test dates												Means
		9/15-20/70			10/2-7/70			10/18-23/70			11/23-28/71			
Constant	Good	88	88	94	75	83	96	87	92	75	71	95	63	83.9
	Poor	84	87	36	56	68	76	67	48	70	73	67	56	65.7
Declining	Good	92	100	95	100	73	100	88	86	83	68	86	88	88.2
	Poor	39	64	88	27	42	9	23	32	23	28	36	44	37.9

Movers

Temperature	Substrate	Test dates						Means
		10/26-31/70			11/3-8/70			
Constant	Good	100	96	91	62	100	96	90.8
	Poor	9	73	75	50	57	68	55.3
Declining	Good	74	90	96	80	92	100	88.7
	Poor	18	14	50	37	28	88	39.2

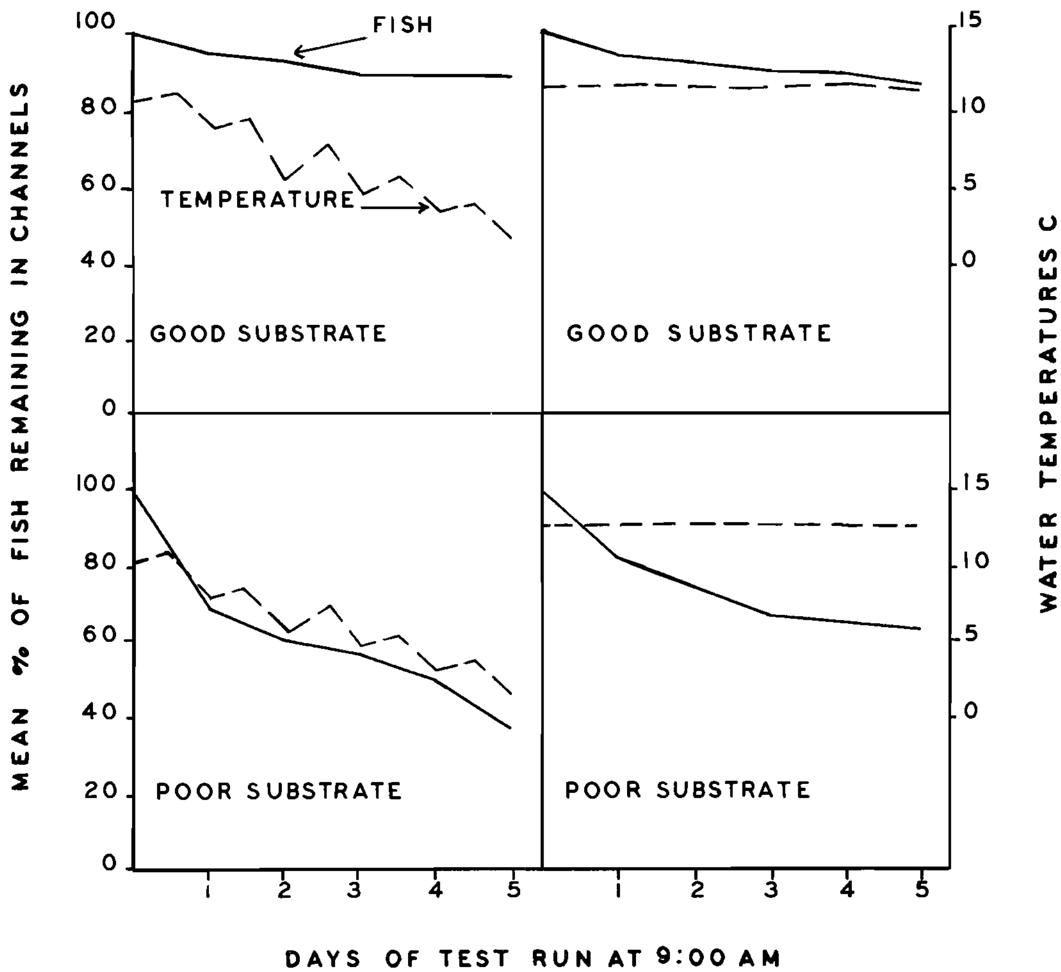

Figure 3. A summary of all tests conducted with age 0+ chinook from the Lemhi River illustrating the mean percentage of fish which remained in channels with each temperature-substrate type throughout the test run.

