THE REPRODUCTION OF SALMONIDS IN THE INLETS OF ELK LAKE, MONTANA

by

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of

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VITA

The author, John Andrew Lund, was born May 10, 1942 in Mobridge, South Dakota to George and Ruth Lund. He graduated from Spearfish High School, Spearfish, South Dakota in May 1960. In September 1960, he entered the U. S. Navy and served four years. In September 1964, he enrolled at South Dakota State University at Brookings from which he graduated with a Bachelor of Science degree in Wildlife Biology in January 1969. He was married in June of 1968 to Evelyn Kay Lindhorst of Wecota, South Dakota. From March 1969 through August 1971 he was employed by the South Dakota Game, Fish and Parks Department. In September 1971 he began graduate studies at Montana State University.

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ABSTRACT

The natural reproduction of Arctic grayling, cutthroat trout, rainbow trout and rainbow trout-cutthroat trout hybrids in the inlets of Elk Lake was studied during the spring and summer of 1972 and 1973. Grayling, cutthroat, rainbow and hybrid trout ran in Narrows Creek, while only grayling used Limestone Creek. In Narrows Creek trout runs started May 10, 1972 and May 17, 1973, coinciding with the disappearance of ice from the lake and increased stream flows. Grayling runs started 7 and 10 days later, respectively, during the two years of the study. Total number of spawners entering Narrows Creek in 1972 and 1973 were 520 and 459, respectively. Sixty-four percent of the grayling, 31 percent of the cutthroat trout, 26 percent of the hybrid trout and 30 percent of the rainbow trout tagged during the 1972 spawning run returned to spawn in 1973. The average fecundity of grayling and cutthroat trout sampled was 8,170 and 1,954 eggs per female, respectively. Fry emigrations started in late June each year with the grayling fry preceding trout fry by 12 days. A total of 79.6 percent of the grayling fry and 94.5 percent of the trout fry emigrated downstream between 8:00 p.m. and 8:00 a.m. A total of 618 and 2,082 grayling fry emigrated from Narrows Creek in 1972 and 1973, representing a spawning efficiency of 0.04 and 0.12 percent, respectively. Trout fry production was 7,502 and 2,484 fish in 1972 and 1973, representing a spawning efficiency of 2.5 and 1.2 percent. An estimated 2,797 and 2,432 trout fry also remained in Narrows Creek after the emigration periods in 1972 and 1973, respectively. A total of 196 grayling migrated upstream in Limestone Creek in 1973; however, no fry were produced in the stream. The amount of water flow in the inlets and substrate conditions were considered important factors in controlling fry production.

INTRODUCTION

The Montana Fish and Game Department is attempting to manage populations of game fish on a self-sustaining basis where possible. Although both Arctic grayling *(Thymallus arcticus)* and cutthroat trout *(Salmo clarki)* spawn in the two inlets to Elk Lake, their contribution of fish to the harvest seems to be limited. Local fishermen have described fishing as "good" only after the planting of "catchable" sized trout. In 1971 the Montana Fish and Game Department began a series of investigations to, in part, provide information on how to increase the recruitment of wild fish to the fishery.

This study was part of the overall study and was designed to determine the size and composition of the spawning runs in Narrows and Limestone Creeks and to evaluate the resulting production of emigrating fry. This study was pursued during the spring and summer of 1972 and 1973.

DESCRIPTION OF STUDY AREA

Elk Lake is located in southwestern Montana approximately 40 air kilometers west of the town of West Yellowstone in the Beaverhead National Forest, Beaverhead County. It is situated in the northwest corner of the Centennial Valley in an outlet channel of a large Pleistocene lake which covered the entire valley (Vincent, 1963). The lake lies in an elongate basin at an elevation of 2,035 meters and is flanked by steep hills bearing sagebrush-grassland vegetation on the west and conifers on the east.

The lake has a maximum depth of 21.3 meters and a surface area of 115 hectares (Figure 1). It is moderately eutrophic, having dissolved oxygen levels of less than 1.5 p.p.m. below 11 meters during July and August of 1972 and 1973. Additional characteristics of the lake are given in Table 1.

Narrows and Limestone Creeks are the main tributaries of Elk Lake. The Narrows Creek drainage is 5.6 kilometers long and contains a pond lying 1.1 kilometers above the mouth of the stream (Figure 1). Springs approximately 0.8 kilometers above the pond provide most of the flow, with the stream becoming intermittent above the springs. Flows near the mouth of the creek varied from a high of about 5.0 m^3/min. during May to 0.3 m^3/min. during August. A resort providing lodging for fishermen and hunters is located near the mouth of the creek.

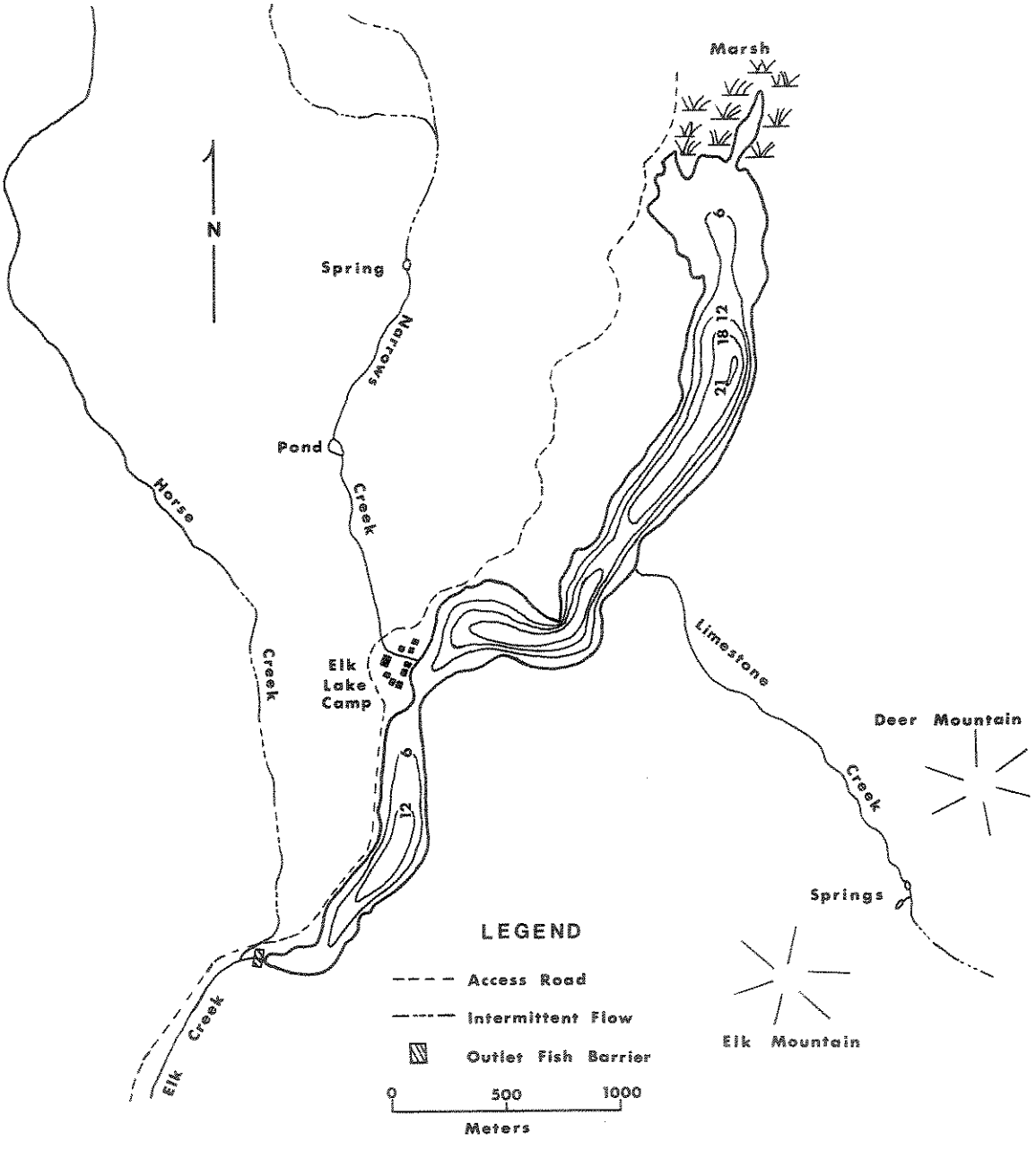

Figure 1. Map of Elk Lake and its tributaries.

