THE GERRARD RAINBOW TROUT OF KOOTENAY LAKE, BRITISH COLUMBIA - A DISCUSSION OF THEIR LIFE HISTORY WITH MANAGEMENT, RESEARCH AND ENHANCEMENT RECOMMENDATIONS

by

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DEDICATION

This report is dedicated

to the late

Gil Palmer

ACKNOWLEDGEMENTS

The Gerrard rainbow trout have been important to the people of the Kootenays since 1912 when a hatchery and egg collecting station first began operating upon these fish. Since then, many persons have devoted significant portions of their lives to the study and maintenance of these fish and the author is thankful for this opportunity to express his gratitude to them. Although many names have been lost from earlier times, the hard work of such fishery officers as J.N. Hames, G.J. Morgan, W. Reid, J.F. Thompson, T.T. White, and particularly, L. Ogilvie who drowned working in the Lardeau River in 1919, is appreciated.

More recently, Pete Ewart, Ted Hunter, Rod McCrae, Gil Palmer, Jimmy Robinson and Ted Rutherglen have played important roles in furthering our understanding of these fish. This document is dedicated to Gil Palmer who was the official guardian of the Gerrard fish from 1959 - 1975. During the spawning seasons of each of these years, Gil, and usually his wife, Glady, resided at the spawning grounds looking after these fish, but always found time to expound upon them to curious passers by.

This report represents the amalgamation of results from a number of studies and it is with sincere appreciation that A. Acara, H. Andrusak, G.F. Hartman and T.G. Northcote are acknowledged for their contributions.

A number of others deserve recognition. C. Houston provided much of the material which enabled the historical section to be researched. At the field and laboratory level assistance has been received from D. Crowley, L. Fleck, G. Northcote, L. Scottnicki, S. Steele and C. Wightman. I would also like to thank D. McKay and B. Sanson for typing the report.

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TABLE OF CONTENTS

INTRODUCTION

Located in southeastern British Columbia, Kootenay Lake boasts one of the finest sport fisheries of the province with a net worth of $5.8 million in 1967 (Pearse and Laub, 1969). A number of species including rainbow trout, Dolly Varden char, kokanee, mountain whitefish, burbot and sturgeon are eagerly sought by anglers from all over western North America.

A major attribute of Kootenay Lake is its ability to consistently produce trophy fish. Unusually large rainbow trout, not infrequently over 9 kg, are a special attraction for anglers. Historically, the large rainbow caught in the fishery are thought to have been derived from two stocks of trout, both spawning in restricted portions of the northern inlet to Kootenay Lake. One stock of large rainbow, the Duncan River stock, which spawned in portions of the lower Duncan River upstream from its confluence with the Lardeau River, has been virtually eliminated as a result of the Duncan Dam, completed in 1967. The remaining Gerrard stock spawn only in a short portion of the upper Lardeau River between its origin at Trout Lake and the confluence with its first tributary, Mobbs Creek (Fig. 1). The Gerrard rainbow trout are considered to be genetically isolated from other rainbow in Kootenay Lake (Cartwright, 1961).

The Gerrard stock trout are the subject of this document. Because of their economic and recreational importance, a number of studies have been performed on various aspects of their life history, yet many of the findings remain unpublished. This report serves to amalgamate these results.

STUDY AREA

GENERAL DESCRIPTION

Kootenay Lake is a large oligotrophic lake (Vernon, 1957; Cloern, 1976) approximately 105 km in length. It has a somewhat unusual shape with a northern, southern, and western arm (Fig. 1). The west arm is essentially a widening of the lake's outlet river, the Kootenay. This river joins with the Columbia River approximately 37 km downstream from Nelson at Castlegar. The north and south arms receive the two major inlets to the lake which, when combined with the numerous smaller stream inlets, drain an area of 45,840 km^2 (Cartwright, 1961). The Kootenay River, flowing into the south arm, contributes the bulk of the flow entering Kootenay Lake with a somewhat smaller volume entering the north arm via the Duncan-Lardeau system (Table 1).

Originating at Trout Lake, the Lardeau River flows 65 km downstream to Kootenay Lake (Fig. 1). Trout Lake is similar to Kootenay in that it is oligotrophic (Larkin, 1951). It also serves to provide relatively silt-free water to the upper Lardeau by acting as a settling basin. Along its length the Lardeau is fed by a number of streams of glacial origin. During the summer months each of these streams contributes considerable amounts of silt from both glacial snow melt and erosion (often the result of logging). At a point 13 km upstream from Kootenay Lake, the Lardeau and Duncan River systems join.[1]

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[1]The flow of the Duncan has been regulated since 1966 by the Duncan Dam located several hundred meters above the Lardeau-Duncan confluence.

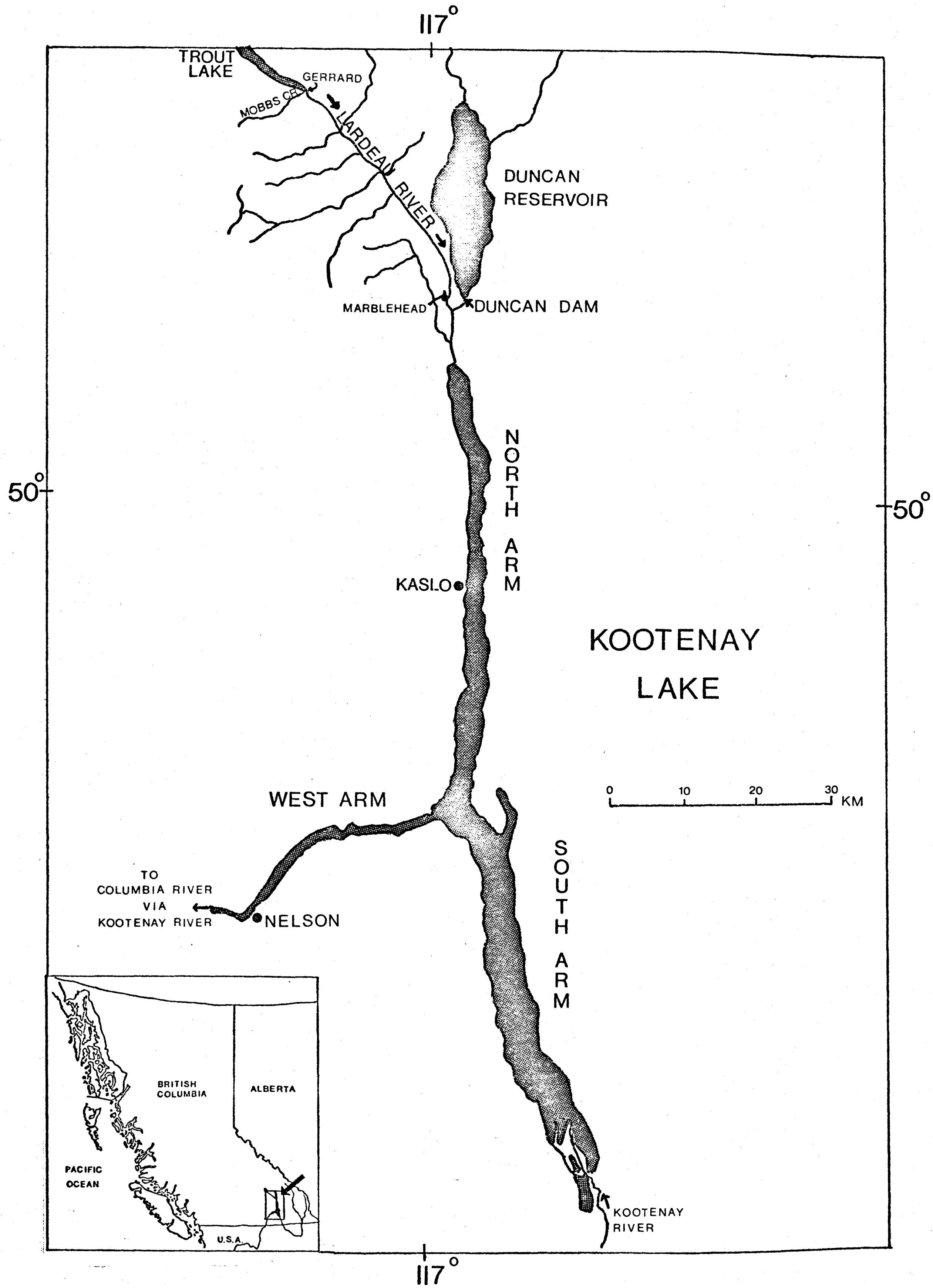

Fig. 1. Location of study area.

Table 1. Mean monthly flows (m^3/sec) of major tributaries to Kootenay Lake over the period 1967 - 1975.

Location	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lardeau River at Marblehead	13	13	14	25	108	227	156	70	37	29	24	17
Duncan River below Lardeau confluence [a]	172	158	70	59	134	251	277	246	150	105	85	202
Kootenai River at Porthill [b]	211	268	254	407	1162	1371	649	315	307	356	337	238
Kootenay River at Corra Linn [c]	472	575	510	505	1370	2363	1504	764	456	519	401	487

[a] bulk of flow entering north arm

[b] bulk of flow entering south arm

[c] Kootenay Lake outlet

GEOLOGICAL CHARACTERISTICS

The geology of the area has been intensively studied by Fyles (1964) and Read (1966). The study region is contained within the Kootenay arc, a curving belt of complexly deformed sedimentary, volcanic, and metamorphic rock extending south from Revelstoke across the U.S. border (Fyles, 1964). This arc has been of economic importance because of its large quantities of silver, lead, zinc, tungsten, gold, and copper.

Kootenay Lake and the Duncan system are contained within the Purcell Trench and bounded to the east by the steeply rising Purcell Mountains (Fulton, 1968). The Lardeau River and Meadow Creek valleys lie to the west of this trench, between it and the Selkirk Mountains. Most valleys of the region, including the Lardeau and Duncan River-Kootenay Lake, have U-shaped cross-sections indicative of their recent glacial history (Rice, 1941) (Fig. 3).

CLIMATE AND VEGETATION

The study area is contained within the interior western hemlock biogeoclimatic zone (Krajina, 1969). Precipitation levels are closely related to elevation. Higher elevations receive in excess of 150 cm per year while most of the region receives between 75 and 100 cm. Summers are relatively warm (mean July temperature = 15-21° C) and winters cool (mean January temperature = 3 to - 11° C) (Krajina, 1969). Annual snowfall ranges between 190-673 cm and usually accounts for more than 25 per cent of the total precipitation.

The interior western hemlock zone (interior wet belt) is characterized by a luxuriant forest similar to that found in the coastal forest zone. Both areas possess as their climax tree the western hemlock *(Tsuga heterophylla)*. Other common trees species include Douglas fir, western red cedar, lodgepole and white pine, western larch, white spruce, northwestern white birch, balsam poplar, and trembling birch (Krajina, 1969; Lyons, 1974).

HISTORICAL PERSPECTIVE

Several Indian bands have lived within the study area since the eighteenth century (Jenness, 1967), and those near Kootenay Lake were dependent largely upon fish and game for their existence (Turney-High, 1941). Northcote (1973) estimates that at the time of their population peak around 1800, these Indians exploited 20,000 trout annually, but, considering the small numbers of natives in the north arm area, it seems unlikely that many of these trout were of Gerrard origin.

The first major influx of Europeans to the West Kootenays occurred in the latter half of the nineteenth century (Northcote, 1973). Reports have been made of "black salmon" weighing up to 18 kg being caught in Kootenay Lake during the 1800's (Sissons, 1943). However, while these "black salmon" were probably recently spawned rainbow trout (Dymond, 1932), it seems unlikely that the fishing pressure exerted was of sufficient intensity to affect stock size.

In the late nineteenth and early twentieth centuries, steamship service on Kootenay Lake was the most frequent mode of transportation. With the completion of the C.P.R. line from Lardeau to Gerrard in 1902 (Fyles, 1964), the Lardeau valley opened up to the white man. It was soon realized that a population of large trout used the outlet of Trout Lake for spawning each spring and in the early 1900's the federal Department of Fisheries decided to construct a hatchery at this outlet. Very little was known of the Gerrard fish in those early days but it seemed logical that they originated from Trout Lake. A sill was laid across Trout Lake at its outlet and a large trap and fence with several holding pens built. Imagine the dismay of the hatchery officers awaiting the spawning run of 1914 when they found large trout accumulating downstream of the fence! When it was realized that the trout were originating from Kootenay Lake, these officers developed an elaborate seining technique to catch the fish. A large seine (4.6 m x 36.6 m) was attached to the downstream side of the Gerrard bridge, dropped into the river and, as it was floating downstream, quickly pulled to shore (Barrett, M.S. 1949). This method was used each spring for the duration of the hatchery operation.

The hatchery and egg collecting station at Gerrard was operated by the federal Department of Fisheries from 1912 to 1932 and later reopened and operated by provincial authorities from 1939 to 1949 and again in 1952. Eggs were collected from between 50 to 350 large females annually over this period.

In the early 1900's a small sawmill operated near the outlet of Trout Lake, maintaining a log boom across the outlet to prevent logs from floating downstream. The mill stored surplus timber behind this boom which occasionally would break free sending considerable debris downstream. A large log jam known as the Handy Jam developed near 31 mile of the Lardeau River and continued to grow in size until it became a serious impediment to fish passage. By 1923 the jam was substantial and few fish were reaching Gerrard. The federal government seriously considered closing down the hatchery because of the lack of spawners (C. Houston, pers. comm.).

Minor improvements were made frequently to the log jam but authorities were reluctant to permit its complete removal because large numbers of rainbow fry used the area for rearing. In 1940, a channel was built to the north of the jam to allow passage of spawners and their progeny. It was then felt that large numbers of fry were stranded in the area every summer as water levels receded. Finally, in 1951, the channel was enlarged and considerable portions of the jam removed and burned, enabling fish once again to successfully migrate to and from the spawning grounds (Robinson, M.S. 1951).

During this time heavy fishing pressure in Kootenay Lake was also serving to reduce the numbers of Gerrard trout. Perhaps several hundred large trout were taken annually in the 1920's by local fisheries in the Kaslo and Balfour areas (Northcote, 1973). During the 1940's the Nelson Gyro Club annually sponsored the Kootenay Lake Trout Fishing Derby lasting from the first of May until the middle of November. Reports indicate an excess of 3000 trout, each weighing more than 2 kg. to have been caught during the ten years of the derby's existence. Undoubtedly, many others were caught during this time, of which there are no records.

Between 1949 and 1951 the Gerrard hatchery and egg collecting station was closed, the Handy log jam cleared, and the Kootenay Lake fishing derby discontinued. The Gerrard trout were thus given a reprieve for a few years. However, since the completion of the Duncan Dam in 1967, they have become the only stock known to contribute to the trophy rainbow fishery of Kootenay Lake.

In recent years the important role of the Gerrard trout to the Kootenay Lake sport fishery has been realized. As a result, a number of regulatory measures and developmental schemes have been introduced both to protect the Gerrard stock and to increase their numbers.

Regulatory measures introduced which protect Gerrard trout have included:

1. The closure of the Lardeau River and its sloughs and backwaters to angling at all times. This measure offers protection not only to adult fish when migrating to and from Gerrard and while spawning but also to juvenile trout rearing within the Lardeau system.

2. The closure of Kootenay Lake north of a line between Lost Ledge Creek and Salisbury Creek, to angling, from February to June 30 each year. This offers protection to Gerrard pre-spawners and kelts after they return to Kootenay Lake.

3. The classification of Kootenay Lake as a special lake, thus requiring non-Canadians to obtain a special lakes' license in addition to a basic angling license (except in the main lake from June 12 to September 30).

Schemes which have been developed to increase the number of large Kootenay Lake trout have included:

1. The addition of gravel to the spawning area at Gerrard to increase the size of this area and hence reduce the occurrence of repeat spawning.

2. The introduction to the Duncan River of progeny from returning (1970-71) Duncan River stock adults.

3. The establishment at Meadow Creek of a small experimental hatchery-type operation where Duncan River fry are raised and released. It is anticipated that these fry will migrate to Kootenay Lake where they will enter the fishery and eventually return to Meadow Creek for egg collection purposes (Andrusak and Fleck, 1977).