Table 3. Mean density of age 0+ chinook which remained in channels with each temperature-substrate type for all tests with chinook from the Lemhi River and Stanley Basin.

Temperature / Substrate	Constant Good	Constant Poor	Declining Good	Declining Poor
Lemhi chinook 1970 & 1971				
Mean # of fish remaining in channels	20	12	20	8
Square meters per fish	0.20	0.34	0.20	0.51
Fish per square meter	5	3	5	2
Stanley Basin chinook 1970				
Mean # of fish remaining in channels	9	10	14	8
Square meters per fish	0.46	0.41	0.29	0.51
Fish per square meter	2	2	3	2
Stanley Basin chinook 1971				
Mean # of fish remaining in channels	14	12	17	9
Square meters per fish	0.29	0.34	0.24	0.46
Fish per square meter	3	3	4	2

of the fish left channels with declining water temperatures from good and poor substrates respectively (Figure 5). Emigration from channels with declining temperature-good substrate decreased each night as temperatures declined to 5 C and nearly ceased as temperatures declined further. Emigration from channels with constant temperature-poor substrate decreased steadily as the test progressed. Mean densities of fish remaining in the channels at the end of the test ranged from two fish/m^2 in declining temperature-poor substrate to three fish/m^2 in declining temperature-good substrate. I was unsure of the validity of these test results because of the large amount of variation (Table 5).

Stanley Basin chinook, 1971

In the 1971 tests, fewer fish left channels with good substrate than channels with poor substrate (Table 6). The mean percentages of fish leaving good substrate from the two water temperature regimes differed little (Figure 5). Emigration from channels with declining temperature-good substrate decreased as temperatures declined to 5C and virtually ceased as temperates declined further. Emigration from channels with constant temperature-good substrate declined progressively. Good substrate supported mean densities of three and four fish/m^2 respectively, in channels with constant and declining water temperatures.

More fish left channels with poor substrate than channels with good substrate. More fish left channels with declining temperature-poor substrate than channels with constant temperature-poor substrate (Figure 5). Emigration from channels with constant temperature-poor substrate peaked the first night and declined

Table 4. The mean percentage of juvenile chinook salmon from the Lemhi River which remained in channels with the different substrate types on acclimation prior to each test run in water temperatures of 10-12 C.

Substrate	Pre-movers					Movers		
	1	2	3	4	Mean	1	2	Mean
Good	86.7	94.0	87.9	86.7	88.9	89.3	88.2	86.5
Poor	82.0	86.0	91.4	78.7	84.5	53.3	60.7	64.4