TABLE 1. MEASUREMENTS OF SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF ELK LAKE AND ITS INLETS DURING THE SUMMERS OF 1972 AND 1973.

Property	Elk Lake Range (average)	Narrows Creek Range (average)	Limestone Creek Range (average)
pH	7.21-8.60	7.26-7.58	7.85-8.04
Conductivity (micromhos)	175-230 (203)	84-115 (96)	230-260 (243)
Total Hardness (as ppm $CaCO_3$)	73.0-85.4 (79.9)	20.0-32.0 (26.8)	110.0-115.8 (113.6)
Total Alkalinity (as ppm $CaCO_3$)	120.0-204.0 (175.3)	40.0-73.4 (55.8)	155.0-229.8 (204.1)
Water Temperatures (°C) Surface (maximum)	6.2-19.4 (15.3)	5.0-20.6 (15.2)	2.8-20.0 (14.8)
Water Temperatures (°C) Surface (minimum)	3.6-7.2* (5.0)	2.8-14.4 (9.4)	0.6-11.1 (6.1)

*At lake bottom.

The Limestone Creek drainage is approximately 4.8 kilometers long, with flows being maintained by springs 2.0 kilometers from the lake. Flows near the lake varied from about 3.4 m^3/min. during May to 0.3 m^3/min. during July and August. The calculated values of selected chemical properties of Limestone Creek were considerably higher than those of Narrows Creek (Table 1).

Several species of fish are present in Elk Lake and its tributaries. Cutthroat trout have been stocked in the lake annually since 1954. Rainbow trout *(Salmo gairdneri)* were last stocked in 1950; however, a small naturally reproducing population still exists. Rainbow

trout-cutthroat trout hybrids are produced in Narrows Creek and found in the lake. Small numbers of rainbow trout, cutthroat trout and rainbow trout-cutthroat trout hybrids are resident in the pond on Narrows Creek. Lake trout *(Salvelinus namaycush)* are probably indigenous to Elk Lake (Vincent, 1963). However, the present stock may not be the indigenous strain because of hatchery plants made in the area during the 1890's. Arctic grayling were native to most of the lakes and streams of the valley but disappeared from Elk Lake around 1930 (Nelson, 1954). Hatchery plants in 1954, 1955 and 1957 reestablished the species in the lake. The white sucker *(Catostomus commersoni)*, burbot *(Lota lota)* and mottled sculpin *(Cottus bairdi)* are also native to the area and present in the lake. Other species of fish present in the area have been prevented from entering the lake since the mid-1950's when a coarse rock and gravel barrier was placed across the outlet.

examined to determine if they had spawned, and all cutthroat trout were inspected for hatchery marks.

Ovaries were taken from small numbers of grayling, cutthroat trout and rainbow trout-cutthroat trout hybrids captured on spawning runs during both years of the study and preserved in 10 percent formalin. The number of mature eggs in each fish was estimated by weighing the entire egg mass, taking about a 10 percent subsample by weight and counting the number of eggs in the subsample. The total number of mature eggs in the fish was then estimated by proportion. Egg retention was estimated by counting retained eggs stripped from live spent females.

A fry trap was placed about 6 meters downstream from the adult trap on Narrows Creek and operated from June 15 to September 15, 1972 and from June 23 to September 13, 1973. It consisted of a 0.5 x 2.1 meters shute channeling one-third of the stream flow into each of three 0.3 x 0.5 x 0.9 meter boxes screened with twenty-mesh plastic door screen. This trap was checked at 8:00 a.m., 12:30 p.m. and 8:00 p.m. daily. All fry and fingerlings captured were counted and released below the trap. Fry were only identified as either grayling or trout, but fingerlings were identified to species. The total lengths of samples of fry and fingerlings were taken throughout the emigration period.

Fry traps were maintained in Limestone Creek from June 27 to July

22, 1972 and from June 25 to July 23, 1973. During 1972 the trap used had a single 0.3 x 0.6 x 0.6 meter box. The trap used in 1973 had a 0.3 x 0.6 x 1.2 meter box. Both boxes were enclosed with twenty-mesh plastic door screen. Fry captured were identified, counted and released downstream from the traps.

A one-way trap measuring 0.9 x 1.2 meters and covered with galvanized hardware screen having a 0.95 centimeter mesh was placed immediately below the pond on Narrows Creek and operated from May 16 to September 11, 1973. This trap was designed to capture fingerlings and advanced fry moving downstream from the pond. Fish captured in this trap were measured, identified to species when possible, and released into Elk Lake.

During the first week of October each year, estimates were made of the number of trout fry remaining in Narrows Creek from below the pond to its mouth. This portion of the stream was divided into three sections of equal length with approximately 33 meters being electrofished in each section. The fry captured were fin clipped and released. A Peterson estimate was calculated for each subsection following the recapture run. The subsection estimates were combined and the average expanded by proportion to the entire 1.1 kilometers of stream length.

From mid-May to mid-September of 1972 and 1973, the daily temperature variations of Narrows and Limestone Creek were measured with Taylor maximum-minimum thermometers placed near the mouths of the

streams. Rates of flow were calculated for Narrows Creek in 1972 and both streams in 1973 using stream velocities determined by the "float method". Total hardness, total alkalinity and pH measurements were made on water samples using the HACH Model DR-EL Field Kit; and conductivity measurements were taken with a Beckman Solu Bridge. The depths of loose gravel at 18 spawning sites in Narrows Creek below the pond were measured.

RESULTS

Spawning Migrations

Timing of Narrows Creek Runs

Spawning runs started on May 10 in 1972 and on May 17 in 1973, coinciding with the disappearance of ice from the lake. Rainbow trout and rainbow trout-cutthroat trout hybrids dominated the early part of each run with their numbers peaking on May 14, 1972 and May 17, 1973. Cutthroat trout outnumbered the rainbow and hybrid trout in the runs after the first four days each year with their peak numbers occurring on May 20 and May 27, in 1972 and 1973, respectively. Grayling runs started 7 and 10 days later than the rainbow and hybrid runs during the two years of this study, respectively. These findings contrast with Brown (1938), who stated grayling often run in advance of rainbow and cutthroat trout. However, Kruse (1959) reported rainbow trout-cutthroat trout hybrids run one to three weeks prior to grayling in Grebe Lake, Yellowstone National Park.

Rainbow, cutthroat and hybrid trout started their upstream migrations (Figure 2) as stream flows increased from spring runoff. Snyder and Tanner (1960) and Sumner (1952) have reported a similar response by cutthroat trout to increased flows. Grayling began their runs on declining stream flows when daily lake and stream temperatures averaged approximately 7°C. During 1973 the surface temperature of the lake and the average stream temperature were near 10° and above 7°C,