THE LIFE HISTORY OF THE GERRARD TROUT

ADULT FISH WITHIN THE LARDEAU RIVER

Upstream Migration

The Marblehead fish counting fence (Fig. 2) was used to enumerate a portion of the 1966 and most of the 1967 spawning runs. Fourteen fish, tagged at Marblehead in 1967, took an average of 11 days to reach Gerrard, migrating 4.6 km per day.

While Gerrard spawners migrate at night (Fig. 4), diel patterns of other adult salmonids migrating upstream are extremely variable. Chapman (1941) found that most upper Columbia River steelhead migrate during the day, as did Mottley (1938), and Hartman, Northcote, and Lindsey (1962) in studies of rainbow trout. Banks (1969), however, cites numerous cases of salmonids migrating upstream during the night and concludes that "there is conflict between the need for light in order to ascend obstacles, and a preference for darkness or turbid waters in unobstructed passages." Light is not the sole factor governing

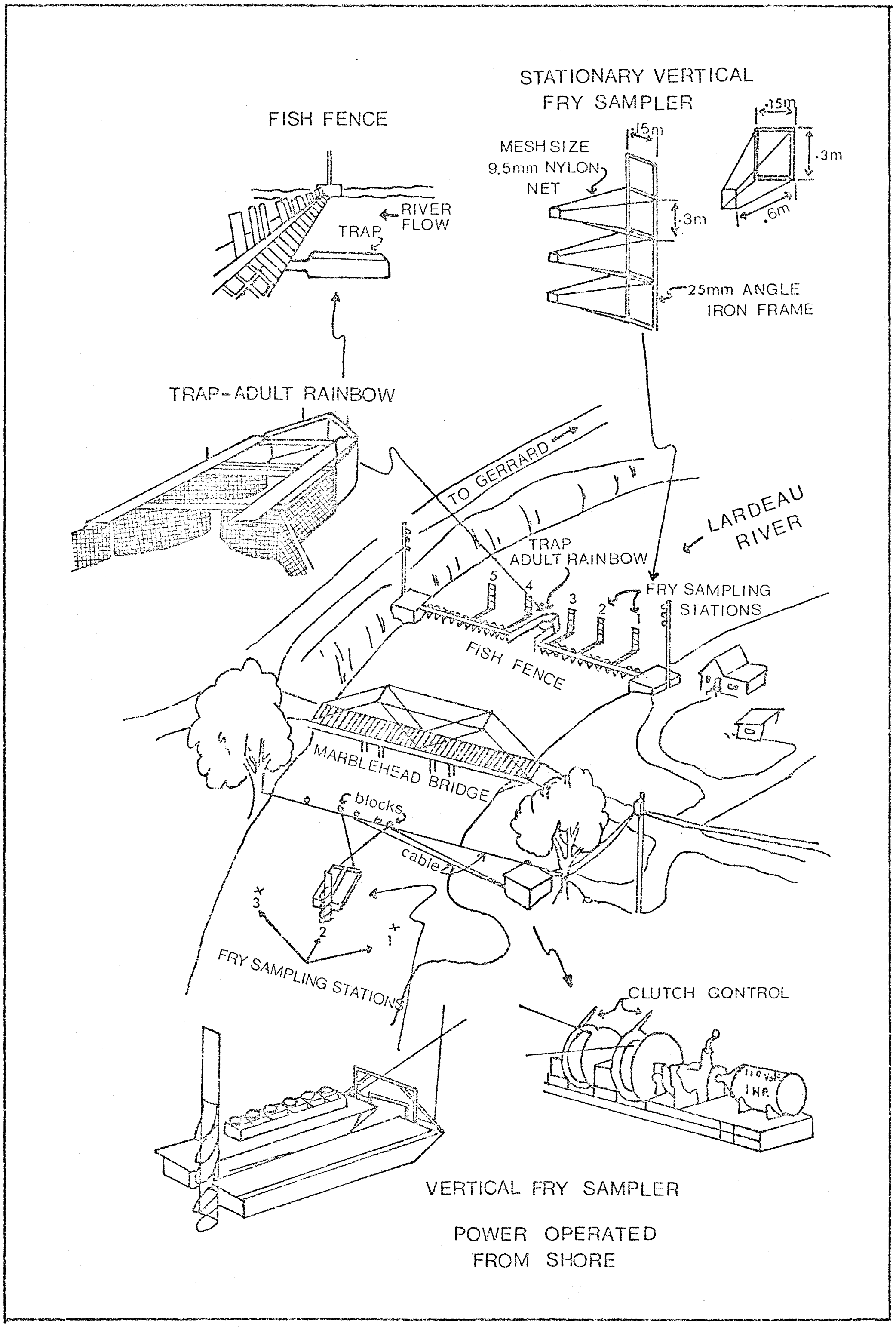

Fig. 2. Marblehead fish counting fence.

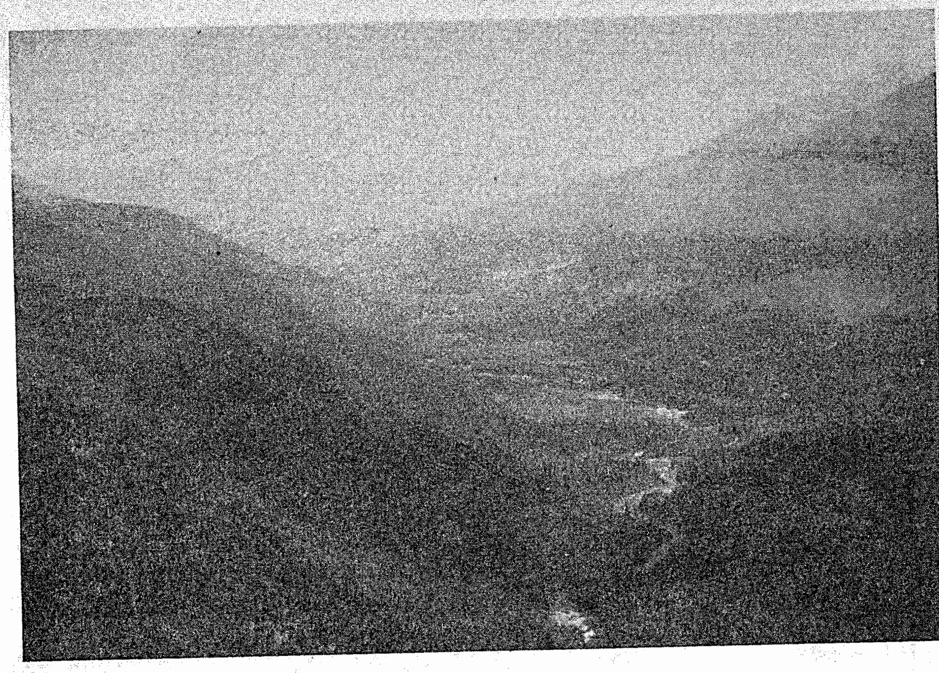

Fig. 3. Lardeau River valley looking downstream from hill near Gerrard.

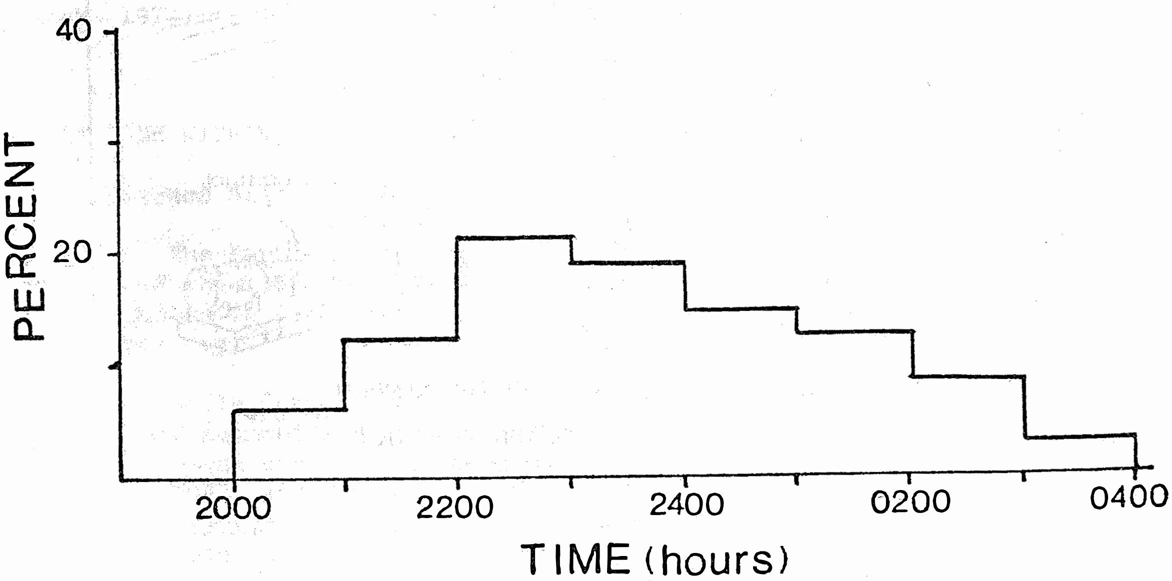

Fig. 4. Diel upstream migration pattern of Gerrard spawners.

upstream migration. Banks (1969) found rate of flow, temperature, water quality, general weather patterns and flow problems caused by dams and other obstacles to be potentially as important in controlling upstream salmonid migration.

The Duncan Dam has significantly altered flow and, to a lesser extent, temperature in the lower Duncan River when Gerrard trout are migrating upstream. Peterson and Withler (1965) predicted that these changes could have a serious effect on the Gerrard trout.

Spawners counts at Gerrard, discharge readings in the lower Duncan River from 1961 until 1976, as well as temperature readings in the lower Duncan for the years since 1968, (Fig. 5) suggest:

1. Rapidly increasing spawner counts at Gerrard were often preceded by surges in river discharge. In 10 out of 16 years, numbers of spawners at Gerrard increased quickly 5-15 days after an increase in discharge of at least 100 per cent in the lower Duncan River. The time lag was roughly equivalent to the computed migratory period from Kootenay Lake to Gerrard.

2. Temperature did not play as important a role as discharge in stimulating upstream migration. From 9 years of data, temperatures in the lower Duncan ranged between 3.9° and 6.3° C twelve days prior to the peak spawning count at Gerrard.

3. The Duncan Dam has decreased flow and altered temperature in the lower Duncan River during the upstream migratory period of the Gerrard rainbow trout. However, no consistent changes in the timing, duration, or intensity of spawning runs have been observed.

Population Estimates at Gerrard

The large rainbow of the north arm are thought to spawn only at Gerrard and are probably the only rainbow spawning there. A fish fence across the Lardeau River at Gerrard from 1914 to 1949 prevented the entrance of large fish from Trout Lake, removing any genetic strains of large outlet spawning trout.

Early estimates of spawner abundance were available from hatchery records. The hatchery and egg collection station at Gerrard was operated by various authorities from 1912 to 1932, 1939 to 1949 and again in 1952. From records indicating numbers of eggs taken by the egg collection station at Gerrard (Table 2) and known numbers of females spawning in certain years it is estimated that the average female produced approximately 3900 eggs. This number is low compared to recent fecundity estimates, but not surprising since egg collectors often avoided removing all eggs from females (so that some could be spawned naturally) (R.A. Rutherglen, pers. comm.) and many fish were at least partially spent when captured. Using 3900 eggs as an average, the numbers of females stripped, and then from calculated sex ratios, the total numbers of spawners captured was determined.

For purposes of estimating stock size, the seining operation was inefficient, since seining was restricted to the area immediately downstream from the Gerrard bridge and fish were often able to escape capture. Trevor White, acting superintendent for the Gerrard hatchery and egg collection station

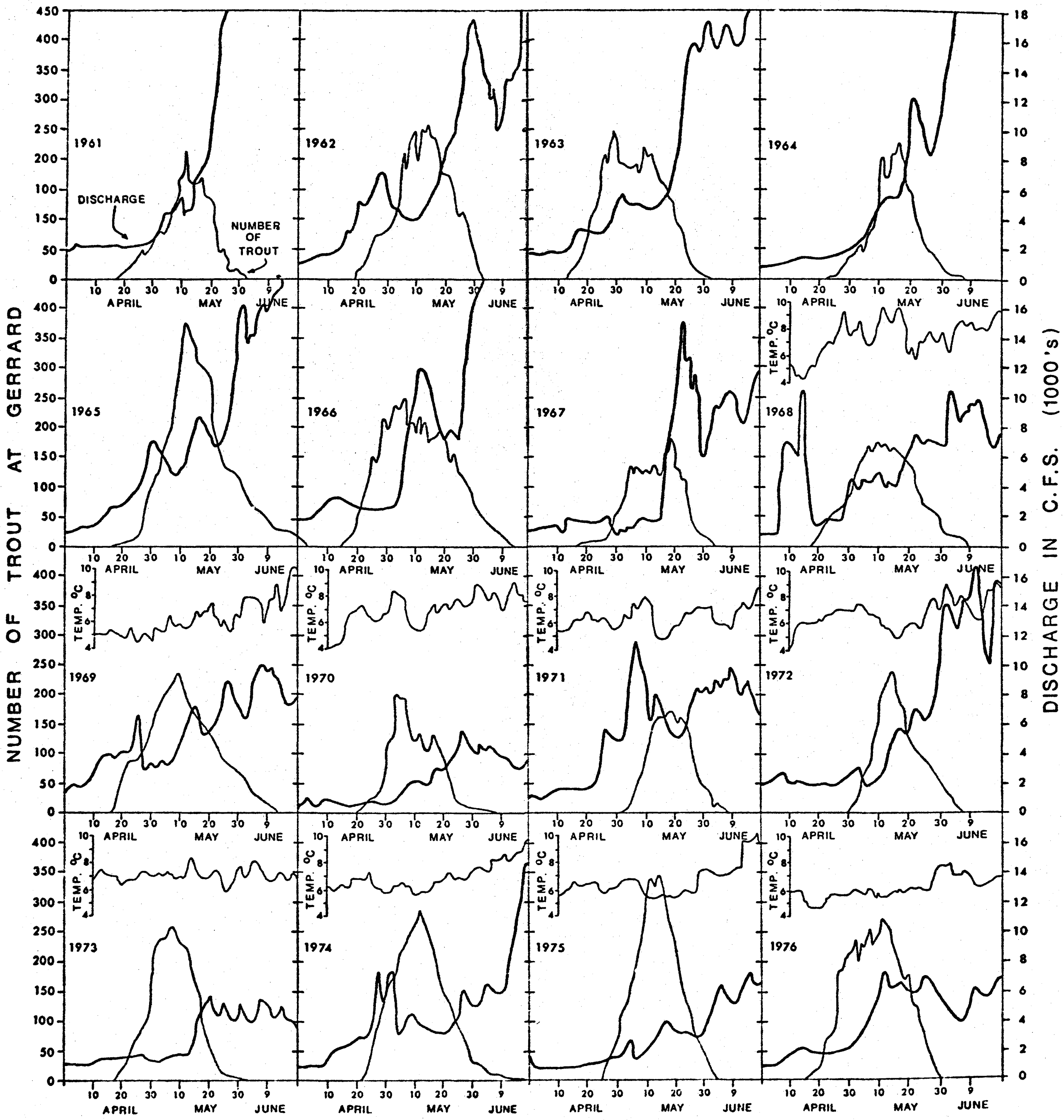

Fig. 5. Spawner counts at Gerrard, discharge and temperature readings in the lower Duncan River.