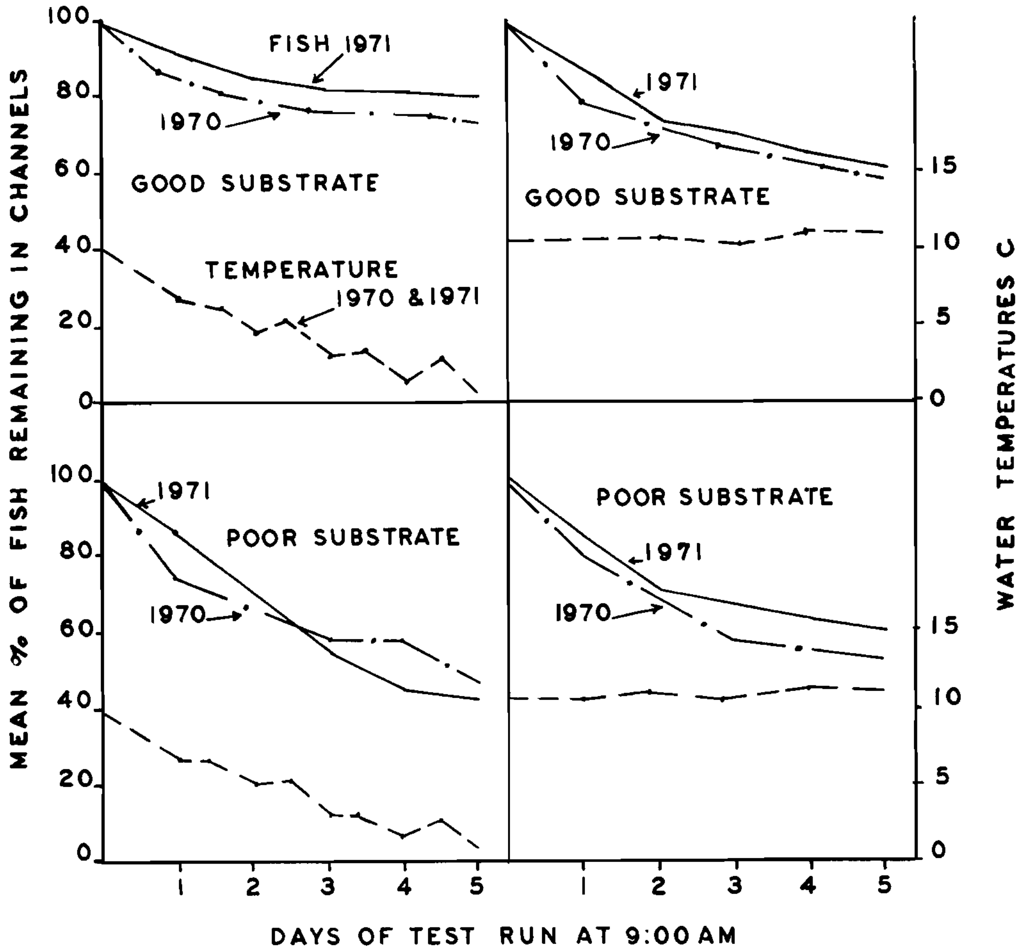

Figure 4. A summary of all tests conducted in 1970 and 1971 with age 0+ chinook from Stanley Basin illustrating the mean percentage of fish which remained in channels with each temperature-substrate type throughout the test run.

Table 5. Mean percentage of age 0+ chinook from Lemhi River and Stanley Basin which remained in channels with each temperature-substrate type in each test.

Lemhi chinook

Temperature	Substrate	Pre-movers 1970			Pre-movers 1971	Movers 1970	
Constant	Good	90	85	84	76	96	86
	Poor	68	67	62	66	52	58
Declining	Good	96	91	86	81	86	91
	Poor	63	26	26	36	28	51

Stanley Basin chinook

Temperature	Substrate	1970					1971		
Constant	Good	60	35	73	69	54	70	57	59
	Poor	30	40	74	60	63	61	63	60
Declining	Good	74	66	73	88	72	81	75	83
	Poor	18	46	48	69	50	46	36	43

steadily thereafter. Emigration from channels with declining temperature-poor substrate peaked during the first two nights as temperatures declined to 5 C and then decreased as temperatures declined further. Channels with poor substrate supported mean densities of three and two fish/m^2 respectively, in constant and declining water temperatures.

Tests with race and size

Nearly equal percentages of chinook from the Lemhi River and Stanley Basin of similar size emigrated from channels with each temperature-substrate type. Small chinook from Stanley Basin responded differently than larger chinook from Stanley Basin to temperature-substrate types (Table 7). More small chinook left channels with constant temperature-good, poor substrate, and declining temperature-good substrate than larger chinook. Fewer small chinook left channels with declining temperature-poor substrate than larger chinook. Different sized chinook from the Lemhi River and Stanley Basin emigrated in different percentages from the temperature-substrate combinations.

In all comparison tests fewer fish left channels with good substrate and more fish left channels with poor substrate. The smallest percentages of fish left channels with declining temperature-good substrate. The greatest percentage left channels with declining temperature-poor substrate (Table 7).

Table 6. The percentage of Stanley Basin chinook which remained in each channel in each test conducted in the fall of 1971.