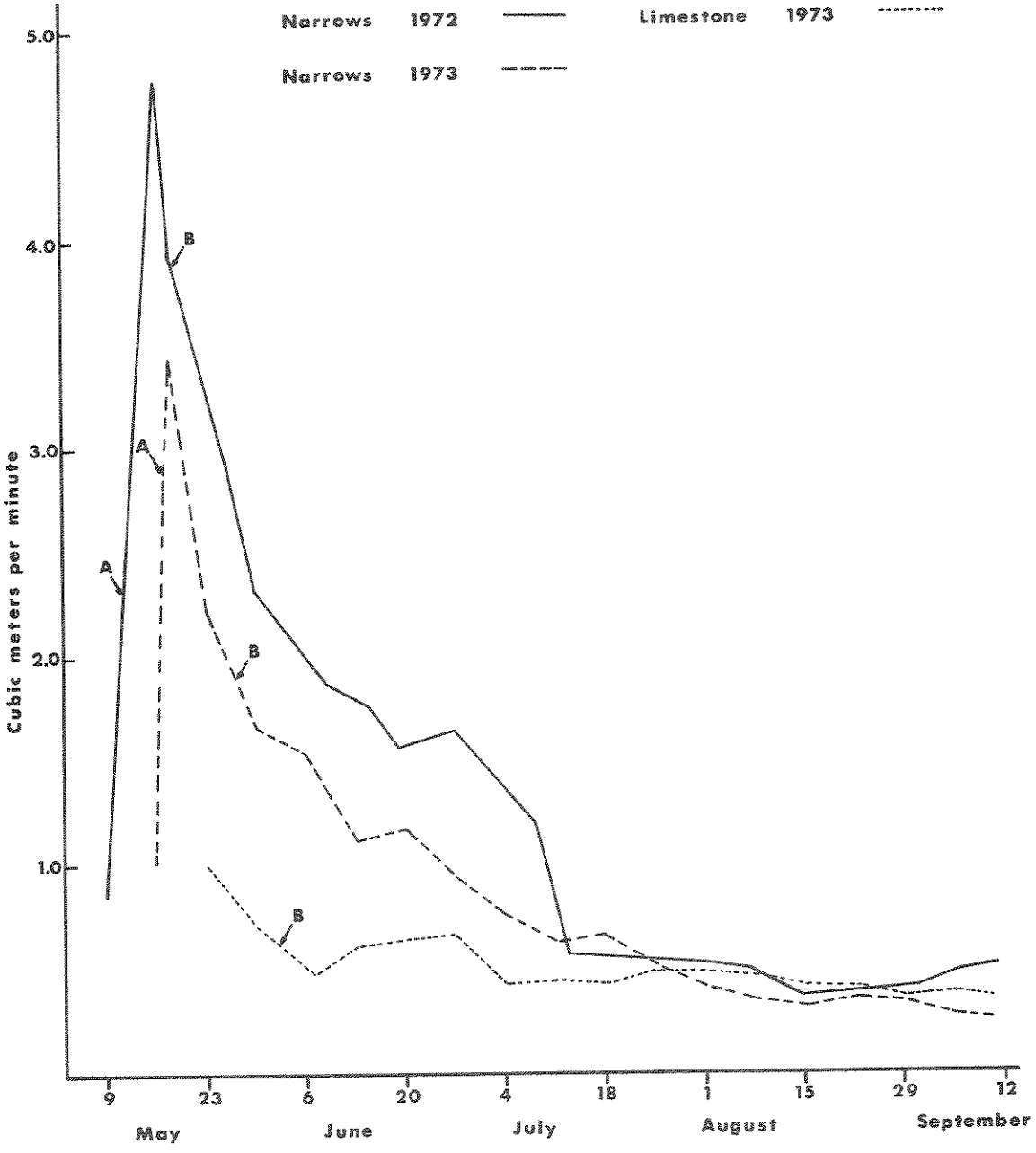

Figure 2. Weekly flows in Narrows and Limestone Creeks showing start of upstream movement by trout (A) and Arctic grayling (B).

respectively, when upstream grayling movement peaked (Figure 3). Kruse (1959) found upstream grayling movements were heaviest when lake temperatures were above 7°C, and Peterman (1972) and Tryon (1947) found most grayling migrated upstream when stream temperatures were between 7-10°C.

Daily average stream temperatures during all upstream migrations ranged from 4.4° to 14.4°C (Figure 3). Trout spawning runs occurred over this entire temperature range and did not show the sharp peaks of migration exhibited by the grayling. However, during the spawning season the upstream movements of both trout and grayling were usually inhibited by sharply lower average daily stream temperatures and accelerated by sharply higher temperatures (Figure 3).

Both grayling and trout moved upstream during the day and night. During the study 60 percent of the trout and 66 percent of the grayling entered Narrows Creek between 8:30 a.m. and 6:30 p.m. In 1973, 64 percent of the grayling and 57 percent of the trout entered the stream between 1:00 and 6:30 p.m.

Characteristics of Narrows Creek Runs

The numbers of fish caught on spawning runs in 1972 and 1973 are presented in Tables 2 and 3, respectively, by sex, with lengths and post-spawning weights. The total number of fish in the 1972 run was about 12 percent larger than in the 1973 run, and the average total length and weight of fish in 1972 was 1.0 centimeter and 0.05 kilograms

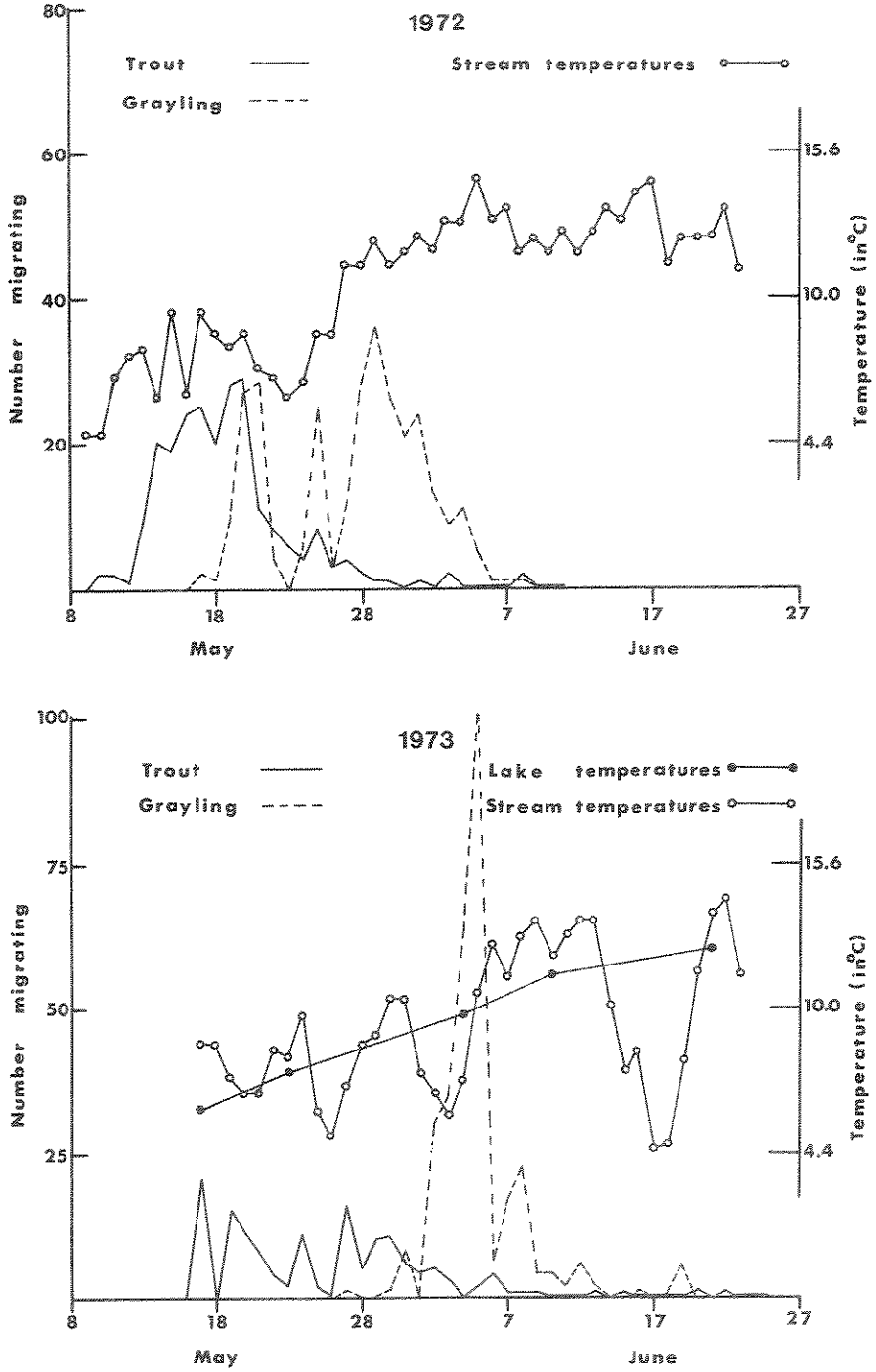

Figure 3. Daily upstream movement of trout and grayling into Narrows Creek, with corresponding average daily stream temperatures and surface temperatures of Elk Lake during 1972 and 1973.