Table 2. Gerrard Spawning Population Estimates: 1913-1952[a]

Year	Number of Fish Stripped: Female	Male	Total	Total Eggs Taken	Total[b] Returned	Per Cent Returned	Estimated Totals: 75%,[c] 50%	50%,[d] 33%
1913	198[f]	252[f]	450	770,000	495,000	64	600	900
1914	224[f]	285[f]	509	870,500	570,000	66	679	1018
1915	165[f]	210[f]	375	640,200	365,000	57	500	750
1916	155[e]	197[f]	352	711,400	540,851	76	469	704
1917	208[e]	239[e]	447	723,500	609,453	84	596	894
1918	214[e]	247[e]	461	1,059,600	747,175	71	615	922
1919	361[e]	459[f]	820	1,402,600	946,450	67	1093	1640
1920	167[e]	127[e]	294	344,000	113,500	33	588	882
1921	122[e]	127[e]	249	460,000	260,000	57	332	498
1922	61[e]	52[e]	113	189,000	99,000	52	226	339
1923	87[e]	174[e]	261	728,500	?	?	348	522
1924	199[e]	317[e]	516	312,800	175,027	56	1032	1548
1925	235[e]	299[f]	522	663,500	273,500	41	1044	1602
1926	170[f]	216[f]	391	660,000	197,000	30	782	1158
1927	134[f]	171[f]	309	522,500	220,000	42	618	915
1928	142[f]	181[f]	327	551,700	216,251	39	654	969
1929	207[f]	252[e]	459	1,008,000	446,913	44	612	918
1930	308[f]	392[f]	700	1,199,500	600,120	50	933	1400
1931	232[f]	295[f]	527	900,521	452,700	50	703	1054
1932	175[f]	223[f]	398	680,750	311,271	46	531	796
1933-1938	closed							
1939	193[f]	246[f]	439	750,000	0	0	585	878
1940	328[f]	417[f]	745	1,275,000	100,000	8	993	1490
1941	231[f]	294[f]	525	900,000	0	0	700	1050
1942	258[f]	328[f]	586	1,005,000	100,000	10	781	1172
1943	129[f]	164[f]	293	503,000	30,000	6	391	586
1944	132[f]	168[f]	300	512,000	0	0	400	600
1945	263[f]	335[f]	598	1,022,000	0	0	797	1196
1946	119[e]	168[e]	287	554,000	0	0	383	574
1947	91[e]	152[e]	243	456,000	96,500	21	324	486
1948	106[e]	162[e]	268	455,000	0	0	357	536
1949	54[f]	69[f]	123	210,000	97,256	46	164	246
1952	67[f]	85[f]	152	262,000	142,640	54	203	304

[a] See text for detailed explanation of how figures obtained.

[b] Total number returned as eggs, fry or fingerlings to the Lardeau River and its tributaries.

[c] Estimated total number of fish spawning at Gerrard assuming 75 per cent of spawners captured in normal years but only 50 per cent in poor years.

[d] As above only assuming capture efficiencies of 50 and 33 per cent.

[e] Figures obtained chiefly from annual reports submitted by superintendents of Gerrard hatchery.

[f] Figures determined from estimated male:female ratios and numbers of eggs per female.

from 1920 to 1922, indicated five fish to be the large number captured by this method at one time (White, M.S. 1921). Annual reports repeatedly requested alternative methods of capturing spawning trout.

To determine numbers of spawners at Gerrard using hatchery data, the critical assumption was the proportion of the spawning population captured by the egg collectors. Bud Thompson[1] estimated 90 per cent of the fish which escaped the traps located at the fence to have been seined. However, Reid (M.S. 1929), superintendent of the Nelson-Gerrard hatcheries from 1927-1929, predicted that egg takes by the hatchery could be increased by 3 to 5 times if the hatchery fence were moved suggesting only 20 to 33 per cent of the fish spawning at Gerrard were captured.

The situation was further complicated by the effects of the Handy Jam, which prevented many spawners from reaching Gerrard, particularly in times of low water. Reports indicate some spawning to have taken place below this obstruction when conditions were sufficiently poor.

For years when water level or log jam conditions were unusually poor, seining operations at Gerrard captured a smaller proportion of the total spawning population than in normal years (Northcote, 1973). It was assumed that in typical years 50 per cent of all spawners were seined, while only 33 per cent were seined in unfavourable years. In a second series of calculations, it was assumed that 75 per cent of all spawners were successfully seined in average years and only 50 per cent in unfavourable years (Table 2).

Presently, population estimates for north arm rainbow are determined in two ways; catch per unit effort data and peak counts of spawners at Gerrard. Both are often difficult to interpret. Runs with high peak counts may be small but of short duration, while runs with low peak counts can be large but with their time of arrival spread out. Northcote and Wilkie (1963) showed that shore counts of spawners compared favorably with diver and helicopter counts only under conditions of good visibility. Daily shore counts of spawners have been made annually since 1961, and some counts are available from previous years. Annual peak counts have frequently been used as an index of the number of spawners (e.g. Andrusak and Crowley, M.S. 1976) but no attempt has been made to convert peak counts to total counts.

Hartman and Galbraith (1970), on the basis of visual counts and length-of-stay data, estimated the 1966 run to consist of 650 fish. In 1967, 574 large rainbow were counted moving upstream past the Marblehead fence between April 8 and May 11. The fence was removed because of high water but an additional 65 fish were estimated to migrate upstream for a total of 639. Using the maximum daily peak counts for 1966 and 1967 of 249 and 180 respectively, an average conversion factor $\left(\frac{\text{total count}}{\text{maximum peak count}}\right)$ of 3.08 was obtained, and used to transform maximum peak counts for the years 1957-1976 to numbers of spawners (Table 3).

Numbers of spawners at Gerrard in recent years have also been calculated by dividing the number of fish days (sum of the daily counts) by the average number of days spent by the fish on the spawning grounds (McNeil, 1964). Unfortunately, residence time varies considerably from year to year and within a spawning run.

[1]Letter to the editor, Nelson Daily News, May 17, 1932.

Table 3. Gerrard Spawning Population Estimates: 1957-1976[a]

Year	Date of Peak Count	Water[b] Temp. °C	Water[b] Level	Peak Count	Peak Count Times 3.08	Number Fish Days	Duration Period (Days)	Fish Days ÷ by Duration
1957				44	136			
1958				107	330			
1959				210	647			
1960	May 12		4.3	152	468			
1961	May 11	5.6	3.7	214	659	3477	14.3	243
1962	May 14	6.1	3.6	258	795	5782	13.2	438
1963	April 29	5.0	2.7	251	773	6139	15.7	391
1964	May 16	8.1	3.5	234	721	3726	8.5	438
1965	May 11	6.1	4.0	377	1161	8183	13.2	620
1966	May 6	6.9	3.2	249	767	7358	11.3	651
1967	May 19	9.4	3.8	180	554	3534	5.5	643
1968	May 10	6.4	3.3	178	548	4568	12.5	365
1969	May 9	6.1	4.6	237	730	6191	13.2	469
1970	May 4	7.5	2.0	203	625	3592	9.9	363
1971	May 18	4.2	7.0	176	542	3287	17.6	187
1972	May 15	6.7	5.5	238	733	3688	11.8	313
1973	May 7	5.8	2.8	258	795	4844	13.9	348
1974	May 11	6.1	4.8	287	884	6044	13.2	458
1975	May 13	6.7	3.9	346	1066	6145	11.8	521
1976	May 12	6.1	6.4	272	838	6585	13.2	499

[a] See text for detailed explanation of how figures obtained.
[b] At Gerrard on day of peak count.

For example, Hartman and Galbraith (1970) found that early fish remained on the spawning area for approximately 20 to 28 days, while late arriving fish remained only 6 to 7 days.

Average duration periods were calculated for 1966 (11.3 days) and 1967 (5.5 days) by dividing the number of fish days by the number of spawners. In computing duration periods for other years, it was assumed that a direct relationship existed between water temperature and length-of-stay at Gerrard. Assuming a straight line relationship, the equation describing the line produced by a graph of water temperature on the day of peak spawning (x-axis) versus duration period (y-axis) is $y = -2.32x + 27.31$. Using this equation average duration periods were calculated for each of the years 1961-1976. Dividing these periods by total numbers of fish days yielded an additional estimate of numbers of spawners (Table 3). When examining these estimates, however, it must be stressed that there is no evidence of a direct relationship between water temperature and residence time and that only two points were available to calculate the slope of the line produced.

Comparing various methods of calculating numbers of spawners from 1913-1952 (Fig. 6), the following observations can be made:

1. Considerable year-to-year fluctuations occur.

2. While estimates during the years 1913-1932 seemed to fluctuate around 800 spawners, the 1939-1952 figures suggest a general decline in the population.

Considering these observations:

1. The large year-to-year fluctuations are not surprising considering the varying water levels, log jam conditions, and skills of fish collectors at Gerrard. The rapid decline in numbers preceding 1923 was apparently caused by worsening log jam conditions. After this time some attempt was made, on an annual basis, to improve log jam conditions in the river to allow better fish passage. Increased fish numbers after 1923 provide some evidence for the effectiveness of this operation.

2. Three reasons for the apparent decline in numbers of spawners between 1939 and 1949 are:

   a. Heavy fishing pressure on adult stock in Kootenay Lake, largely from the Nelson Gyro Club fish derby.

   b. Progressively deteriorating log jam conditions in the Lardeau.

   c. Cumulative effects of removing spawn from a large proportion of the population. Until its closure in 1932 Gerrard was operated as an egg collection station and hatchery. Following its re-opening in 1939, it was used primarily as a site for egg collections. Eggs collected there were transported usually to the Nelson hatchery, but sometimes to hatcheries operating in Lardeau, Argenta or Kaslo. These hatcheries thus became the sites from which Gerrard fry were distributed. Numbers of eggs, fry or fingerlings returned to the

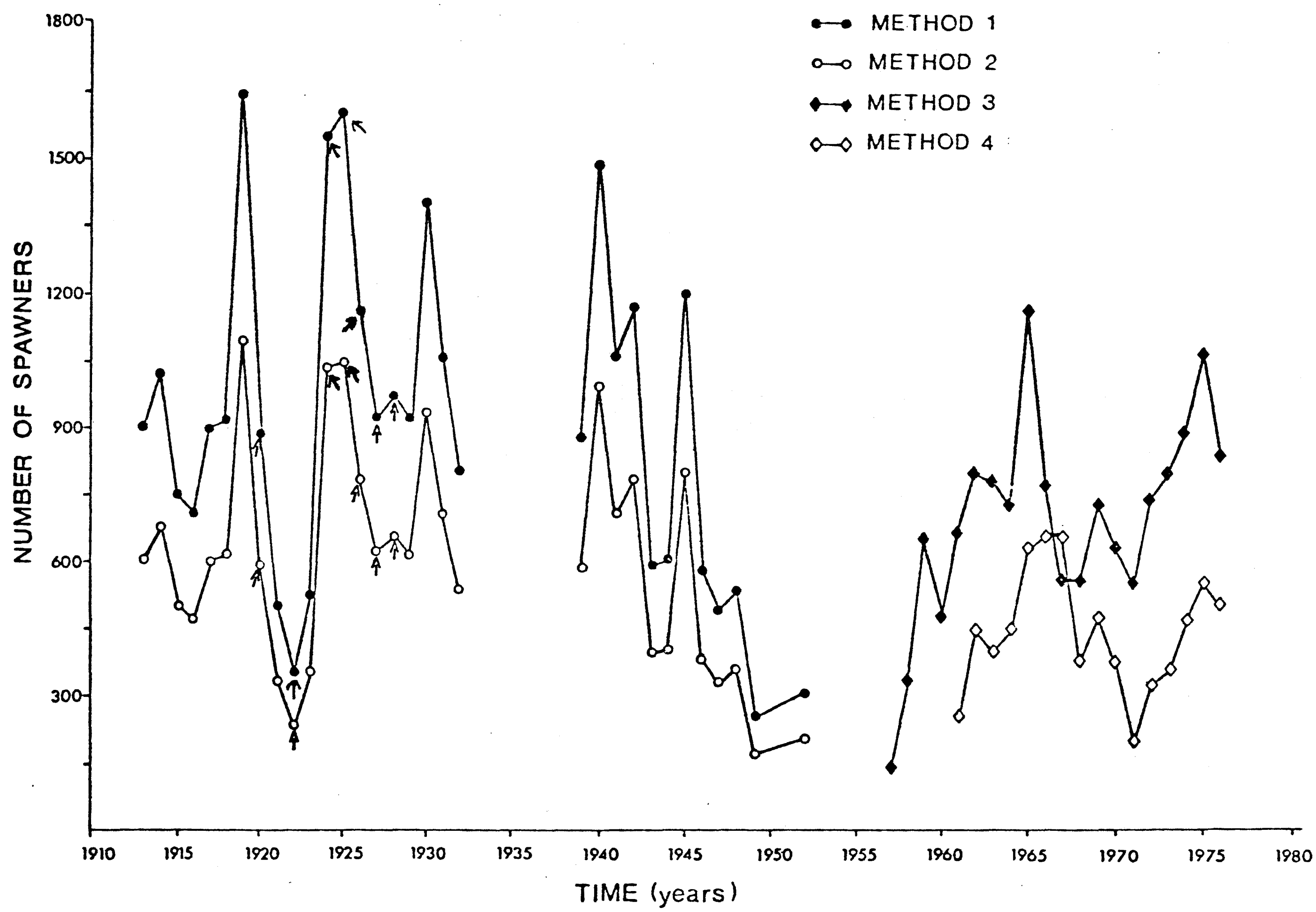

Fig. 6. Estimated number of spawners at Gerrard over time. Method 1 calculated from hatchery records, 50 per cent of spawners assumed captured in normal years but only 33 per cent in poor years indicated by ↑; Method 2 as with Method 1 only assuming capture efficiencies of 75 and 50 per cent; Method 3 estimated by multiplying daily peak counts by 3.08; Method 4 estimated by calculating duration periods from temperatures on days of peak counts and dividing the number of fish days by these periods.

Lardeau system are known for all the years the Gerrard egg collection station operated except for 1923 (Table 2). Of 13.7 million eggs taken from 1913-1932 and exclusive of 1923, 56 per cent were returned to the Lardeau as eggs, fry or fingerlings. From 1939 to 1949 and in 1952, close to 8 million eggs were removed from the system and less than 0.6 million (7 per cent) returned to it. This reduced return rate in later years was largely the result of ignorance on the part of fishery supervisors. Large numbers of Gerrard origin fry were transplanted directly into Kootenay Lake, but it is unlikely that any of these homed to the Lardeau.

Considering the two methods of estimating numbers of spawners at Gerrard in more recent years (Fig. 6), the following observations can be made:

1. While the same general trends are demonstrated in both cases, the plot determined directly from maximum peak counts is of considerably higher magnitude than that determined from computed duration periods.

2. Considering both plots, it appears that numbers of spawners underwent a steady increase from the late 1950's to the mid 1960's, followed by a general decline until about 1971. Most recent evidence suggests that numbers are increasing again.

Considering population estimates for the overall period from 1913-1976, it is significant that levels for the last 19 years are somewhat lower than those of earlier years.

Comparison with Kootenay Lake Fishing Data

Detailed accounts of the Kootenay Lake rainbow fishery (Andrusak, M.S. 1974; Andrusak and Crowley, M.S. 1976) indicate effort has declined in recent years (Table 4), probably in response to decreasing success rates and a partial shift to a fishery for large Dolly Varden (Andrusak and Crowley, M.S. 1976). However, no strong correlation can be seen comparing catches of large north arm trout to numbers of trout spawning at Gerrard.

Spawning at Gerrard

Characteristics of Spawning Area

Only two small areas, constituting a total of 7000 m^2, are utilized by the spawners at Gerrard (Cartwright, 1961; Hartman, 1969). The bottom topography consists of many irregular features (Hartman and Galbraith, 1970), including three large pools between Trout Lake and Mobbs Creek used as resting areas. A series of elevated ridges, within the two main spawning zones, support the majority of spawning. This further reduces the utilizable portion of the river to less than 1320 m^2 (Hartman and Galbraith , 1970).

In areas most heavily utilized for spawning, material ranged from one to 100 mm in size, while less heavily used areas contained gravel greater than 500 mm (Hartman and Galbraith, 1970). Silt content was negligible in the spawning gravel.

Water depths of 175 to 200 cm and velocities of 50 to 90 cm/sec

Table 4. Estimated minimum catch and effort for rainbow trout in the north arm of Kootenay Lake.[1] (Fish > 6.8 kg are assumed to be Gerrard fish.)

Year	Effort (hours)	Per Cent > 36 cm	Per Cent > 6.8 kg	Total Catch	CPUE
1962		54	6		
1963		44	7		
1964		58	7		
1965		60	4		
1966		67	4		
1967		58	7		
1968	28,100	54	5	1,955	0.07
1969	28,560	64	4	1,763	0.06
1970	36,650	43	3	1,816	0.05
1971	29,950	54	9	1,623	0.05
1972	37,750	48	6	943	0.03
1973	37,600	55	7	837	0.02
1974	21,774	68	13	706	0.03
1975	23,100	63	13	1,438	0.06
1976	23,415	92	21	874	0.04

[1]Adapted from Andrusak and Crowley, M.S. 1976.