Temperature	Substrate	Test dates 10/17-21/71			11/1-5/71			11/16-20/71		
Constant	Good	70	58	82	37	55	75	60	58	60
	Poor	60	68	55	70	65	55	52	56	70
Declining	Good	68	84	91	43	88	95	71	91	86
	Poor	50	47	40	17	60	30	60	24	46

Table 7. The percentage of age 0+ chinook which remained in channels with each temperature-substrate type in tests of independence between and within sizes and races of chinook from the Lemhi River and Stanley Basin. CG - constant temperature-good substrate, CP - constant-poor, DG - declining temperature-good substrate, DP - declining-poor.

Race	Date	Mean Size (Fork length)		Percentage of fish remaining			
				CG	CP	DG	DP
Stanley Basin	Nov. 8-12, 1971	80 mm		82	74	88	35
	Dec. 1-5, 1971	81 mm		88	64	97	42
			Means	85	69	92	38
Lemhi chinook	Nov. 8-12, 1971	85 mm		75	67	96	37
	Dec. 1-5, 1971	86 mm		76	76	100	42
			Means	76	72	98	40
Stanley Basin	Nov. 8-12, 1971	56 mm		70	57	95	45
	Dec. 1-5, 1971	58 mm		62	67	85	53
			Means	66	62	90	49

DISCUSSION

I conclude that as water temperatures decline in the fall most juvenile chinook salmon seek a place to hide in the substrate for the coming winter. I believe most downstream movement occurs as an indirect response to declining temperatures where fish fail to find suitable hiding places in the substrate. Some juvenile chinook move downstream in direct response to declining temperatures without regard for hiding places offered by the substrate.

Migrating chinook from the Lemhi River (movers) virtually ceased movement when placed in channels with good substrate. Because few fish emigrated from channels with rock and rubble substrate my idea of good substrate does not appear unrealistic. Movers clearly preferred good substrate over poor substrate even after acclimation for a week in the fiberglass vats at 10-12 C. Significantly more movers than pre-movers left channels with gravel substrate on completion of acclimation than I expected. I attribute this difference in response to previous exposure of the movers to declining water temperatures. I did not subject pre-movers to declining temperatures until the test. Once subjected to declining water temperatures, significantly more pre-movers left channels with poor substrate than good substrate. Thus, when placed in channels with a suitable rock and rubble substrate, few chinook (movers or pre-movers) emigrated.

In 1970, chinook from Stanley Basin refused to feed on the diets I offered them. I attribute the variable results of these tests to loss of condition and starvation of the fish used. Even with this problem the mean percentages of fish leaving channels with each temperature-substrate type for all 1970 tests differ little from the results of 1971 tests with chinook from Stanley Basin (Table 8).

Table 8. Means of all tests with chinook from the Lemhi River and Stanley Basin pooled to show the percentage of fish which remained in channels with each temperature-substrate type.

Temperature	Substrate	Lemhi chinook Pre-movers	Lemhi chinook Movers	Stanley chinook 1970	Stanley chinook 1971
Constant	Good	84	91	59	62
	Poor	66	56	54	60
Declining	Good	88	88	77	80
	Poor	38	40	46	42

Both chinook from Stanley Basin and Lemhi River emigrated in a similar pattern from channels with the temperature-substrate types tested, but the rate of emigration differed between the two races (Table 8). Similar emigration patterns from channels with each temperature-substrate type for both races suggest that racial differences are minimal. I attribute most of the difference in emigration between the races to difference in size. Chinook from Stanley Basin, 80-81 mm mean fork length, and the Lemhi River, 85-86 mm mean fork length, emigrated from channels with each temperature-substrate type in nearly equal percentages (Table 7). Smaller chinook from Stanley Basin, 56-58 mm mean fork length, emigrated from the channels in significantly different percentages than the larger chinook from Stanley Basin and the Lemhi

River.

I did not observe any chinook above the substrate in channels with good substrate after temperatures declined below 5-7 C. As water temperatures declined in channels with poor substrate, fish which remained in the channels usually bunched together at the upstream end of the channel and remained close to or in contact with the bottom. In channels with constant water temperature and good substrate chinook actively moved about, maintaining focal points or territories and behaved aggressively. In channels with poor substrate and constant water temperature the chinook most frequently schooled. I did not observe fish feeding in channels with declining water temperatures, however I observed chinook in channels with constant water temperatures feeding on live shrimp and occasionally on drifting surface and sub-surface insects present in the channels.