TABLE 2. NUMBERS, TOTAL LENGTHS AND POST-SPAWNING WEIGHTS OF FISH, BY SPECIES AND SEX, CAPTURED ON THE SPAWNING RUN IN NARROWS CREEK, 1972.

Species	Sex	Number Caught	Number Measured	Total Length(cm) Range (average)	Number Weighed	Weight(kg) Range (average)
Grayling						
	female	203	194	29.7-45.0 (38.9)	157	0.25-0.73 (0.51)
	male	95	93	29.5-47.0 (40.1)	93	0.21-0.85 (0.56)
Total (average)		298	287	(39.4)	250	(0.53)
Cutthroat trout--unmarked*						
	female	50	50	34.3-50.3 (43.2)	30	0.45-1.14 (0.81)
	male	20	19	38.1-48.8 (43.9)	17	0.65-1.11 (0.88)
Total (average)		70	69	(43.4)	47	(0.83)
Cutthroat trout--marked (hatchery)						
	female	62	59	34.0-49.3 (43.4)	39	0.46-1.12 (0.85)
	male	35	34	35.3-48.5 (44.2)	34	0.56-1.27 (0.87)
Total (average)		97	93	(43.7)	73	(0.86)
Rainbow-cutthroat trout hybrids						
	female	21	21	40.9-54.4 (48.5)	21	0.54-1.50 (1.08)
	male	14	14	30.7-52.1 (46.5)	14	0.31-1.38 (1.02)
Total (average)		35	35	(47.8)	35	(1.06)
Rainbow trout						
	female	13	13	33.5-53.8 (44.2)	13	0.34-1.46 (0.85)
	male	7	7	27.4-47.2 (37.1)	7	0.21-0.91 (0.53)
Total (average)		20	20	(41.7)	20	(0.73)
Grand Total (ave.)		520	505	(41.3)	425	(0.67)

*Includes both wild and unmarked hatchery fish.

TABLE 3. NUMBERS, TOTAL LENGTHS AND POST-SPAWNING WEIGHTS OF FISH, BY SPECIES AND SEX, CAPTURED ON THE SPAWNING RUN IN NARROWS CREEK, 1973.

Species	Sex	Number Caught	Number Measured	Total Length (cm) Range (average)	Number Weighed	Weight (kg) Range (average)
Grayling						
	female	195	195	29.7-43.9 (37.8)	111	0.23-0.66 (0.48)
	male	117	117	30.5-45.7 (38.6)	85	0.25-0.72 (0.48)
Total (average)		312	312	(38.1)	196	(0.48)
Cutthroat trout--unmarked*						
	female	28	28	38.1-50.0 (44.5)	23	0.63-1.12 (0.84)
	male	13	13	41.7-57.2 (47.2)	9	0.70-1.34 (0.89)
Total (average)		41	41	(45.5)	32	(0.85)
Cutthroat trout--marked (hatchery)						
	female	31	31	36.3-50.3 (44.7)	29	0.58-1.14 (0.78)
	male	20	20	38.6-49.0 (43.4)	19	0.57-1.05 (0.79)
Total (average)		51	51	(44.2)	48	(0.79)
Rainbow-cutthroat trout hybrids						
	female	24	23	39.9-54.9 (48.3)	23	0.54-1.44 (0.95)
	male	16	16	30.0-54.4 (41.4)	16	0.26-1.29 (0.69)
Total (average)		40	39	(45.5)	39	(0.87)
Rainbow trout						
	female	13	13	37.1-52.8 (45.2)	11	0.48-1.18 (0.79)
	male	2	2	34.0-41.9 (38.1)	2	0.41-0.59 (0.50)
Total (average)		15	15	(44.2)	13	(0.74)
Grand Total (ave.)		459	458	(40.3)	328	(0.62)

*Includes both wild and unmarked hatchery fish.

greater, respectively, than in 1973.

In 1972 and 1973 grayling made up 57 and 68 percent, respectively, of all adults moving upstream. Grayling comprised a greater proportion of the 1973 run because 14 more grayling and 61 fewer of other species ran in 1973 than in 1972.

Grayling females outnumbered males in the runs by a ratio of 2.1:1.0 and 1.7:1.0 in 1972 and 1973, respectively. Females, however, may not outnumber males in the population. Peterman (1972) found a female to male ratio of 2.9:1.0 for grayling spawning in the primary inlet of Lake Agnes. However, he found a significantly lower ratio of females to males in the lake. He attributed the difference between ratios obtained in the stream and the lake to antagonistic behavior between males at the mouth of the inlet which may have prevented some of them from entering the stream. In this study grayling were also noted to congregate at the mouth of Narrows Creek before moving upstream, but interaction between males could not be observed because of the high turbidity of the water.

The average total length and weight of grayling in the runs declined by 1.3 centimeters and 0.05 kilograms from 1972 to 1973, respectively. Males were 1.5 centimeters shorter and 0.08 kilograms lighter, and females were 1.0 centimeter shorter and 0.04 kilograms lighter in 1973 than in 1972. During each year the average total length of males was greater than females.

Cutthroat trout made up the second largest component of each run. They accounted for 32 and 20 percent of the runs in 1972 and 1973, respectively, and declined by 75 fish the second year.

Cutthroat trout females outnumbered males by a ratio of 2.0:1.0 in 1972 and 1.8:1.0 in 1973. Snyder and Tanner (1960) and Sumner (1952) have also reported more females than males in runs. Snyder and Tanner (1960) have suggested male cutthroat may be more vulnerable to fishing pressure during the spawning season, thus producing more females in the run. During this study, fishing near the mouth of Narrows Creek during the spawning season produced a higher percentage of male cutthroat trout.

The total length of all cutthroat trout in the runs increased 1.0 centimeter from 1972 to 1973, while the average weight decreased by 0.04 kilograms. Males were 0.8 centimeters longer but weighed 0.05 kilograms less in 1973 than in 1972. During 1973 females were 1.3 centimeters longer and 0.03 kilograms lighter than in the 1972 run.

Since 1967, a percentage of the cutthroat trout plants in Elk Lake have been fin clipped (Table 4) so their returns to the creel could be evaluated. Marked cutthroat trout made up 58 and 55 percent of the cutthroat trout runs into Narrows Creek in 1972 and 1973, respectively (Tables 2 and 3).

Selected characteristics of marked cutthroat trout caught in the runs are shown in Table 5. The 1969 plant of subcatchables dominated

TABLE 4. NUMBERS, LENGTHS AND MARKS OF THE CUTTHROAT TROUT STOCKED IN ELK LAKE FROM 1967 THROUGH 1973.

Date of Plant	Number Planted	Percent Marked	Average Total Length When Planted (cm)	Mark (Fin Clip)
6/7/67	1,000	0	15.2	--
10/9/67	4,000	40.0	12.7	Left pelvic
6/21/68	5,736	36.9	22.9	Adipose
9/12/68	12,000	33.3	11.7	Left pectoral
6/23/69	5,015	100.0	24.1	Adipose and right pelvic
10/7/69	6,006	0	12.7	--
10/5/70	19,998	10.4	10.2	Right pelvic
10/5/70	10,005	20.6	12.7	Adipose
7/21/71	20,063	100.0	10.2	Left pelvic
9/6/72	20,020	100.0	10.2	Right pectoral
6/13/73	1,125	100.0	25.4	Adipose
6/13/73	6,858	100.0	17.8	Adipose and right pectoral

TABLE 5. SELECTED CHARACTERISTICS OF MARKED HATCHERY CUTTHROAT TROUT ENTERING NARROWS CREEK DURING 1972 AND 1973.