20 cm above bottom were typical of most heavily used spawning locations (Hartman and Galbraith, 1970). Intragravel water flows were greater at the crests of the transverse ridges, where nest densities were highest.

While river discharge at Gerrard varies from spawning season to spawning season, rapid changes within one spawning period are infrequent. Large scale day-to-day discharge fluctuations are more evident further downstream.

During spring, water temperatures are relatively high at Gerrard. Hartman and Galbraith (1970) showed consistently warmer water temperatures at Gerrard compared to downstream during the spawning runs of 1966 and 1967. Mobbs Creek and other streams of glacial origin have the effect of progressively lowering the temperature downstream.

Spawning Behavior and Advantages to Spawning at Gerrard

There are a number of advantages to spawning at Gerrard. Warmer water temperatures result in faster egg development and more rapid initial fry growth. Low sediment loads increase survival rates of developing eggs. The combination of warm spring water temperatures, stable water velocities, medium depths, clear water and irregular bottom topography make the Gerrard site ideal for spawning (Hartman and Galbraith, 1970).

Hartman (1969, 1970) found that most nest digging was nocturnal during the initial stages of the run, but increased until digging was continuous around the clock at the peak of spawning. A close similarity was found between the digging behavior of the Gerrard trout and that described by McCart (1969) for *Oncorhynchus nerka*. The spawning act altered digging and body flexure frequencies drastically. Tactile stimuli were important to females when selecting nest sites and covering eggs (Hartman, 1970).

It has been suggested that many of the physical characteristics of the spawning environment at Gerrard, and the behavioral traits displayed by Gerrard spawners may favor large sized individuals (Hartman, 1969). The large gravel and rapid water are similar to those reported in the literature for other stocks of large sized salmonids. Large fish are able to hold position more easily in heavy current than smaller fish, and larger females can construct nests easiest and most effectively in coarse gravel. In addition, the aggressive behavior commonly exhibited by Gerrard males may select for large males in the population. Hartman (1969) found large males to be more dominant and successful during spawning than small males.

Age Composition, Length, and Weight

Accurate data on the age composition, lengths, and weights of Gerrard spawners are lacking. In early years, these data were not collected by hatchery personnel, and more recently, management policy has prohibited interference with spawning fish. However, some information is available from the creel program monitoring the trophy rainbow fishery in the north arm. All large fish caught are now likely of Gerrard origin, though prior to the Duncan Dam, they were a mixture of Gerrard and Duncan stocks.

Cartwright (1961), in a detailed scale examination found that 46 out of 50 north arm rainbow with spawning checks had spawned at five or six years of age. Considering the relatively large size of these fish at spawning (average back calculated fork length = 66.3 cm), most were probably Lardeau-Duncan spawners. Acara (M.S. 1969) collected additional scales from Kootenay Lake trout. Of 237 fish from the north arm fishery with spawning checks, 86 per cent had spawned between the ages of 4 and 8 years, with the mean age between 5 and 6 (Fig. 7). It is probable that some of the younger fish were not Lardeau-Duncan spawners. Length measurements have been made of spawners sampled for egg collection purposes which can be considered representative of the spawning population. Between May 10-16, 1949 and on April 30, 1963 and May 12, 1964, a total of 84 female and 135 male spawners were captured and measured. Fork lengths ranged between 48.2 and 97.0 cm with females averaging 75.7 cm and males 81.9 cm. The length-weight relationship (Fig. 8) of 110 rainbow trout captured by the north arm fishery between 1941-1964 was log Y = -4.851 + 2.931 log X. Northcote (1973) detected a change in this relationship for large Kootenay Lake rainbow over this period, finding trout larger than 40 cm in the mid 1960's to be significantly heavier than similar sized fish taken in the 1940's.

Sex Ratios

Sex ratios of spawners were computed from hatchery records for 1913-1952 (Table 2). For the eleven years that numbers of both sexes were available, a total of 1374 females were captured compared to 1765 males or, 1 female for every 1.3 males. Over these years the proportion of females ranged from a low of 37 per cent to a high of 57 per cent. These sex ratios are consistent with those reported by others for the same species. Pautzke and Meigs (1940) found steelhead ratios in Washington close to 1:1, Shapovalov and Taft (1954) in California reported ratios of 1:1.1 favoring females while Moring and Lantz (1975) found the Alsea River steelhead population to favor males by a ratio of 2.2:1. Females have been reported to be the dominant steelhead sex in British Columbia with ratios ranging between 1:1.3 and 1:3.2 (Withler, 1966).

Fecundity

Egg counts from 35 gravid females in 1966 produced a curve of the form $F = aL^b$ (Bagenal, 1967) (Fig. 9) where F equals numbers of eggs in thousands, L equals fish length (cm) and a and b are 1.81 and 1.94 respectively. A logarithmic transformation yields:

$$\text{Log } F = \log 1.81 + 1.94 \text{ Log } L.$$

Gerrard females (average fork length = 75.7 cm) contain an average of 8076 eggs which is within the fecundity range of similar sized trout. Shapovalov and Taft (1954) estimate 9040 eggs for this sized steelhead; Bulkley (1967) indicates comparable Alsea River steelhead produce 4827 eggs. Examination of spawned out Gerrard trout (Acara, M.S. 1969) showed a 10 per cent retention rate for Gerrard females. It is estimated that an average of 7268 eggs per female are deposited at Gerrard.

Downstream Migration

The fish counting fence at Marblehead was used to enumerate downstream migrants until May 8 in 1967, at which point the fence was removed due to high water. Between May 1 - May 8 30 large spawners passed by the fence, all moving downstream at night. Large rainbow have not been reported in the Lardeau later than June. Thus, it appears that after spawning, fish at Gerrard move downstream to Kootenay Lake almost immediately.

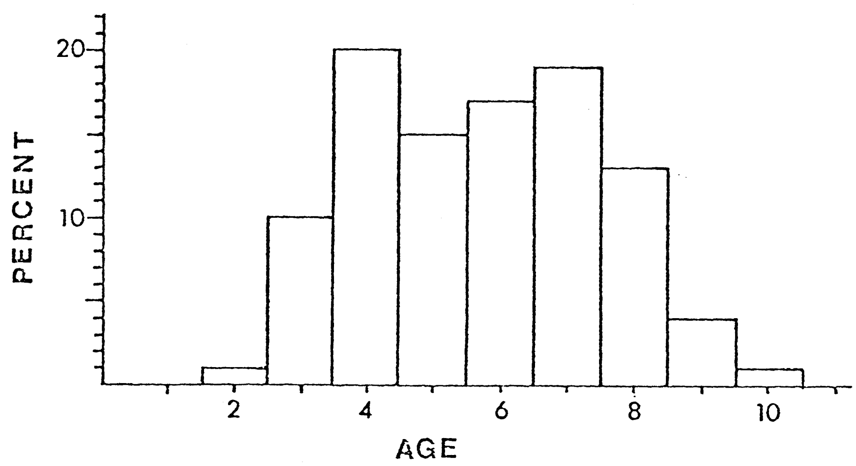

Fig. 7. Age frequency of trout that would have spawned next season, captured by the north arm fishery.

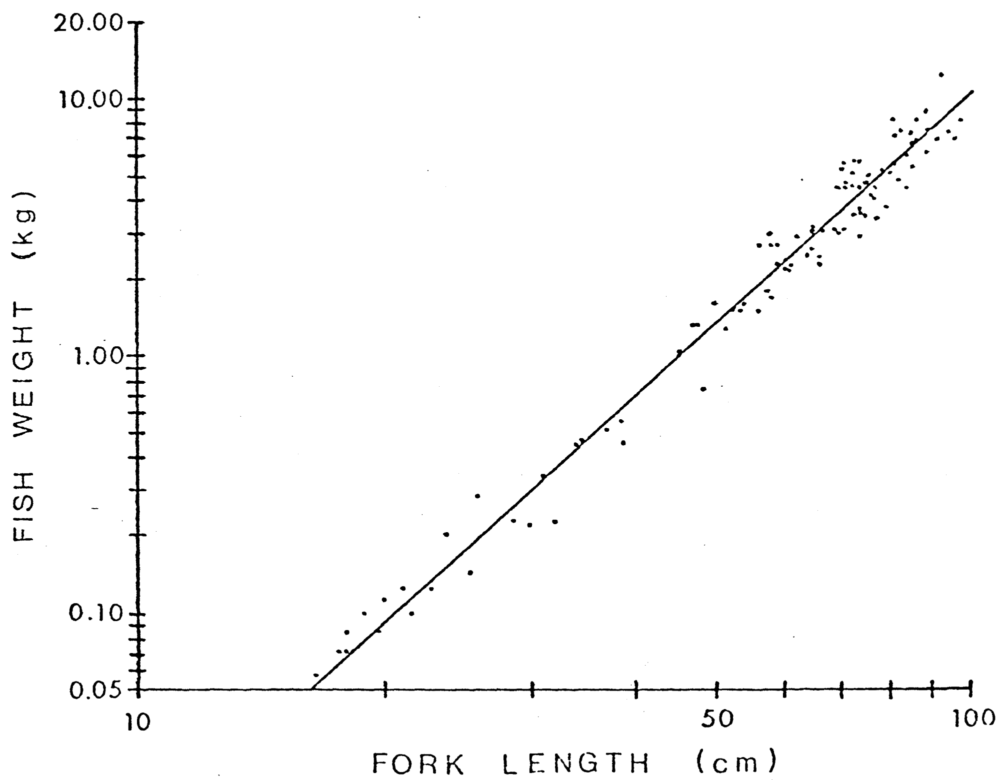

Fig. 8. Length-weight relationship of trout captured by the north arm fishery.

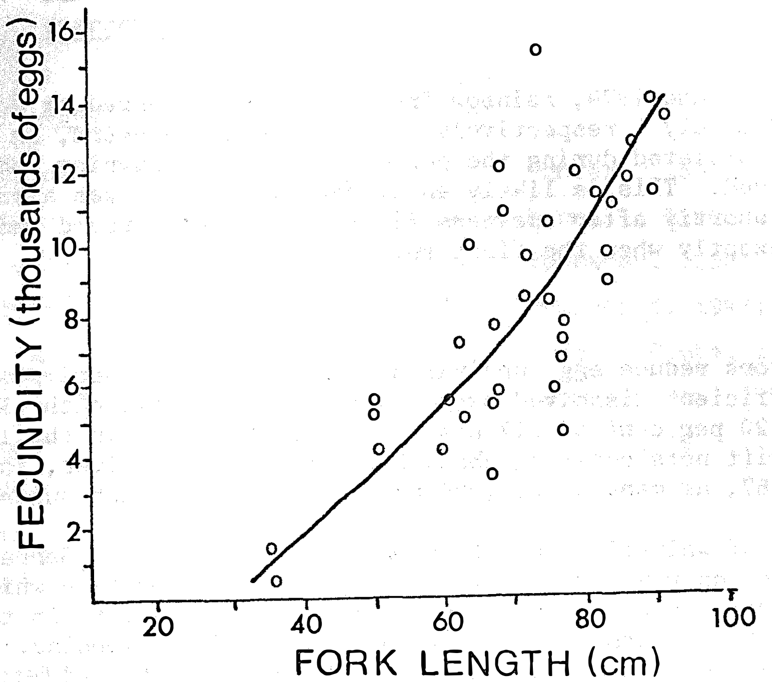

Fig. 9. Length-fecundity plot.

Fig. 10. Rearing habitat at Gerrard during high water.

INCUBATION, HATCHING, AND EGG SURVIVAL

Development

In 1958, 1959 and 1974, rainbow fry were first observed at Gerrard on June 18, July 7 and July 5 respectively. For these three years, an average of 971 heat units accumulated during the period from first spawning until when fry were first observed. This is likely an overestimate as it was assumed that spawning began very shortly after spawners first arrived at Gerrard and it is impossible to know exactly when the first fry emerged.

Egg Survival

Three factors reduce egg survival at Gerrard; nest superimposition, predation, and insufficient dissolved oxygen. Hartman and Galbraith (1970) found approximately 20 per cent of 217 nests were superimposed in the 1966 and 1967 runs. Using drift nets covering about 2 per cent of the river, they estimated that in 1967, as many as 135,000 eggs were lost through superimposition.

The impact of whitefish predation on developing eggs at Gerrard has been a matter of some controversy. Large numbers of rocky mountain whitefish (2000 to 4000) move onto the spawning grounds from Trout Lake late in the day during the spawning run, returning to Trout Lake in the early morning. These fish often are associated with spawning and pre-spawning trout, and feed on eggs and/or aquatic insect larvae displaced during digging activities. Ninety-seven whitefish captured from the river during spawning contained an average of 2.6 eggs each. It was estimated (Hartman and Galbraith, 1970) that if 2000 whitefish consumed 2.6 eggs per night for 20 nights approximately 104,000 eggs would be lost. Most of the eggs examined that were captured in drift samplers or consumed by whitefish were in the early stages of development. However, eggs lost through displacement would be unlikely to survive even though successfully fertilized.

Egg predation from other sources is probable but difficult to quantify. Considerable numbers of the slimy sculpin *(Cottus cognatus)* are found in the Lardeau at Gerrard. Phillips and Claire (1966) suggest that sculpins can be significant predators on salmonid eggs and alevins where gravel sizes are large. Various invertebrates are also known to predate on developing eggs and fry although results suggest that, at least for stonefly nymphs, predatory effects are probably minimal (Nicola, 1968).

Survival rate of developing embryos at Gerrard has not been determined but is estimated here from survival rates for other salmonids. Survival rates under natural conditions from egg deposition to emergence (Table 5) suggest a great deal of variability among species, and within individual species. As a general rule, fish of the genus *Oncorhynchus* have poorer survival rates than fish of the genus *Salmo*.

Survival rates to emergence at Gerrard are probably quite high. Gravel is large, permitting adequate intragravel water movement and high dissolved oxygen, sedimentation is not serious due to the settling out effect of Trout Lake, and water levels are relatively constant. A fairly conservative estimate for the survival rate of those eggs successfully deposited in redds at Gerrard is 50 per cent, with most mortality from superimposition.

Table 5. Survival rates under natural conditions from egg deposition to fry emergence.

Species	Per Cent Survival	Reference
Chum salmon	5.7-31.1	Hunter, 1959
Pink salmon	0.2-32.3	Merrell, 1962; Wickett, 1962
Sockeye salmon	1.8-19.3	Foerster, 1968
Coho salmon	11.8-37.9	Pritchard, 1947; Moring & Lantz, 1975
Chinook salmon	7.0-32.0	Wales & Coots, 1955
Atlantic salmon (landlocked)	92.0	Warner, 1963
Brown trout	91.4	Hobbs, 1948
Brook trout	90.0	McFadden, 1961
Yellowstone cutthroat trout	25.0-40.0	Ball & Cope, 1961
Steelhead	75.0-86.3	Briggs, 1953; Shapavolov & Taft, 1954

JUVENILE LIFE HISTORY

Rearing Potential of the Lardeau River

For this discussion, the Lardeau River has been divided into three sections: upper, extending downstream from Gerrard to Mile 26 (~ 15 river kilometers); central, extending downstream from Mile 26 to Mile 15 (~ 23.2 river kilometers); and lower, the remaining 26.4 river kilometers to Kootenay Lake.

Physical and biological characteristics vary considerably along the length of the river. Summer temperatures in the upper river range between 15° and 20° C, further downstream they are usually 2° - 7° C cooler. While Trout Lake generally freezes over in winter the Lardeau does not. January temperatures are usually between 0.5° and 5° C along the river's length.

The upper river contains excellent rearing habitat, a mean gradient of 3.4 m/km, relatively large substrate and little silt and fine sand. Productive riffle areas are frequently interrupted by deep pools, and excellent side channel rearing habitat abounds, especially during high water summer months. In the mainstem, scattered log debris provides additional rearing habitat.

The middle region of the river has a similar gradient (3.6 m/km) but the combined effect of a number of glacial tributaries is noticeable. Substrate is smaller and in places glacial flour and silt are deposited. Nevertheless, while fewer pools separate runs and riffles in the main river, and side channels have become less common, the mainstem still possesses numerous good rearing areas.

The lower portion of the river, in contrast to the upper and middle regions, contains little suitable rearing habitat. River gradient is 1.6 m/km, and due to the irregular flows of tributaries, the river bottom is unstable, especially below the Duncan River confluence. Small gravel predominates in this area with heavy deposits of glacial flour and silt.