More of the larger chinook remained in channels with large rock and rubble substrate than smaller chinook (Figure 5). With increasing length, fewer chinook remained in channels with declining water temperature and poor substrate. I suggest that as chinook approach 80 mm fork length they show an increased preference for rock and rubble substrate in which to hide. I believe the smaller chinook (65 mm fork length or less) emigrate essentially in a random manner from the substrate types. When subjected to declining water temperatures the smaller chinook show a clear preference for good substrate. Miller (1970) suggests random dispersal of fry in the upper Salmon River modified by water temperature, fry density, racial stock, and light at night.

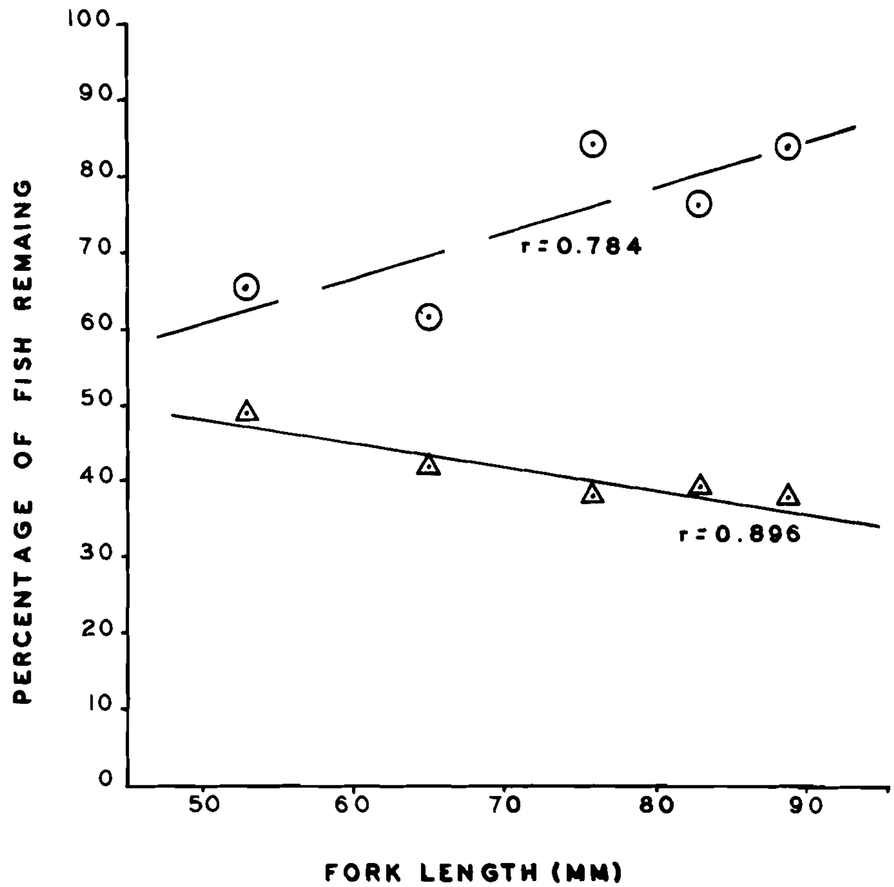

Figure 5. The percentage of age 0+ chinook which remained in channels with constant temperature-good substrate (⊙) and declining temperature-poor substrate (△) correlated with the mean fork lengths of fish tested in 1970 and 1971.

Substrate type did not affect fry movement. He arbitrarily defined fry as any fish less than 50 mm fork length. Thus as chinook grow, their habitat requirements change with both increasing size and the time of year.