Year Planted	Age When Planted	Age During Spawning Run	Number in Run	Percent of Run	Total Length(cm) Range (average)
		1972			
1968	0+	4	16	17.6	43.4-49.3 (46.5)
1969	1+	4	69	75.8	35.3-48.5 (43.2)
1970	0+	2	6	6.6	34.0-44.7 (41.1)
Total			91	100.0	
		1973			
1968	0+	5	6	11.8	43.2-50.3 (47.8)
1969	1+	5	27	52.9	36.1-48.8 (43.9)
1970	0+	3	12	23.5	39.4-46.7 (44.2)
1971	0+	2	6	11.8	39.4-45.2 (41.4)
Total			51	100.0	

marked cutthroat trout runs during 1972 and 1973; however, their number and percentage decreased in 1973. The decline of the 1968 and 1969 plants and the absence of four year old hatchery fish in the 1973 run (Table 5) may account for the lower numbers of cutthroat migrating in 1973.

Unmarked cutthroat trout consisted of wild trout and hatchery fish which were not marked during the years 1967-1970 (Table 4). This group made up 42 and 45 percent of the cutthroat trout runs in 1972 and 1973, respectively. However, their numbers decreased by 29 fish between the two years (Tables 2 and 3). The decrease in the number of unmarked cutthroat trout was proportional to the decrease in marked hatchery fish and was probably due to the decline of unmarked hatchery cutthroat trout planted in 1968 and 1969 (Table 4).

Although the number of hybrid trout in the run increased by 13 percent from 1972 to 1973 and the number of rainbow trout decreased by 25 percent, their combined numbers remained constant over the two years. Since rainbow trout are not presently stocked, their numbers should continue to decrease in future years.

The average time migrating adults spent in Narrows Creek was estimated by the following procedure. Fish entering and leaving the stream were counted daily. One fish remaining in the stream for one day constituted one fish-day. Total fish-days divided by total number of fish was used to give an estimate of the average length of time a

fish stayed in the stream. During both years males stayed longer in Narrows Creek than females (Table 6). Males may have made up for their

TABLE 6. ESTIMATED AVERAGE NUMBER OF DAYS SPENT IN NARROWS CREEK BY MALE AND FEMALE CUTTHROAT TROUT AND ARCTIC GRAYLING.

Species	Year	Average Stay in Stream (Days) Males	Females
Arctic grayling	1972	14.3	11.7
	1973	10.9	8.5
	Average	12.6	10.1
Cutthroat trout	1972	14.8	10.2
	1973	20.6	10.8
	Average	17.7	10.5

lack of numbers by staying longer and mating with more than one female. Smith (1941) found male cutthroat trout readily spawned with more than one female.

Mortality of adult fish occurred while they were in Narrows Creek on their spawning runs. Grayling losses accounted for 3.7 and 29.8 percent of the total upstream migration in 1972 and 1973, respectively. Trout losses were 3.2 percent in 1972 and 8.8 percent in 1973. Some of the fish seemed to die from exhaustion each year. However, in 1973 a lower stream flow allowed an increase in predation to occur.

A total of 183 (64 percent) grayling, 50 (31 percent) cutthroat trout, 9 (26 percent) hybrid trout and 6 (30 percent) rainbow trout tagged during the spawning run in 1972 returned again in 1973. An associated creel census on Elk Lake revealed an estimated 46 percent of

the cutthroat trout tagged on the spawning run in 1972 were taken by fishermen during that summer. An additional 11 percent were caught by fishermen in May of 1973 before and during the spawning run. Only an estimated five percent of the tagged grayling were taken by fishermen between the 1972 and 1973 spawning runs, with the remaining loss probably due to natural mortality.

Timing of Limestone Creek Runs

No spawners were trapped here in 1972. However, adult grayling, the only species found using the stream, were seen in the stream from May 31 to June 11, 1972 with a maximum of 31 fish being counted on June 4. In 1973 upstream migrations occurred from June 2 to June 14, with the peak movement taking place on June 4 when the average stream temperature was 7.2°C and the surface lake temperature was 9.7°C (Figure 4). The upstream movement in Limestone Creek during 1973 started 6 days later than the Narrows Creek grayling run. The delay may have been caused by the lower average stream temperatures found in this stream.

Male and female grayling averaged less than one day in this stream. These grayling exhibited a daily movement into and out of the stream similar to those found by Bishop (1971) and Tryon (1947). Most of the fish entered the inlet during the afternoon when water temperatures were maximum and then attempted to leave again in the evening as water temperatures decreased. Only a few females were able to complete

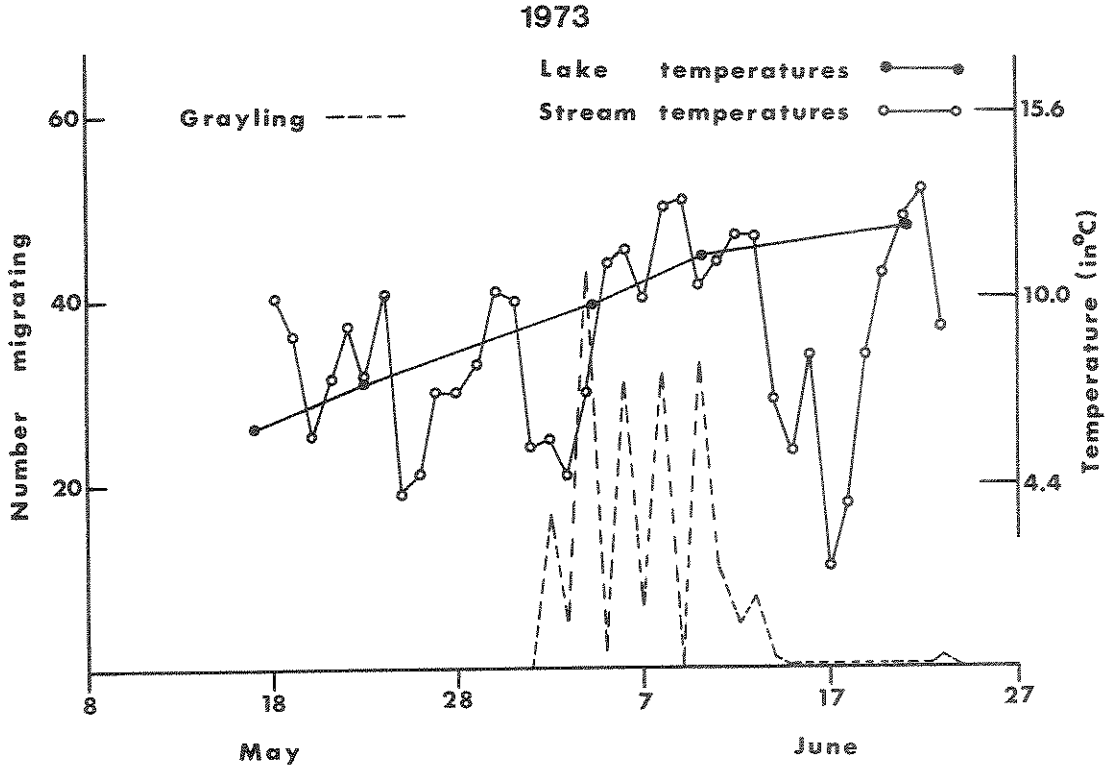

Figure 4. Daily upstream movement of grayling into Limestone Creek, with corresponding average daily stream temperatures and surface temperatures of Elk Lake in 1973.

spawning in the stream. This may have been caused by trapping operations which delayed fish from moving upstream when afternoon temperatures were suitable.

Characteristics of Limestone Creek Runs

The number of grayling caught on the spawning run in 1973 is presented in Table 7.

TABLE 7. NUMBERS, TOTAL LENGTHS AND WEIGHTS OF GRAYLING, BY SEX, CAPTURED ON THE SPAWNING RUN IN LIMESTONE CREEK IN 1973.