Biological productivity also varies along the river. Cartwright (1961) found almost twice as many aquatic invertebrates in the poorest of his benthic samples from the upper river as compared to the best of his samples from the lower river.

The relationship between stream drift and standing crop of benthos is not linear (Waters, 1972), and many authors have questioned the usefulness of drift measurement for estimating production (Bailey, 1966; Elliott, 1967; Hynes, 1970). Nevertheless, since juvenile trout in the Lardeau are heavily dependent on drifting invertebrates for food, estimates of drift abundance are useful and have been made.

Results of drift sampling (Irvine, M.S. 1978) have been grouped into five categories: zooplankton prey species, riverine prey types, terrestrial forms, non-prey zooplankton, and other non-prey. Zooplankton prey are those species large enough to be fed upon by young fry; riverine prey are chiefly immature insects; terrestrial forms are almost entirely adult insects but also include some non-aquatic immature forms; non-prey zooplankton are those generally not consumed by young trout; and other non-prey forms include *Hydra* and insect exuviae.

Zooplankton were most abundant in the upper river (Table 6), as would be expected since Chandler (1937), Reif (1939), and Gibson and Galbraith (1975) have shown that drift from lakes disappears rapidly along the length of lake-fed rivers. Zooplankton densities were highest during the summer, probably the result of seasonal plankton blooms, and periods of high discharge resulting in more rapid flushing of Trout Lake. High zooplankton densities are also recorded in the lower river during summer months. During this period water levels are sufficiently high, and slack water areas numerous enough, to allow some natural plankton production in side channels and backwaters of the lower river. Also, some lacustrine organisms are introduced via the Duncan reservoir.

Terrestrial insects were scarce in the drift. Numbers were highest in the upper reach during the fall, being almost entirely blackfly *(Simulium spp.)* adults whose larvae are very common in the upper river. In other seasons chironomid and ceratopogonid adults constituted the bulk of terrestrial drift organisms.

Drift patterns of lotic forms were not entirely as expected. Highest densities were usually found in the central region of the river. The work of Badcock (1949), Cushing (1963) and others suggests that benthic productivity should increase further upstream. However, since a direct relationship between benthic biomass and drift does not always occur (Waters, 1972), we cannot assume that drift densities will also be highest further upstream. It is also surprising that highest drift densities occurred during winter and spring since other authors (Waters, 1962; Hartman, 1963; Bjornn, 1971) have reported greater numbers during summer months. The differing results may be due to the very fine mesh of the drift nets used in this study. Most of the winter drift were early instar chironomid larvae which would not have been retained using normal samplers. The important finding is that food is unlikely a significant factor controlling trout population levels in the Lardeau during winter.

In conclusion, while habitats suitable for early salmonid rearing occur along the entire length of the Lardeau River, physical and biological factors are such that this habitat is concentrated in the upper two-thirds, and generally improves upstream.

Table 6. Average numbers of organisms per 10 m^3 in Lardeau River drift samples[a].

Location	Season	Zooplankton Prey Species[b]	Riverine Prey Types[c]	Terrestrial Forms	Non-prey Zooplankton[d]	Other Non-Prey[e]	Total Prey Organisms	Total Non-Prey Organisms	Total Drift Organisms
Lower	Summer	311.2	0.9	0.4	38.9	3.8	312.4	42.7	355.1
Central	Summer	139.6	3.1	0.7	64.8	4.5	143.4	69.3	212.7
Upper	Summer	296.7	2.1	0.5	239.1	5.0	299.3	244.1	543.4
Lower	Fall		2.1	0.2	1.5	18.5	2.3	20.0	22.3
Central	Fall		3.1	0.2		22.4	3.3	22.4	25.7
Upper	Fall	5.1	2.6	1.6	125.1	5.7	9.3	130.8	140.1
Lower	Winter		5.1			7.1	5.1	7.1	12.2
Central	Winter		11.8		0.1	4.8	11.8	4.9	16.7
Upper	Winter	0.4	4.1		4.4	2.9	4.5	7.3	11.8
Lower	Spring		7.9	0.7		3.2	8.6	3.2	11.8
Central	Spring		5.8		3.4	1.4	5.8	4.8	10.6
Upper	Spring	1.8	5.1	0.1	90.2		7.0	90.2	97.2
Lower	All combined	77.8	4.0	0.3	10.1	6.9	82.1	17.0	99.1
Central	All combined	34.9	5.2	0.2	16.3	8.3	40.3	24.6	64.9
Upper	All combined	77.3	3.5	0.6	113.4	4.1	81.4	117.5	198.9
All combined	Summer	249.2	2.0	0.5	114.3	4.4	251.7	118.7	370.4
All combined	Fall	40.5	2.6	0.7	40.5	15.5	43.8	56.0	99.8
All combined	Winter	0.1	7.0		1.5	3.3	7.1	4.8	11.9
All combined	Spring	0.6	5.2	0.2	31.2	2.4	6.0	33.6	39.6

[a] See text for explanation.

[b] Largely *Daphnia galeata mendotae, Epishura nevadensis* and *Bosmina longirostris.*

[c] Chiefly immature insects.

[d] Mainly *Kellicottia longispina* and *Cyclops bicuspidatus.*

[e] *Hydra,* insect exuviae etc.

Emergence Patterns and Migratory Behavior

Throughout most of the egg development period, water temperature and discharge increase. By emergence, water levels are declining but are sufficiently high to provide excellent initial rearing habitat, i.e., areas with abundant cover, relatively high temperatures and minimal current (Fig. 10).

By counting fry along the river bank Northcote (1969) found numbers to increase as light intensities dropped towards the end of the day suggesting that fry emergence begins around dusk. Fry traps near the Gerrard bridge and 1350 meters further downstream indicated most downstream movement took place shortly after dusk, with reduced movement continuing throughout the night. Some fry emerging at Gerrard move upstream into Trout Lake (Northcote, 1969) but represent only a small portion of the total fry. Reports (Northcote, 1969; G. F. Hartman, pers. comm.) indicate yearling and older juvenile trout congregate near the Trout Lake outlet during late summer. However, fyke nets operated near the Trout Lake outlet in August of 1974 failed to capture any of these trout migrating downstream.

In 1974, fry were abundant along the river banks at Gerrard from July 10 until August 9. By the latter date, discharge had declined from 150 m^3/sec to 50 m^3/sec, and water depth had decreased by two meters. Much of the fry rearing area had disappeared by early August and it is probable that decreasing rearing space resulted in fry displacement.

Mean lengths of fry dipnetted at Gerrard compared with downstream migrating fry captured by fyke nets situated just above Mobbs Creek (Tables 7 and 8) showed non-migrating fry at Gerrard were significantly larger than migrating fry at Mobbs Creek. Thus, while many of the fry emerging at Gerrard migrated downstream immediately, some reared there for varying, but probably short, periods of time.

In the summer of 1966 numbers of rainbow fry migrating downstream were estimated at Marblehead until August 31 (Acara, M.S. 1969). During the high water period, lasting until August 5, a pontoon vertical sampler was used. After water levels began to recede sampling was conducted by stationary vertical samplers operated from the Marblehead fence (Fig. 2).

Downstream fry migration was nocturnal and no fry were caught between 0500-2100 hours. In the early part of the run (July 7-26) all fry migrated between 2300-0400 hours, but later (July 27-August 31), migration occurred between 2200-0300 hours. Northcote (1962) found a similar migration pattern with Loon Lake fry. Downstream migrating fry were first captured at Marblehead on July 7, with catches peaking on July 17 (Fig. 11). A steady decline took place until the end of July, after which small, but relatively constant numbers were captured throughout August. During this time migrating fry gradually increased in length (Fig. 11).

An estimated 108,000 fry migrated downstream past the Marblehead fence during July and August 1966. No yearlings were captured. In 1966 one million fry should have been produced from the estimated 709 fish spawning at Gerrard (Table 3). Even if migration estimates were in error, clearly, not all Gerrard fry migrate during their first summer.

Density estimates of trout over a wide range of habitat types in the

Table 7. Length frequency and range data of fry captured by fyke nets immediately upstream from Mobbs Creek and fry dipnetted at Gerrard.

Method of Capture and Location	Date	N	Mean Size (mm)	Range (mm)
Fyke nets - just above Mobbs Creek	July 5 - 15	57	29.6	24.1 - 36.6
Fyke nets - just above Mobbs Creek	July 16 - 25	74	30.2	24.7 - 34.0
Fyke nets - just above Mobbs Creek	July 5 - 25	131	29.9	24.1 - 36.6
Dip net - Gerrard	July 26/27	118	32.1	27.2 - 49.0
Dip net - Gerrard	Aug 8/9	102	33.0	27.4 - 48.0
Dip net - Gerrard	July 26/27 & Aug 8/9	220	32.5	27.2 - 49.0

Table 8. T test results comparing lengths of fry captured at Gerrard and above Mobbs Creek.

Populations being tested	t calc.	d.f.	t .05
Mobbs Creek July 5 - 15 vs Mobbs Creek July 16 - 25	1.57	129	1.66
Mobbs Creek July 5 - 25 vs Gerrard July 26/27	5.52	247	1.65
Mobbs Creek July 5 - 25 vs Gerrard August 8/9	6.75	231	1.65
Gerrard July 26/27 vs Gerrard August 8/9	1.55	218	1.65

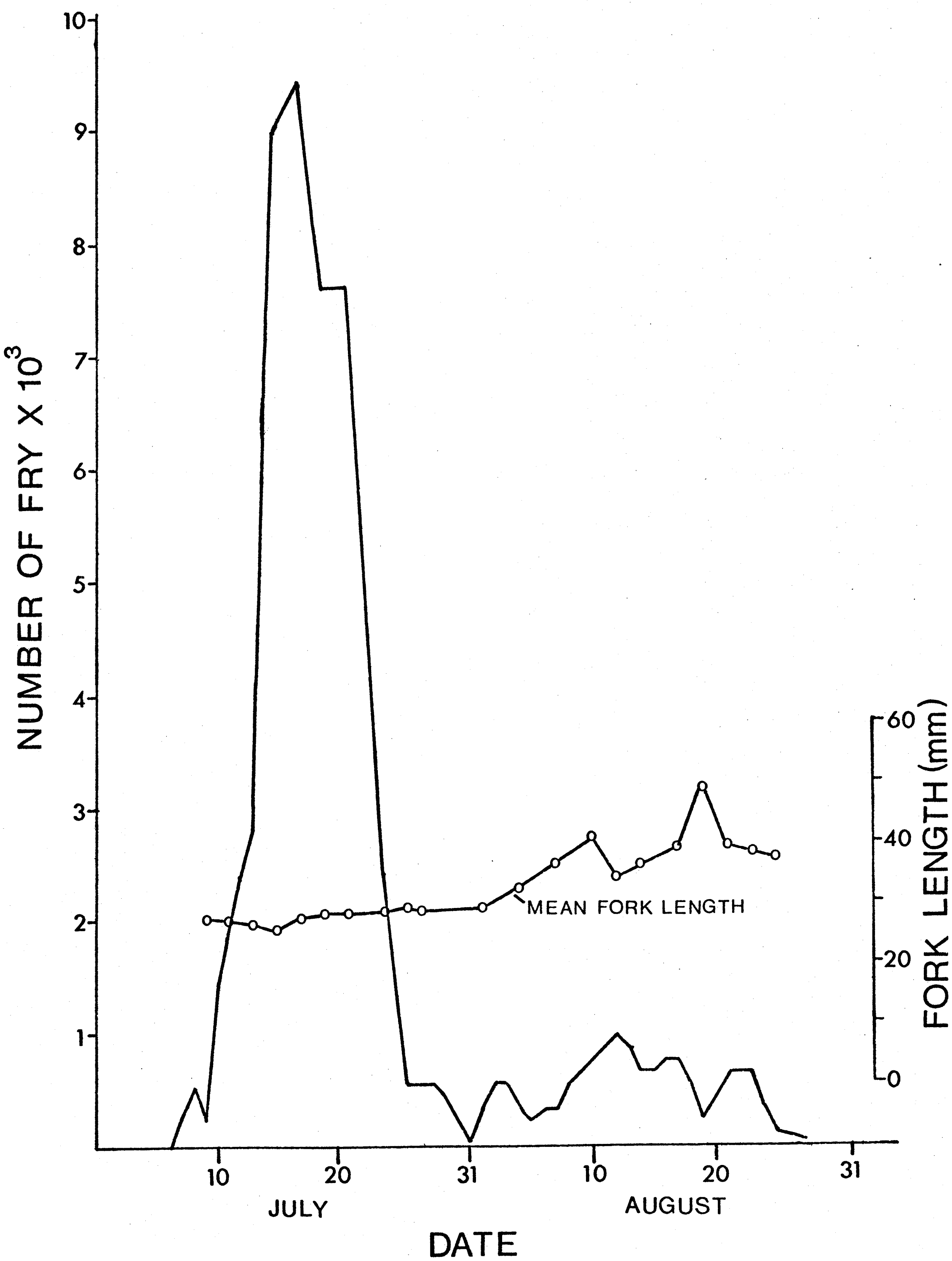

Fig. 11. Numbers and mean lengths of fry captured at the Marblehead fish counting fence.

Lardeau were obtained by electrofishing during the spring, summer, fall, and winter of 1974 as well as the spring of 1975 (Irvine, M.S. 1978). Seasonal density averages for all habitat types indicated a definite reduction in fry density between autumn and spring (Fig. 12). While this was partially attributable to fry mortality, it was chiefly the result of spring emigration from the system. A further reduction by summer indicated migration continued until then.

Underyearling trout were always more abundant above Mile 20.4 but yearlings during the spring were not (Fig. 13), suggesting that a general downstream migration was in progress. Seasonal density changes of older rainbow are also suggestive of a spring migration (Fig. 12). However, their low densities, combined with an absence from Marblehead fence catches implies that most trout migrate to Kootenay Lake during their first spring.

Habitat Descriptions

The upper Lardeau is important as an initial rearing area and newly emerged fry were studied in this area (Irvine, M.S. 1978). During the summer of 1974 eight stations were established to determine the role of overhanging cover, water depth, and current velocity in habitat selection by very young fry. Results obtained by snorkeling (Table 9) indicated the importance of cover to recently emerged fry. Also, fry were rarely encountered in areas with heavy current, yet were fairly abundant in similar, but calmer, areas. Evidence also indicated that fry preferred shallow regions.

The early habitat requirements of Gerrard fry are very similar to those reported in the literature for other salmonid fry. Hartman (1965), Lister and Genoe (1970), Mundie (1974), and others have reported the importance of slower water along the margins of streams. Most of the features suggested by Boussu (1954) and Mundie (1969) for optimal rearing-shallow depth, numerous marginal back eddies, copious overhanging vegetation, banks permitting hiding places, and high biological productivity are all prevalent at Gerrard.

Areas downstream of Gerrard provide the majority of rearing habitat after water levels have decreased in late summer. Information on habitat preferences of juvenile trout (0+, 1+) in this region was obtained during all seasons by electrofishing, and additionally during summer by direct counts using skin diving gear. Many small areas of relatively uniform habitat were sampled, each being categorized using a classification scheme similar to Allen (1951).

Results obtained downstream by diving were similar to Gerrard with pool habitats preferred by recently emerged trout (Table 10). A comparison of pools with and without overhanging cover indicated that young fry sought areas with overhanging cover. Water velocity, substrate size, and water depth tend to separate different age classes. Fry were found in areas of minimal current while older juveniles selected areas of medium current; fry were generally found in shallower areas than older fish, and in areas with smaller substrate size (Table 10).