Stuart (1957) reported emigration of age 0+ brown trout from nursery streams at the end of their first summer. The downstream emigration occurred as temperatures declined from 8-10 C to 4-7 C. These fish returned to the stream the following spring as lake water temperatures rose above 10 C. He also observed salmon fry leaving the Dunalastair streams and commented that he never found any salmon in these streams during winter. Hartman (1963 & 1965) observed that juvenile coho, steelhead, and brown trout associated closely with rock and rubble substrate with low water temperatures during winter. Chapman (1966), Chapman and Bjornn (1969), Bjornn (1971), and Hartman (1963 & 1965) all suggest that winter hiding behavior has adaptive survival value. Winter association with large rock and rubble substrate offers protection from predation, scouring, displacement by high water flows, and also conserves energy. Reimers (1957) concluded that winter mortality results primarily from exposure to winter conditions including ice, slush, collapsing snow banks and fluctuating water flows.

In streams with water temperatures declining below 10 C in the fall, the number of emigrating trout and salmon would likely reflect the amount of protective cover and hiding spaces available in the substrate and fish population density. Emigration tapers off in late fall as temperatures decline below 5 C

Substrate type did not affect fry movement. He arbitrarily defined fry as any fish less than 50 mm fork length. Thus as chinook grow, their habitat requirements change with both increasing size and the time of year.

Stuart (1957) reported emigration of age 0+ brown trout from nursery streams at the end of their first summer. The downstream emigration occurred as temperatures declined from 8-10 C to 4-7 C. These fish returned to the stream the following spring as lake water temperatures rose above 10 C. He also observed salmon fry leaving the Dunalastair streams and commented that he never found any salmon in these streams during winter. Hartman (1963 & 1965) observed that juvenile coho, steelhead, and brown trout associated closely with rock and rubble substrate with low water temperatures during winter. Chapman (1966), Chapman and Bjornn (1969), Bjornn (1971), and Hartman (1963 & 1965) all suggest that winter hiding behavior has adaptive survival value. Winter association with large rock and rubble substrate offers protection from predation, scouring, displacement by high water flows, and also conserves energy. Reimers (1957) concluded that winter mortality results primarily from exposure to winter conditions including ice, slush, collapsing snow banks and fluctuating water flows.

In streams with water temperatures declining below 10 C in the fall, the number of emigrating trout and salmon would likely reflect the amount of protective cover and hiding spaces available in the substrate and fish population density. Emigration tapers off in late fall as temperatures decline below 5 C for the winter and the population density declines to within capacity of the winter habitat. I contend that juvenile chinook salmon find rock and rubble substrate an important component of their winter habitat.

LITERATURE CITED

Bjornn, T.C. 1971. Trout and Salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Amer. Fish. Soc. 100:423-438.

____________ 1971 b. Salmon and Steelhead production and yield studies, Lemhi Big Springs Creek, Job No. II a. Salmon and Steelhead yield, escapement, and harvest studies, Lemhi River, Job No. II b. Salmon and Steelhead Investigations, Idaho Dept. of Fish and Game, Boise, 34 p.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100(913): 345-357.

Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. H.R. MacMillan Lectures in Fisheries, Symp. on Salmon and Trout in Streams, Univ. of British Columbia, Vancouver, Canada, Feb. 1968, pp. 153-176.

Hartman, G.F. 1963. Observations on behavior of juvenile brown trout in a stream aquarium during winter and spring. J. Fish. Res. Bd. Canada 20:769-787.

____________ 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*O. kisutch*) and Steelhead trout (*S. gairdneri*). J. Fish. Res. Bd. Canada 22(4):1035-1081.

Miller, W. 1970. Factors influencing migration of chinook salmon fry (*Oncorhynchus tshawytscha*) in the Salmon River, Idaho. Doctoral thesis 1970, Univ. of Idaho, Moscow, Idaho. 80 p.

Reimers, N. 1957. Some aspects of the relation between stream foods and trout survival. Calif. Fish and Game 43:43-69.

Sokal, R. and J. Rohlf. 1969. Biometry. W.H. Freeman and Company, San Francisco. 776 p.

Stuart, T.A. 1957. The migrations and homing behavior of brown trout (*Salmo trutta L.*). Freshw. and Salm. Fish. Res., Scotland 18:27 p.