Species	Sex	Number Counted	Number Measured	Total Length(cm) Range (average)	Number Weighed	Weight(kg) Range (average)
Artic grayling						
	female	102	102	29.7-43.4 (36.1)	100	0.25-0.83 (0.49)
	male	94	94	30.2-50.0 (36.1)	93	0.24-0.69 (0.43)
Total (average)		196	196	(36.1)	193	(0.46)

Grayling females outnumbered males by a ratio of only 1.1:1.0 compared with the 1.7:1.0 ratio found for grayling in Narrows Creek. The average length of grayling in this run was 2.0 centimeters shorter than that found for the Narrows Creek run during 1973. However, there was a higher proportion of younger fish entering Limestone Creek that year. Only three adult fish died in the stream in 1973.

Age and Growth

Age and growth determinations were made from scales taken primarily from grayling and trout captured on spawning runs during 1972 and 1973. Back calculations of growth were made on projected scales assuming a linear relationship between body length and anterior scale radius with the intercept at zero.

Scales were taken from about 87 percent of the grayling running in 1972 and 1973. In Narrows Creek grayling in age groups IV and V dominated the run in 1972, while age III fish were the most numerous in 1973 (Table 8). The oldest grayling in these two runs were two males, age VII, that measured 45.7 and 47.0 centimeters in total length. In Limestone Creek most of the migrating grayling in 1973 were in age groups II and III. Since both streams had good numbers of age III grayling migrating in 1973, it may indicate a relatively strong year class was produced in 1970.

In Alaska and northern Canada grayling seldom reach sexual maturity before age VI (Reed, 1964; Bishop, 1971). However, in the southern portion of their range grayling usually mature at age III, with a few maturing at age II (Nelson, 1954; Peterman, 1972). At Elk Lake some of the grayling were sexually mature at age II and made spawning runs (Table 8). However, more age III than age II spawners were present each year indicating that a larger portion of the population matures at age III.

The growth rates of grayling, by sex, from Narrows Creek in 1972 and 1973 and Limestone Creek in 1973 were similar (Table 8). Calculated growth rates for males and females were similar to age I. From ages II-VI, however, males were 1.0-1.5 centimeters longer than females. Reed (1964) found that immature male and female grayling had similar growth rates in Alaska, and that mature males grew faster than mature females.

The average growth rate (sexes combined) from Elk Lake exceed those found by Nelson (1954), Kruse (1959), Peterman (1972) and Brown (1943) for other populations in this region. However, the pattern of rapid growth the first two years of life, followed by a greatly reduced rate after maturity, was similar to those found by the above authors.

The age structure was determined for 84 and 86 percent of all cutthroat trout, rainbow trout and rainbow trout-cutthroat trout hybrids entering Narrows Creek in 1972 and 1973, respectively (Table 9). Age IV and V cutthroat trout in 1972 and 1973, respectively, dominated the run and were predominately hatchery fish.

Male trout of all species first became sexually mature at age II and female trout at age III. However, some females may not mature until age IV, as indicated by the larger number of female cutthroat and hybrid trout migrating at age IV. The highest number of rainbow trout females migrated at age III each year, which may mean they mature sooner

TABLE 9. AGE COMPOSITION, BY SEX, OF ADULT CUTTHROAT, RAINBOW AND HYBRID TROUT TRAPPED IN NARROWS CREEK, 1972 AND 1973. (M = male; F = female)

Age Group	Species	Number Migrating 1972 M	1972 F	1973 M	1973 F
Cutthroat Trout					
II		6	0	6	0
III		3	4	2	12
IV		36	82	5	13
V		4	5	15	28
Total		49	91	28	53
Rainbow Trout					
II		3	0	1	0
III		1	4	1	5
IV		1	3	0	2
V		2	2	0	3
Total		7	9	2	10
Rainbow Trout-Cutthroat Trout Hybrids					
II		2	0	4	0
III		1	4	4	5
IV		7	12	2	7
V		3	5	0	7
VI		0	0	0	1
Total		13	21	10	20

than cutthroat or hybrid trout.

Growth rates were calculated from scales and lengths taken from 177 cutthroat trout, 53 rainbow trout and 170 rainbow trout-cutthroat trout hybrids (Table 10). Scales were collected during creel checks and from spawning fish in 1972 and 1973. Since the calculated growth rates of taxa taken in 1972 and 1973 were similar, data were combined. Hybrid trout showed the highest rate of growth, followed by rainbow

TABLE 10. AVERAGE CALCULATED TOTAL LENGTHS AT EACH ANNULUS FOR CUTTHROAT, RAINBOW AND HYBRID TROUT COLLECTED DURING 1972 AND 1973.

Age Group	Number	Average Total Length	Calculated Length in cm at each Annulus					
			1	2	3	4	5	6
Cutthroat Trout								
I	5	12.2	8.4					
II	20	32.5	11.4	24.6				
III	64	39.6	10.4	21.3	36.8			
IV	69	43.4	10.9	24.1	36.1	43.2		
V	19	47.5	9.7	18.8	34.8	43.2	47.5	
Rainbow Trout								
I	4	11.7	8.4					
II	14	33.3	8.4	27.9				
III	17	41.1	8.1	25.4	38.9			
IV	9	45.7	7.4	22.6	37.3	44.7		
V	9	48.3	6.6	16.0	33.3	43.3	48.0	
Rainbow Trout-Cutthroat Trout hybrids								
I	13	12.2	8.1					
II	46	35.1	8.4	29.5				
III	56	42.4	8.4	23.1	40.1			
IV	38	48.8	8.4	23.4	40.4	48.5		
V	16	51.1	7.1	19.1	36.1	46.5	50.8	
VI	1	51.3	6.1	21.6	36.3	45.5	48.3	51.1

trout and then cutthroat trout. The higher rate of growth by hybrid trout may be due to "hybrid vigor". Because data from the fishermen are included in Table 10, it does not reflect the relative abundance of age groups in the spawning population.

Egg Production

A total of 12 grayling and 10 cutthroat trout females were collected for counts of mature eggs. Specimens were selected randomly within each of three size groups which spanned the size range of the spawning population. The range and average number of eggs per sample group are given in Table 11.

TABLE 11. RANGE AND AVERAGE NUMBER OF MATURE EGGS PER FEMALE BY TOTAL LENGTH GROUPS. (CI = 95% Confidence Interval)

Species	Length Groups of Fish (cm)	Average Length of Sample Fish (cm)	Number of Eggs Range	Number of Eggs Mean (CI)
Arctic Grayling				
	29.7 to 35.5	33.3 (4)*	4,600-7,519	5,970 (4,774-7,166)
	35.6 to 40.5	37.6 (5)	7,805-10,634	9,162 (8,122-10,202)
	40.6 to 45.0	42.7 (3)	7,407-13,365	9,454 (5,616-13,292)
	Average	37.3 (12)	4,600-13,365	8,170 (6,822-9,518)
Cutthroat Trout				
	34.0 to 41.9	39.4 (3)	1,326-1,904	1,607 (1,279-1,935)
	42.0 to 46.9	44.7 (4)	1,824-2,275	2,072 (1,890-2,254)
	47.0 to 50.3	47.2 (3)	1,911-2,540	2,144 (1,754-2,534)
	Average	43.9 (10)	1,326-2,540	1,954 (1,744-2,164)

*Sample size

The average numbers of eggs found in the two smaller size groups of grayling were similar to those found by other investigators in fish of comparable length. Fifteen grayling from the Mackenzie River in Canada having a mean total length of 38.6 centimeters averaged 9,670 eggs each (Bishop, 1971). Brown (1938) found that nine grayling from Rogers Lake, Montana averaging 34.7 centimeters contained an average of 5,828 eggs. Two groups of cutthroat from nearby Henrys Lake, Idaho with mean total lengths of 38.6 and 49.3 centimeters averaged 1,577 and 1,914 eggs, respectively (Irving, 1956). These egg counts were similar to the first and last sample groups collected here (Table 11).

Potential egg production and egg deposition were estimated for each species in Table 12. The total number of female grayling and cutthroat trout in each of the three length intervals (Table 11), multiplied by the average number of eggs found for that size group, gave the number of eggs carried upstream by that group. Potential egg production for each species was then computed by totaling the estimated egg production of the three size groups.