Electrofishing density estimates were obtained during May 1974 (spring), August 1974 (summer), October 1974 (fall), late December 1974 early January 1975 (winter); and May 1975 (spring). Capture efficiencies varied seasonally and were probably lowest in log jam areas, where it seemed fish were better able to avoid capture. Nevertheless, results suggest in summer,

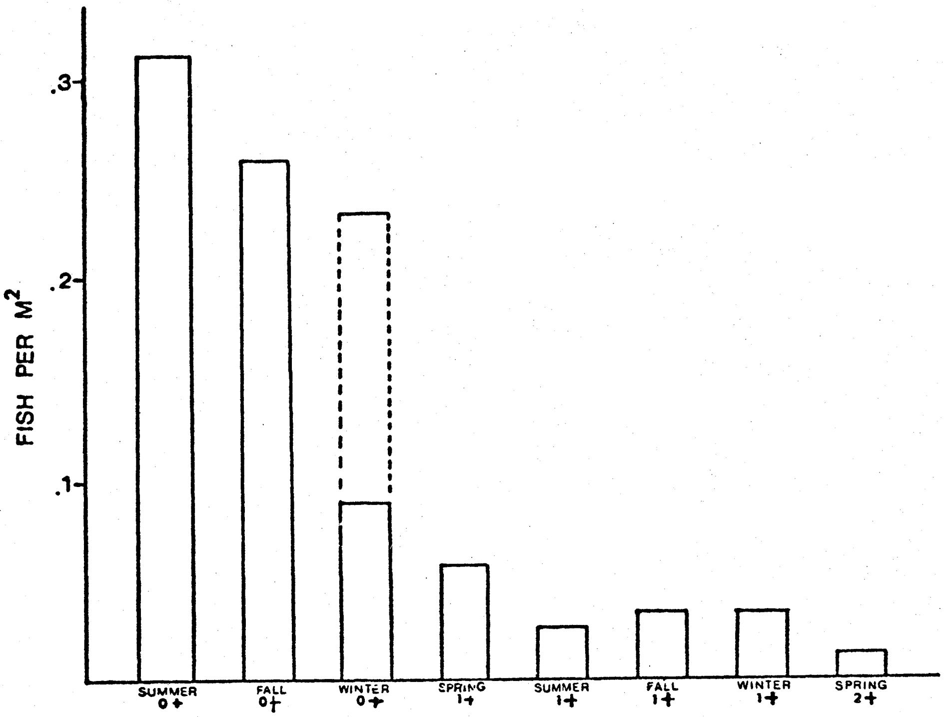

Fig. 12. Seasonal density estimates in the Lardeau (Extension of winter density histogram indicates density results that would likely have been obtained if winter fishing efficiencies were comparable to other seasons).

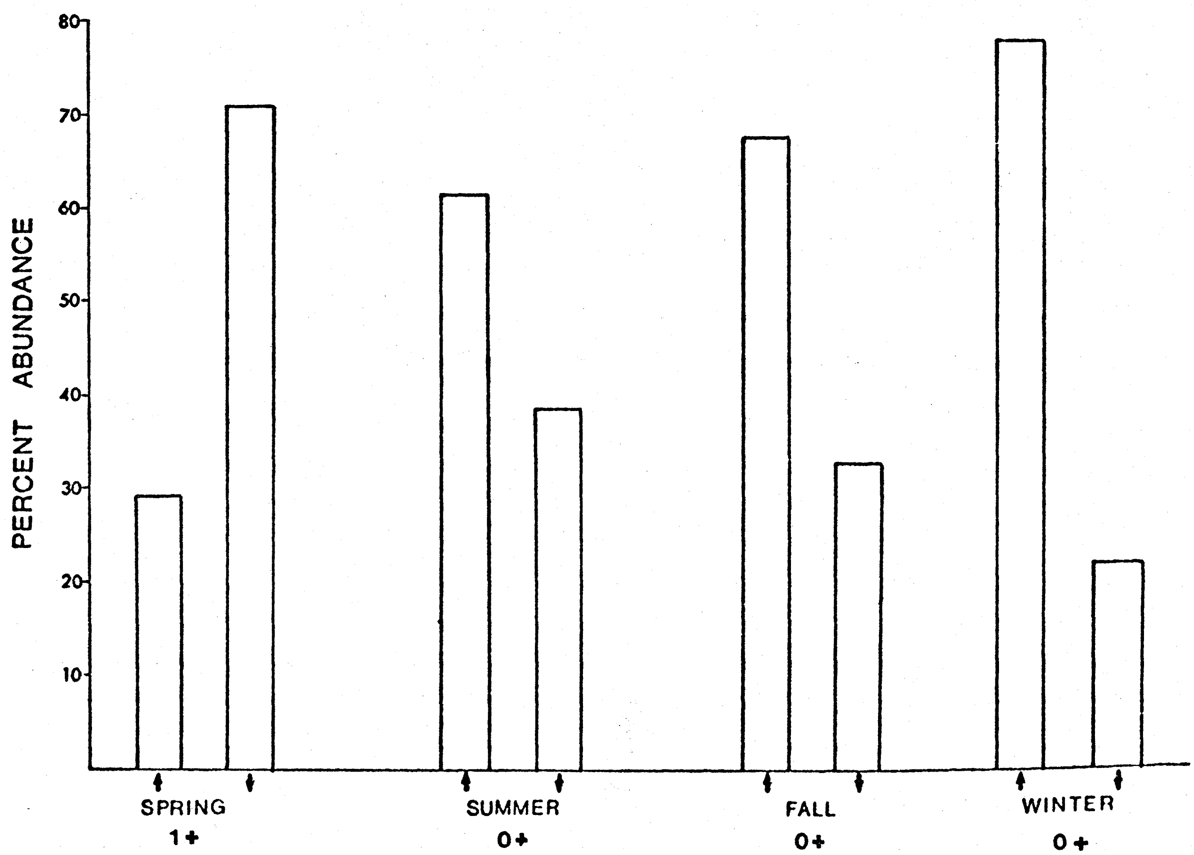

Fig. 13. Relative trout densities in the upper (↑) and lower (↓) halves of the river.

Table 9. Fry densities and physical descriptions of sampling sites at Gerrard.

Station Number	Area (m^2)	Overhanging Cover (+ or -)	Current Velocity (cm/sec)	Average Depth (cm)	Substrate Type	Fry Density (no./m^2)
1	4	-	<7.5	63	large rocks, (>15 cm dia.), grasses, silt	0.6
2	4	+	<7.5	24	medium rocks (8 - 20 cm dia.), grasses	0.5
3	4	-	<7.5	30	same as above	0.3
4	4	+	<7.5	20	same as above	1.9
5	4	-	<7.5	11.5	same as above	0.8
6	4	-	67	70	small gravel, (<8 cm dia.)	0.0
7	4	-	45	34.5	same as above	0.1
8	8	-	<7.5	36	organic debris	1.1

Table 10. Summer diving observation results downstream of Gerrard.

Runs and Pools	Run	0+	1+	Pool	0+	1+
Totals	1553 m^2	202	21	172 m^2	83	0
Densities (per m^2)		.13	.01		.48	0

Pools	With Overhanging Cover	0+	1+	Without Overhanging Cover	0+	1+
Totals	97 m^2	71	0	75 m^2	12	0
Densities (per m^2)		.73	0		.16	0

Surface Water Velocity	0-15 cm/sec	0+	1+	15-45 cm/sec	0+	1+	45-90 cm/sec	0+	1+	>90 cm/sec	0+	1+
Totals	577 m^2	224	0	448 m^2	48	11	460 m^2	13	10	240 m^2	0	0
Densities (per m^2)		.39	0		.10	.02		.03	.02		0	0

Substrate Size	<8 cm	0+	1+	8-20 cm	0+	1+	>20 cm	0+	1+
Totals	704 m^2	212	6	513 m^2	32	6	508 m^2	41	9
Densities (per m^2)		.30	.01		.06	.01		.08	.02

Water Depth	0-40 cm	0+	1+	40-80 cm	0+	1+	80-120 cm	0+	1+	>120 cm	0+	1+
Totals	611 m^2	224	5	374 m^2	61	7	340 m^2	0	6	400 m^2	0	3
Densities (per m^2)		.37	.01		.16	.02		0	.02		0	.01

1+ rainbow were found primarily in run and riffle habitat (Fig. 14). By fall there seemed to be a movement out of the riffles and into areas of slower current, such as pools. By winter, almost all fish were found in run habitats. During spring they adjusted to a more summer-like distribution. While riffle areas were increasing in importance, log jam areas were also significant. During summer, recently emerged fry avoid fast current riffle areas, preferring pool and run type habitats. A similar distribution exists in the fall, except there appears to have been a partial shift away from run habitats towards riffles. This is probably related to increased body size and the fishes improved ability to hold position in rapidly flowing water. By winter underyearlings have moved out of the riffles and are back in pool and run habitats. In spring, slow water areas still appear to be favoured, but log jams are also important (Fig. 14).

Juveniles (1+) were found chiefly in areas of relatively fast water during summer months (Fig. 14). By winter their distribution had shifted to areas having surface velocities less than 45 cm/sec. In spring their distribution was similar to that of fall. Yearling trout were most frequent in areas where substrate size exceeded 20 cm, except during summer (Fig. 14). Shifts in distribution related to velocity are less apparent for underyearling trout. They always tended to select areas of minimal current. Underyearling trout were usually most abundant in areas of medium sized substrate (8-20 cm) (Fig. 14). Areas of predominantly small substrate did not provide sufficient cover for young trout, and areas predominant in the largest size substrate were also typically where current velocities exceed those preferred by young trout.

Numbers of 1+ trout captured in pools (Fig. 14) were limited. However, there was a slight shift from deeper pools in the summer to shallower pools in the winter (Fig. 15). Trends were similar and more apparent for 0+ trout.

Stream habitat selection studies are lacking for non-anadromous rainbow trout populations but the results presented here agree, in general, with those available for steelhead populations. Compared to 1+ steelhead Everest and Chapman (1972) found 0+ steelhead in the summer commonly chose areas of slower current (< 15 cm/sec versus 50-100 cm/sec) and shallower depth (< 15 cm versus 60-75 cm). Pearlstone (1976) also found a segregation of year classes of summer rearing steelhead with 0+ fish in shallower regions of the stream (30 cm versus 53 cm) over smaller substrate (1-10 cm versus 5-20 cm) than 1+ steelhead. Comparable results were obtained for Lardeau River rainbow with current velocity, substrate size, and pool depth each resulting in a segregation of year classes at various times of the year. Bustard (1973) and Bustard and Narver (1975) reported that, in winter, juvenile *Salmo gairdneri* seek out areas of low velocity, with underyearlings frequently entering the substrate in shallow areas along the stream margin. In the Lardeau both age classes were found in low velocity regions during the winter. Underyearlings were usually in the substrate and often closer to the stream margin than older trout. Bustard (1973) and Bustard and Narver (1975) also found log jams to be of prime importance to overwintering yearling steelhead. Results obtained in the Lardeau River by electroshocking suggest log jam areas are only moderately important but this may be largely due to the low efficiency of this sampling technique in log jam areas.

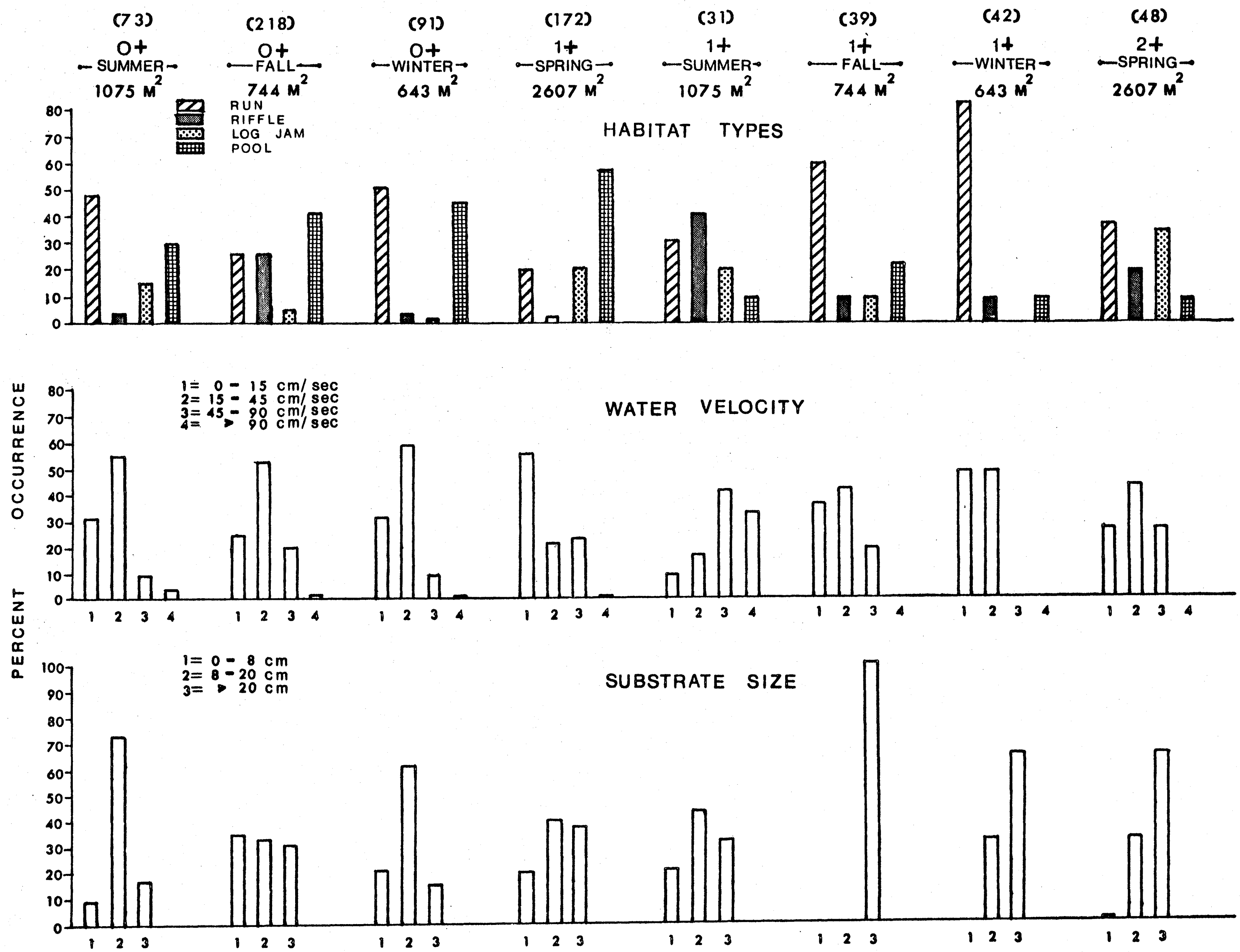

Fig. 14. Per cent occurrence of juvenile rainbow trout by habitat type, surface water velocity, and mean substrate size (numbers of fish in brackets).

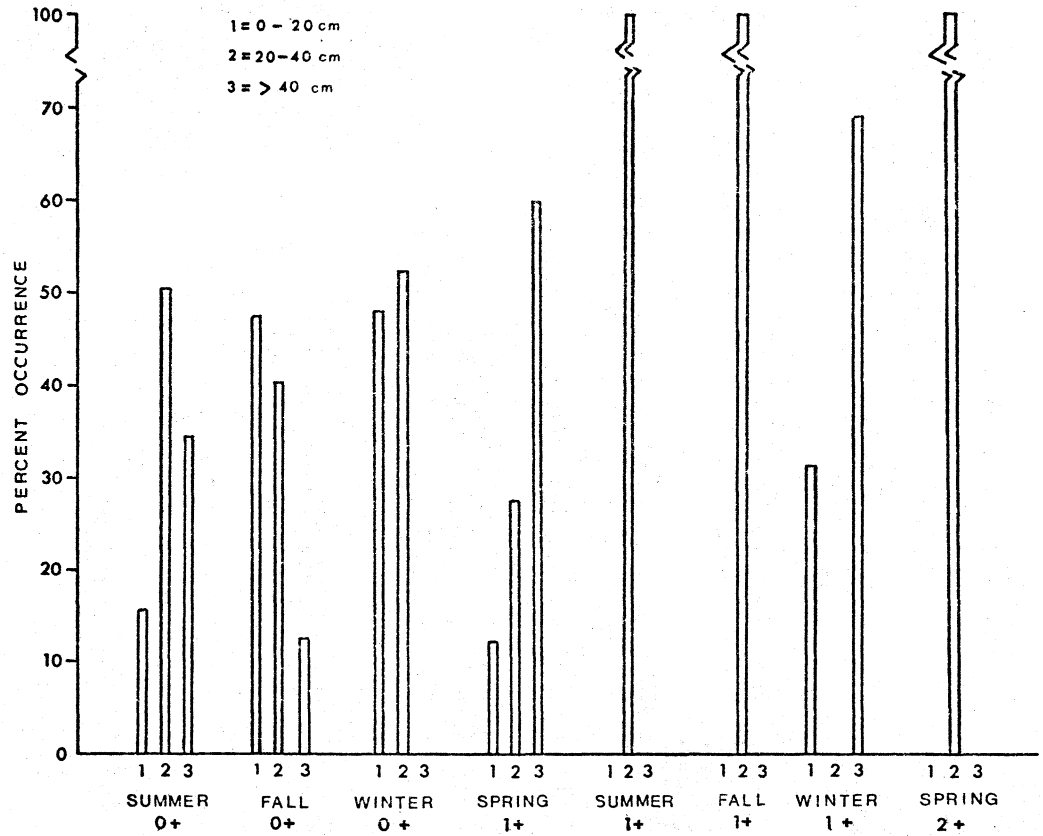

Fig. 15. Per cent occurrence of 0+ and 1+ trout in pools by depth.