Egg deposition (Table 12) equals potential egg production minus the number of eggs in fish that failed to spawn. Egg retention by spent females was considered low enough to be disregarded in figuring egg deposition. In 189 spent females it was found to be less than one percent. The average number of eggs retained by each species was determined for grayling, cutthroat, rainbow and hybrid trout and was

TABLE 12. ESTIMATED POTENTIAL EGG PRODUCTION AND EGG DEPOSITION OF GRAYLING AND TROUT IN THE INLETS OF ELK LAKE, 1972 AND 1973. (CI = 95% Confidence Interval)

Inlet	Fish Species	Number of Females Moving Upstream	Potential Egg Production(CI)	Number of Females Spawning	Egg Deposition(CI)
Narrows			1972		
	Grayling	194	1,727,060 (±395,456)	170	1,510,636 (±342,204)
	Cutthroat	112	214,007 (±29,282)	91	173,534 (±23,814)
	Hybrids	21	51,450	17	41,650
	Rainbow	13	31,200	12	28,800
Narrows			1973		
	Grayling	195	1,743,130 (±308,978)	104	929,960 (±165,524)
	Cutthroat	59	117,532 (±14,986)	53	105,493 (±13,540)
	Hybrids	23	56,350	23	56,350
	Rainbow	13	31,200	9	21,600
Limestone			1973		
	Grayling	102	848,944 (±146,822)	6	55,556 (±11,836)

11.5, 13.0, 17.6 and 4.1 eggs, respectively.

Only two hybrid trout were collected. They averaged 53.6 centimeters in total length and contained an average of 2,712 eggs. Since migrating hybrid females averaged only 48.3 centimeters in 1972 and 1973, egg production was estimated by proportion to be 2,450 eggs per fish. No rainbow trout females were taken because of low numbers migrating. Rounsefell (1957) found that rainbow trout averaging 43.9

centimeters total length contained 2,400 eggs on the average. On this basis rainbow females in the Elk Lake runs were estimated to have 2,400 eggs since they also averaged 43.9 centimeters in total length (Table 12).

Production of Fry and Fingerlings

Fry

The patterns of emigration of fry leaving Narrows Creek in 1972 and 1973 are presented in Figure 5. A total of 8,120 and 4,566 fry were caught leaving the stream from June 22 to September 15, 1972 and from June 25 to September 12, 1973, respectively.

A total of 618 and 2,082 grayling fry were captured leaving the inlet in 1972 and 1973, respectively. Their periods of emigration were from June 22 to July 4, 1972 and from June 25 to July 28, 1973. The peak number of emigrating grayling fry occurred 29 days after the peak upstream movements of the adult grayling in 1972 and 23 days later in 1973. About 98 percent of the grayling fry moved downstream within the first 10 days of the emigration period each year.

A total of 7,502 and 2,484 trout fry were also caught leaving Narrows Creek from July 4 to September 15, 1972 and from July 7 to September 12, 1973, respectively. A few advanced fry were still emigrating when the trap was removed in mid-September of each year. Emigration of trout started 12 days after grayling fry began their

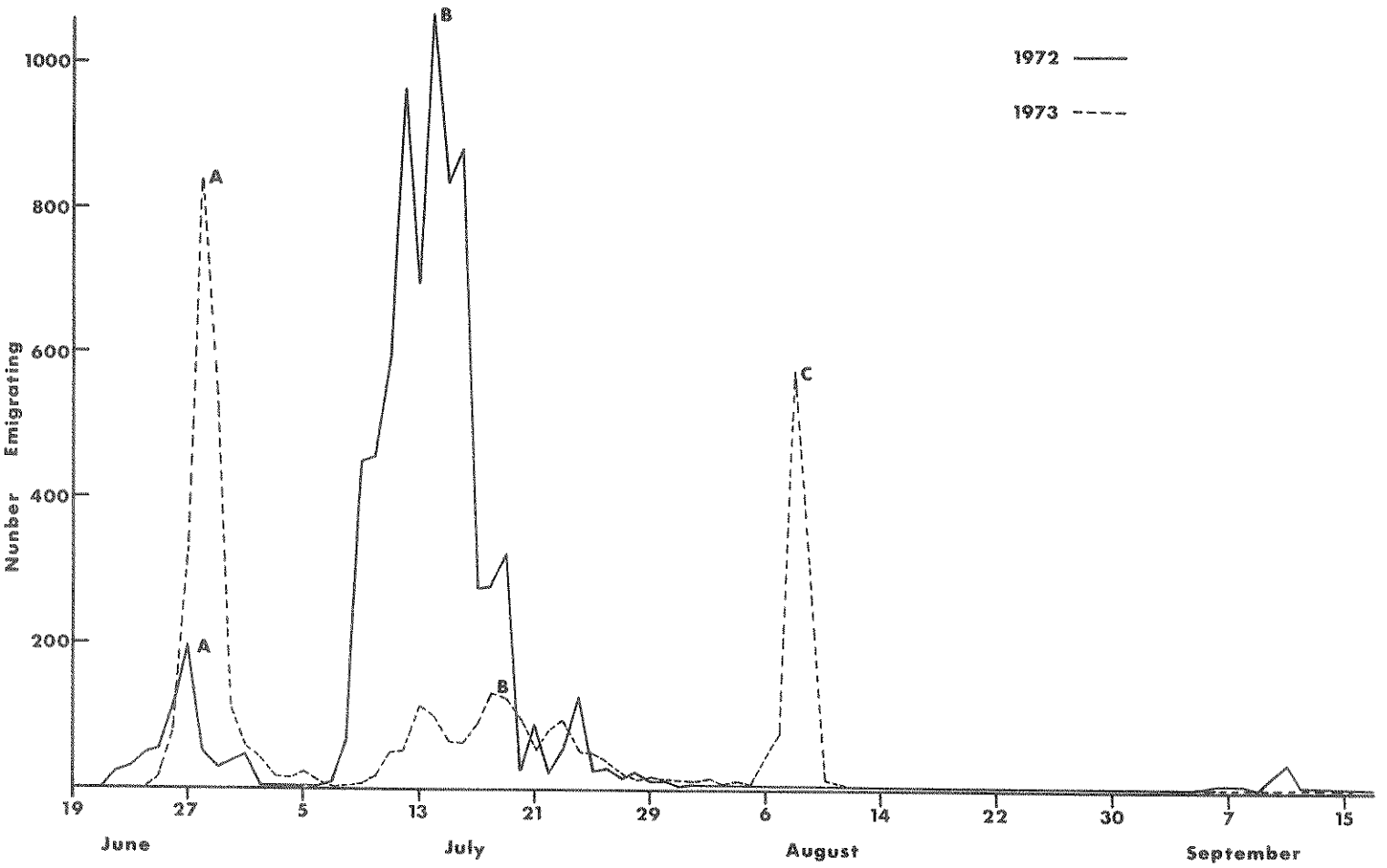

Figure 5. Number of fry emigrating from Narrows Creek in 1972 and 1973. A = peak of grayling fry movements, B = peak of trout fry movements, and C = peak movement of trout caused by dewatering of stream.

downstream movements each year. The peak of the trout fry movements was 55 days after the peak upstream migration of adult trout in 1972 and 57 days later in 1973. During 1973 a second emigration peak (Point C, Figure 5) of trout fry occurred on August 8. This peak occurred when there was a sharp decrease in water flow in the stream caused by a beaver damming the pond outlet. Benson (1960) found a similar increase in cutthroat fry emigrations from Arnica Creek when water levels decreased in that stream. There seemed to be no relationship between stream temperatures and the number of fry emigrating downstream each day.

Light appeared to inhibit the downstream movement of both grayling and trout fry. Peak downstream movement occurred shortly after midnight each night. Grayling and trout fry emerging during daylight hours gathered and remained in the quiet water along the banks and in the slow moving water near the bottom of the stream, respectively. During the two year study, 94.5 percent of the trout fry and 79.6 percent of the grayling fry moved downstream between 8:00 p.m. and 8:00 a.m.