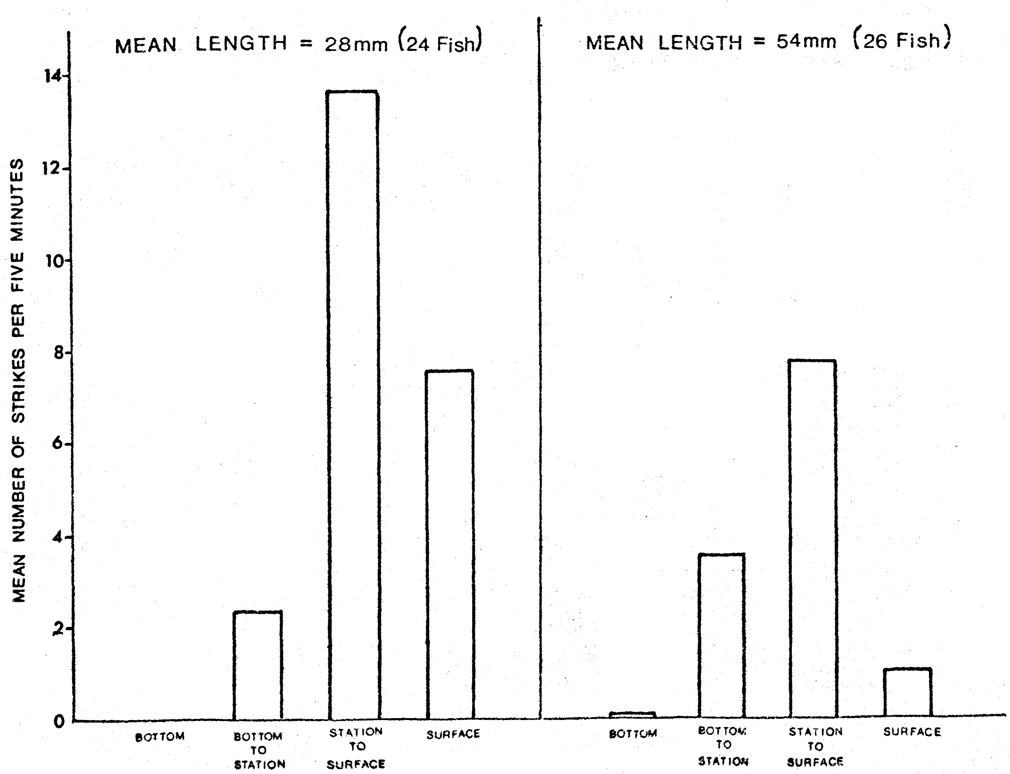

Fig. 16. Strike frequency in different portions of the water column.

Feeding

Observations and Earliest Feeding Patterns

Many attempts have been made to relate the feeding behavior of juvenile salmonids in the lotic environment to invertebrate drift, but only occasionally (Keenleyside, 1962; Jenkins, 1969; Griffith, 1974) has any attempt been made to observe fish feeding in their natural environment. Observations of Gerrard fry confirmed that drifting organisms comprised almost all food organisms consumed (Fig. 16) and that smaller (and presumably younger) fry struck more often per time interval than larger fry. These smaller fry appeared less selective, striking at, and rejecting, non-food items more frequently than older, and more experienced fry. Stomach content analyses found non-food items in their guts more frequently than in older fry.

Trout fed most frequently from that portion of the water column between the surface and their own station. While the second most favoured feeding zone of fry was the surface, larger juveniles fed second most frequently from that area between their station and the river bottom (Fig. 16).

Results of drift sample and fry stomach content analyses (Fig. 17 and 18) (note logarithmic axes) indicated that zooplankters were by far the most abundant potential food source at Gerrard at all times.[1]

Fry feeding and drift sample results from along the northeast bank on July 26 were similar. For both, zooplankton was always the most numerous constituent followed by lotic forms. Terrestrial insects were relatively rare. At the same location on August 8 zooplankters were the most frequently consumed food type in 50 per cent of the cases, being replaced by riverine forms and terrestrial insects at other times. This partial shift in prey preference may have been the result of increased fish size (Table 11) as the fry captured on August 8 were significantly larger than those captured on July 26 ($p = .05$).

Table 11. Length frequency and range data of fry captured at Gerrard.

Location	Date	N	Mean Size (mm)	Range (mm)
Northeast bank	July 26/27	75	30.9	27.2 - 36.9
Northeast bank	Aug 8/9	65	31.6	27.7 - 41.7
Southwest bank	July 26/27	43	34.2	27.8 - 49.0
Southwest bank	Aug 8/9	35	35.5	27.4 - 48.9

Fry captured from along the southwest bank on July 26 utilized zooplankton during one period only. At all other times they fed primarily on the second most numerous prey type. Fry captured from this site on August 8 never consumed zooplankton, but always fed most on the next most abundant food

[1]See Irvine (M.S. 1978) for a more detailed description of these and other fry feeding results.

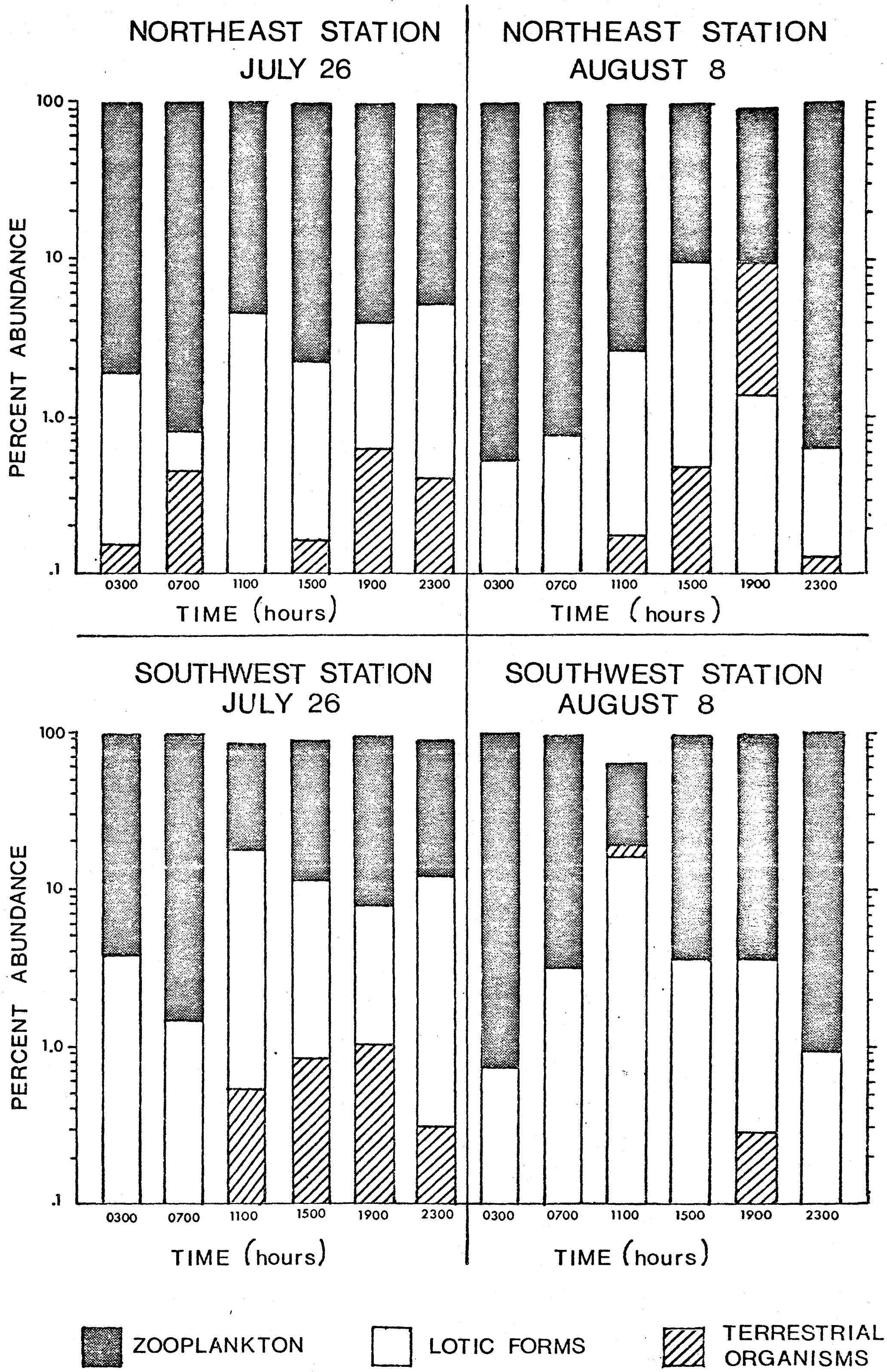

Fig. 17. Drift sample results from Gerrard (prey species only; values constituting histograms are additive).

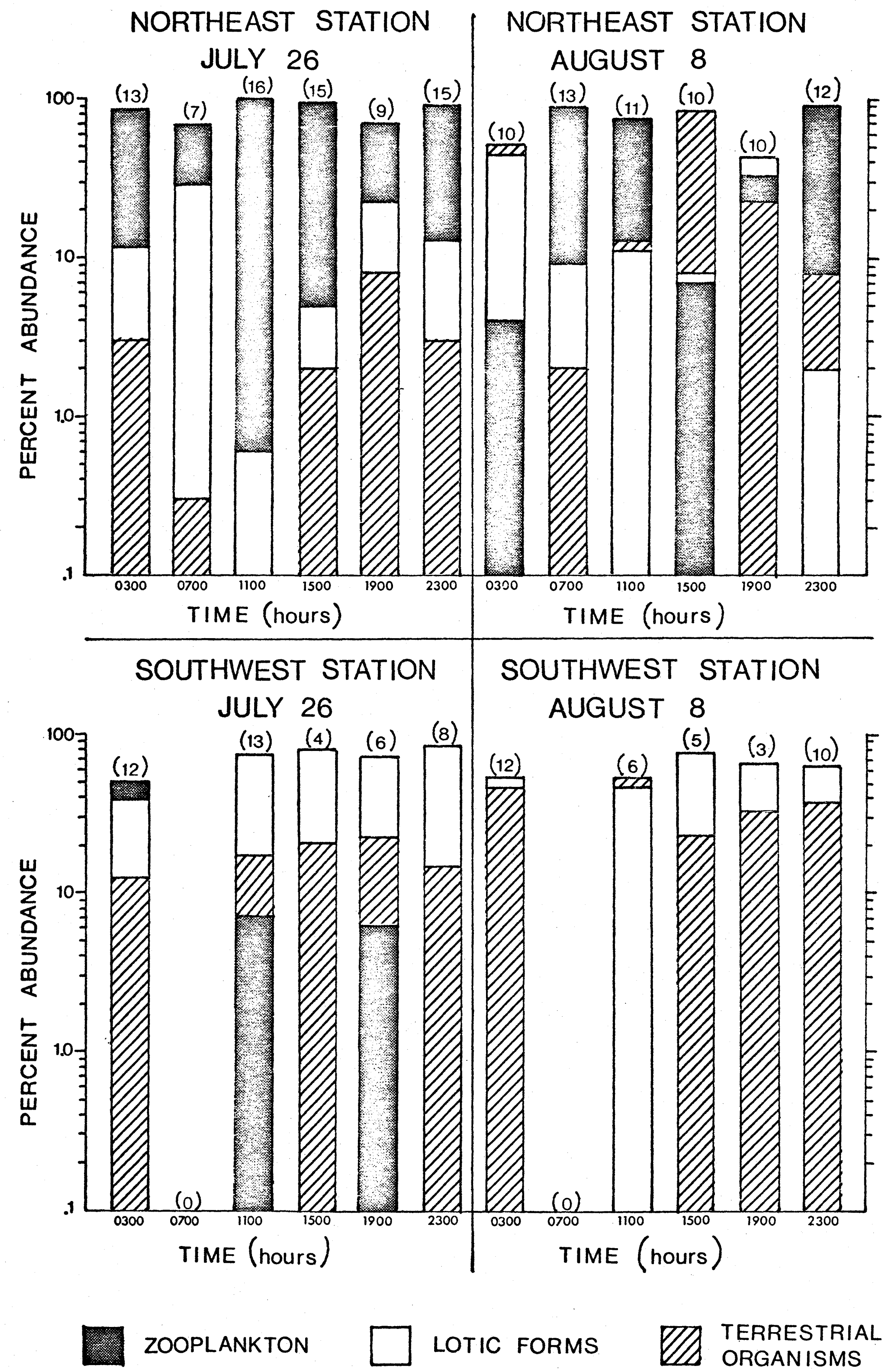

Fig. 18. Fry stomach content results from Gerrard (sample sizes indicated by numbers in brackets ; values constituting histograms are additive).

source. This apparent avoidance of zooplankton as a food source is also likely a consequence of increased size. Southwest bank caught fry were always significantly larger than northeast bank caught fry (p = .05).

These results confirm the conclusion reached earlier (Irvine, M.S. 1973), that zooplankton are very important to fry at Gerrard. Even though fry may only rear there for a short period, the extreme productivity of the area is significant in reducing mortality and increasing growth. Zooplankton appear to be the major food type of just emerged fry, but diminish in importance as fry grow, being replaced by food types which are less abundant, but larger and presumably energetically more profitable to consume. The small changes in fish size over time at particular sampling sites suggest not only that fry probably rear at Gerrard for only short periods, but also that similar sized fry select very similar microhabitats.

Seasonal Patterns

Results from stomach analyses of 96 underyearling trout (Fig. 19), captured in 1974 and 1975, from areas other than Gerrard, illustrate:

1. Zooplankton were consumed only during summer.

2. Chironomid larvae formed an important part of the diet in all seasons, except spring.

3. Other immature aquatic insects (plecoptera and ephemeroptera nymphs, trichoptera larvae) were favored during winter and spring.

4. Diptera pupae were an important dietary constituent during summer and fall, and terrestrial adult insects, especially during the fall.

5. Kokanee fry were consumed during the spring and kokanee eggs formed a significant part of the diet in the fall.

Fry generally fed on those food items most abundant at a given time of year (Table 6).

Substantial numbers of kokanee eggs and fry are consumed by underyearling trout. Older trout also utilize kokanee eggs and fry. Of 295 food items found in the stomachs of ten fall caught yearlings, 67 per cent were kokanee eggs. Two of 9 spring caught 2+ fish had fed upon kokanee fry. Spawning kokanee are present from late August until early November. Downstream migrating kokanee fry are probably present in the river from early April until late June. Kokanee fry and eggs may thus increase the growth rate of juvenile trout. McCart (1966) found rainbow trout from the upper Babine River to have a faster growth rate than trout from the north arm of Babine Lake and suggested this may have been due to the greater availability of salmon eggs and fry to the river trout.