Weekly measurements of the length of emigrating fry in Narrows Creek are given in Table 13. Significant increases in the average size of grayling and trout fry leaving the stream did not occur until after the peak emigration period each year (Figure 5 and Table 13). Snyder and Tanner (1960) reported this same characteristic in

TABLE 13. AVERAGE TOTAL LENGTH OF FRY COLLECTED DURING PERIODS OF THEIR DOWNSTREAM MOVEMENT IN NARROWS CREEK.

Sampling Dates	Species	1972 Sample Size	1972 Average Total Length (cm)	1973 Sample Size	1973 Average Total Length (cm)
June 24-30	Grayling	16	1.4	--	---
July 1-7	"	2	1.7	2	1.8
8-14	"	--	---	3	2.4
22-28	"	--	---	7	4.2
July 8-14	Trout*	40	2.5	3	2.5
15-21	"	40	2.6	4	2.6
22-28	"	22	2.6	17	3.7
29-Aug. 4	"	4	2.8	31	3.8
Aug. 5-11	"	2	3.3	30	4.3
12-18	"	--	---	17	5.2
19-25	"	2	3.9	16	5.7
26-Sept. 1	"	--	---	6	6.2
Sept.2-8	"	--	---	6	5.6
9-15	"	6	5.2	3	5.7

*Includes all cutthroat, rainbow and hybrid trout fry.

their study. Trout fry sampled in 1973 showed a faster growth rate than those collected in 1972. This was probably due to the smaller number of trout fry produced in 1973, having proportionately more food available in the stream.

Some trout fry remained in Narrows Creek after the emigration period each year. Population estimates were made on October 1, 1972 and on October 6, 1973 to determine the number of fry remaining in the stream. The three sample subsections yielded a total estimate of 269±30 fry remaining in 1972 and 217±37 fry in 1973. By expansion,

the number of fry left in the 1.1 kilometers of stream below the pond was estimated at 2,797 for 1972 and 2,432 for 1973.

A few of the trout fry counted leaving the stream in 1972 may have been produced above the pond. A total of 57 trout fry averaging 5.1 centimeters were trapped leaving the pond and entering the stream below the pond between July 25 and August 31, 1973.

Only 79 emigrating grayling fry were captured leaving Limestone Creek between June 29 and July 9, 1972. However, total production for 1972 was estimated at 158 fry since only half of the stream's flow ran through the trap. Although an estimated 55,500 grayling eggs (Table 12) were deposited in 1973, no fry were caught during trapping operations.

Fingerling

The numbers, sizes and species composition of fingerling trout caught emigrating downstream in Narrows Creek from June 16 to September 14, 1972 and from June 24 to August 27, 1973 are given in Table 14. Additional fingerlings may have emigrated prior to fry trap installation both years. A total of 63 fingerlings were caught moving out of the pond to the stream below from May 17 to July 17, 1973. Since Narrows Creek freezes solid in the winter, most, if not all, of the trout fingerlings present in the stream probably come from the pond. No fingerlings were found in Limestone Creek.

TABLE 14. THE SPECIES COMPOSITION, NUMBER AND SIZE OF FINGERLING TROUT CAUGHT EMIGRATING FROM NARROWS CREEK IN 1972 AND 1973.

Species	1972		1973	
	Number Emigrating	Average Total Length (cm)	Number Emigrating	Average Total Length (cm)
Cutthroat	57	10.9	24	9.9
Rainbow	20	9.1	34	10.7
Hybrid	85	10.2	81	10.4
Species not determined	111	8.1	--	---
Totals	273	9.9	139	10.4

Spawning Efficiency

Spawning efficiency (Snyder and Tanner, 1960) is the number of emigrating fry produced, in percent, from the total number of mature eggs contained in all females making the spawning run. The estimated spawning efficiencies computed for fish in the two inlets of Elk Lake are presented in Table 15. The calculated efficiencies for grayling in this study were at best one-twentieth of those found in grayling using the inlets of Grebe Lake (Kruse, 1959). Trout spawning efficiencies ranged from one-half to one-sixth of those found by other authors. Cutthroat trout spawning in the inlets of Trappers Lake had spawning efficiencies averaging 6.2 percent (Snyder and Tanner, 1960). In experiments on cutthroat trout conducted at Convict Creek, California, Smith (1947) found spawning efficiencies of 16 and 15 percent for emigrating fry.

TABLE 15. ESTIMATED SPAWNING EFFICIENCIES IN THE TWO INLET STREAMS TO ELK LAKE DURING 1972 AND 1973.

	Year	Narrows Creek Grayling	Narrows Creek Trout*	Limestone Creek Grayling
Number of females	1972	194	146	---
	1973	195	95	102
Potential egg production	1972	1,727,060	296,657	---
	1973	1,743,130	205,082	848,944
Number of fry	1972	618	7,502	---
	1973	2,082	2,484	0
Spawning efficiency (percent)	1972	0.04	2.53	---
	1973	0.12	1.21	0

*Includes all cutthroat, rainbow and hybrid trout.

Physical Factors Affecting Fry Production

The amount of water available to the stream during the spawning season and the quantity of suitable gravel available for spawning fish seem to significantly influence the production of fry in Narrows Creek. There appears to be a direct relationship between the amount of over-winter precipitation and snow-water available in the spring and fry production the following summer (Table 16) in this stream. Several authors, however, have found the opposite relationship in their studies. Farnes and Bulkley (1964) and Drummond and McKinney (1965) found negative relationships between cutthroat trout year-class strength and fry production, respectively, with the amount of snow-water available. However, Drummond and McKinney (1965) postulated,

TABLE 16. TOTAL NUMBER OF GRAYLING AND TROUT FRY PRODUCED IN NARROWS CREEK IN RELATION TO OVERWINTER SNOW-WATER LEVELS AND PRECIPITATION IN 1971, 1972 AND 1973.

	Year		
	1971	1972	1973
Number of fry produced	23,374*	8,120	4,566
Precipitation (cm) November through April**	31.5	19.7	13.3
Snow-water (cm) available on April 1***	52.3	40.0	23.9

*Fry numbers reported by Peterson (1972).

**Precipitation measured at Red Rock Lakes Refuge, Lakeview, Montana, 16 kilometers southwest of the study area.

***At station near Lakeview, Montana; Soil Conservation Service Report.

from limited data, that fry recruitment could assume a direct relationship below and an inverse relationship above, a threshold point in water flows.

The availability of productive spawning sites seems limited in Narrows Creek. Trout spawned over the entire stream section from below the pond to the lake, while grayling used the lower two-thirds of the section. However, in 1973 trout fry emerged only in the upper one-half of the section and grayling fry only in the middle one-third. Neither emergent trout nor grayling were found in the lower one-third section of stream. The depth of loose spawning gravel at six sites in each one-third of the stream, upper, middle and lower, was 10-20, 8-13 and 0-8 centimeters, respectively. Only those sections with over 8 centimeters of loose gravel had successful production of fry.

DISCUSSION

The recruitment of adult grayling and cutthroat trout in Elk Lake appears to be controlled by the production of fry in Narrows Creek, which seems to be dependent on the number of suitable spawning sites available and the stream flow present during the spawning season. Much of the potential fry production is presently being lost due to the lack of adequate substrate for spawning in the lower one-third of Narrows Creek and the multiple use of spawning sites in other sections of stream which causes dislodgement of previously laid eggs. The addition of suitable sized gravel at proper locations could eliminate or greatly reduce the losses of production from both of the above factors.

It appears a minimum stream flow of approximately 2.0 m^3/min. is needed to allow adult fish access to the uppermost spawning areas. A flow of a similar size is probably also necessary throughout the period of incubation to sustain the intergravel water flow needed for successful egg development. Fry production appears to be dependent on the availability of the previous winter's snow-water. Fry production during years when the overwinter snow-water levels are low might be increased by increasing the height of the existing dam at the pond so that some of the early runoff could be stored and used during the later stages of the spawning run and during incubation.

Limestone Creek appears to have only marginal potential for fry production. Low stream flows may be a major factor in limiting grayling reproduction, with limited production of fry occurring only during years of above average spring runoff. There appears to be no practical way of increasing the water flows in this stream.

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