Spatial Patterns

Spatial trends are not as dramatic as seasonal trends, but the following can be seen (Fig. 20):

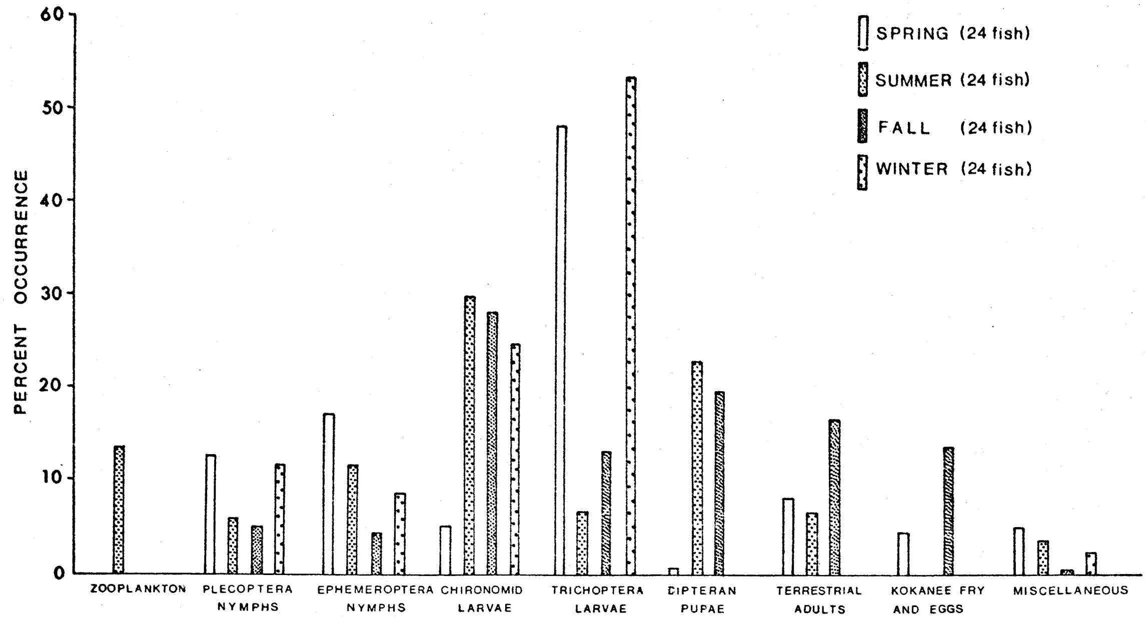

Fig. 19. Seasonal feeding results.

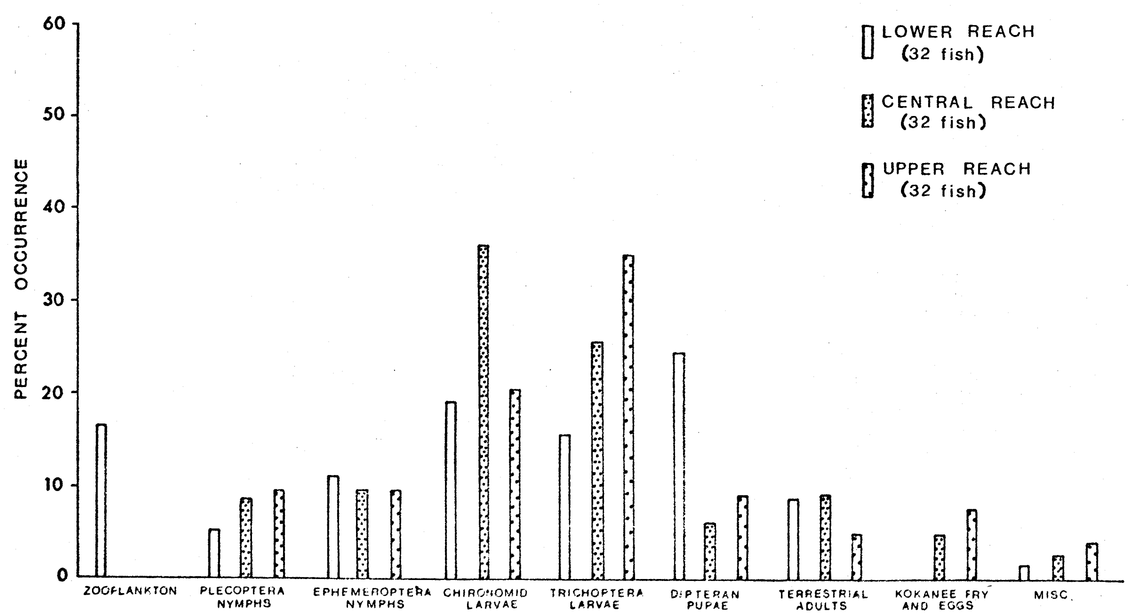

Fig. 20. Longitudinal feeding results.

1. Chironomid larvae are the most important food type in the middle reach.

2. Trichoptera larvae are more important further upstream.

3. Terrestrial insects and diptera pupae seem least important in the upper portion of the river.

4. Zooplankton are utilized in the lower reach.

Field collection by Cartwright (1961) in the summer of 1958 were recently analyzed and provided similar results (Fig. 21), except that zooplankton were the most important food item in the upper reach. Two-thirds of the food items found in 246 fry from the upper regions were zooplankton.

Length, Weight, Growth Rates, and Condition

Due to the size selective nature of the electrofishing technique, frequencies of different age-classes are not completely accurate. During August, the Petersen (length frequency) method was sufficient to distinguish between fry and older juveniles (Fig. 23). Fry ranged between 26.0-62.8 mm with an average of 40.2 mm (Table 12). Older juveniles were almost entirely 1+. Of scales examined from 17 juveniles ranging from 80-161 mm, 16 were from 1+ fish and one from a two-year old. One hundred and forty fry sampled in October ranged from 41.2-92.4 mm with a mean length of 62.0 mm (Table 12). Older fish were once again shown to be almost exclusively 1+. By winter, the length frequency method was no longer always successful in distinguishing between 0+ and older fish (Fig. 23). Scales were examined from 21 fish ranging between 98-157 mm. Three fish were in their first winter, fifteen in their second and three in their third. It was concluded that fish less than 100 mm were in their first winter, while most greater than 100 mm were in their second. Of scales examined from fish captured during May, all those from fish less than 110 mm indicated the completion of only one annulus, while almost all those from larger fish had completed two.

As would be expected, most growth took place between spring and fall, for both age classes. Yearlings grew an average of 12.5 mm per month over this period; their instantaneous growth rates were 0.0143 and 0.0043 per day (weight and length respectively).

The logged length-weight regression for all fish (Fig. 22) reveals two distinct growth stanzas, one above and one below 40 mm. Length-weight regressions were performed for each age class by season and condition factors ($K = W/L^3$) computed (Table 13). Caution must be exercised in the interpretation of these data, especially when comparing summer caught fry to other fish. This is due to the significantly different length-weight relationship of summer caught fish.

Significant increases in condition ($P = .05$) occurred from summer to fall for both age classes, and from winter to spring for the youngest age class. Condition factors for yearlings decreased significantly from fall to winter.

Changes in condition appear related to food abundance and availability, which are restricted by high trout densities. Other workers (Mason and Chapman, 1965; McFadden, 1969; Slaney and Northcote, 1974) have demonstrated a strong relationship between food abundance and territory size, and Kalleberg (1958)

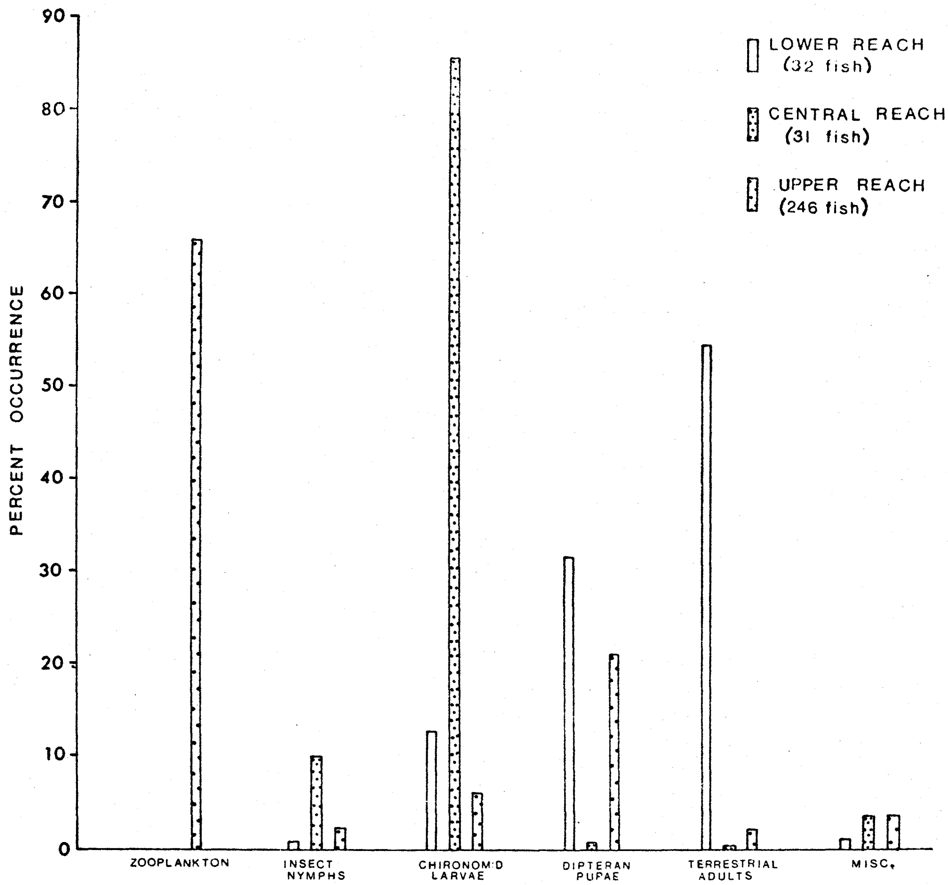

Fig. 21. Summer 1958 longitudinal feeding results.

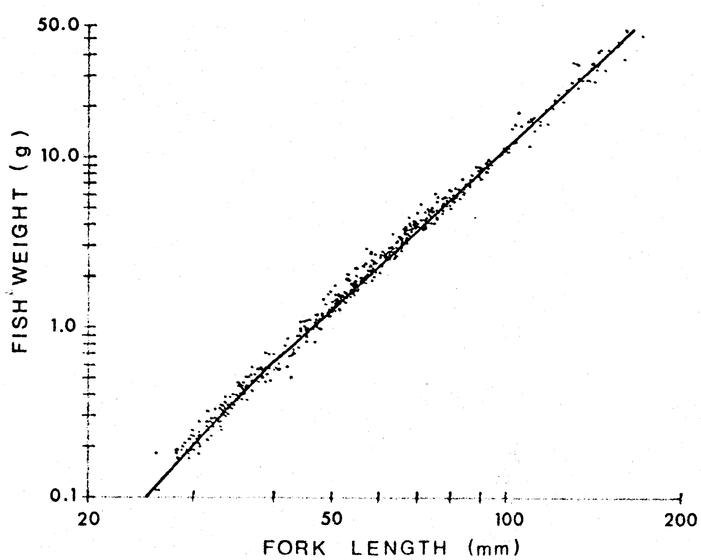

Fig. 22. Length-weight relationship of juvenile Lardeau River trout.

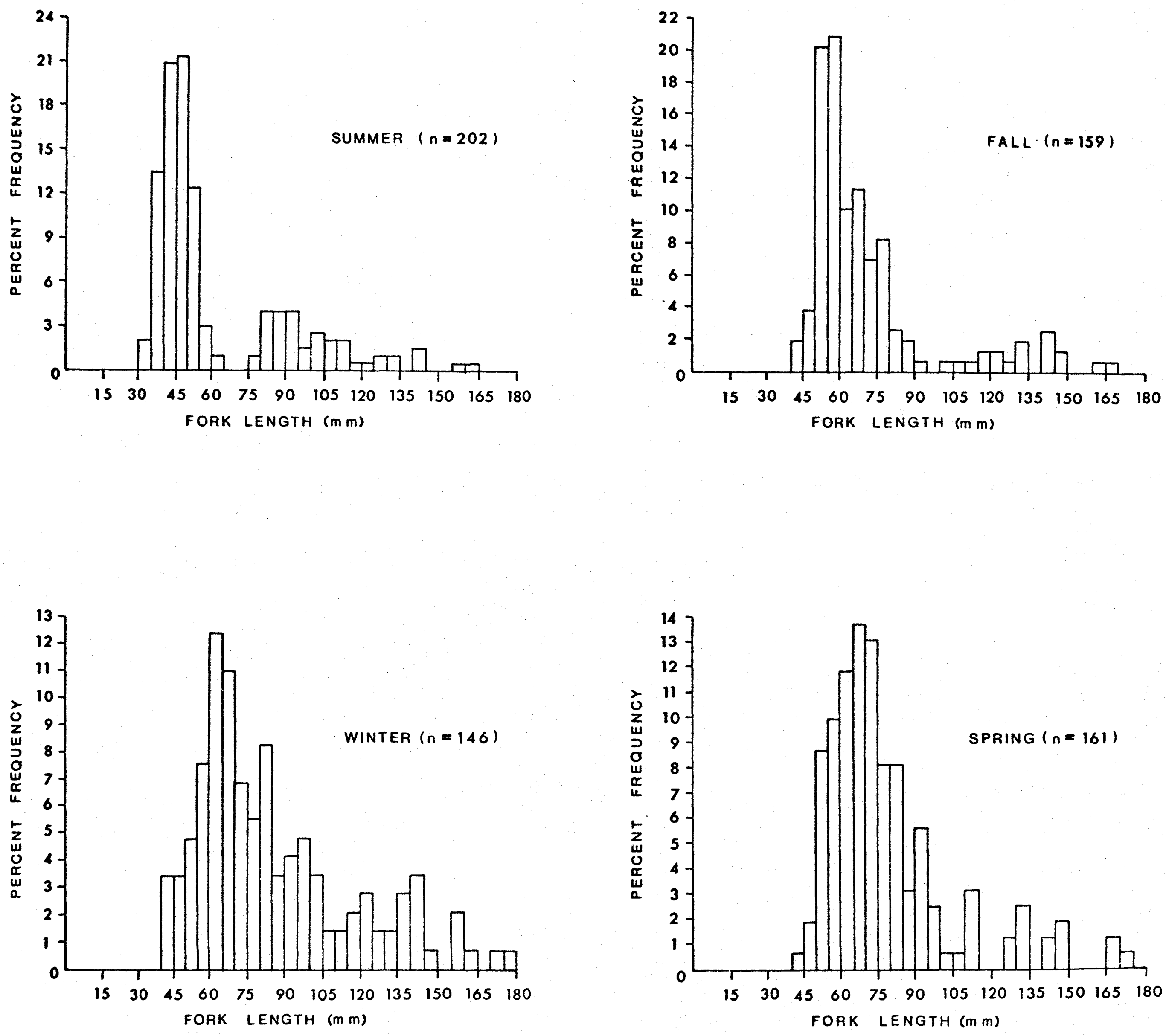

Fig. 23. Length frequency data of juvenile rainbow trout captured by electrofishing.

Table 12. Mean lengths and ranges of juvenile trout from within the Lardeau River.

Fish Population	N	Mean Length (mm)	Range (mm)
Total Summer 0+	261	40.2	26.0 - 62.8
Summer 0+ above mile 20.4	97	36.7	26.0 - 56.3
Summer 0+ below mile 20.4	164	42.3	28.2 - 62.8
Total Fall 0+	140	62.0	41.2 - 92.4
Fall 0+ above mile 20.4	107	63.6	42.2 - 92.4
Fall 0+ below mile 20.4	33	56.8	41.2 - 77.3
Total Winter 0+	112	70.0	40.9 - 100.5
Winter 0+ above mile 20.4	48	76.2	45.1 - 100.5
Winter 0+ below mile 20.4	64	65.4	40.9 - 98.9
Total Spring 1+	142	70.0	44.3 - 109.3
Spring 1+ above mile 20.4	51	71.3	44.3 - 102.0
Spring 1+ below mile 20.4	91	69.3	49.0 - 109.3
Total Summer 1+	53	102.4	75.6 - 160.8
Summer 1+ above mile 20.4	12	124.1	75.6 - 160.8
Summer 1+ below mile 20.4	41	96.0	75.5 - 132.0
Total Fall 1+	19	132.3	102.2 - 168.0
Fall 1+ above mile 20.4	10	136.9	102.2 - 161.3
Fall 1+ below mile 20.4	9	127.1	105.2 - 168.0
Total Winter 1+	34	132.1	101.0 - 175.0
Winter 1+ above mile 20.4	10	136.7	101.9 - 175.0
Winter 1+ below mile 20.4	24	130.2	103.7 - 174.0
Total Spring 2+	19	135.5	111.3 - 171.6
Spring 2+ above mile 20.4	11	139.3	111.3 - 171.6
Spring 2+ below mile 20.4	8	130.3	111.4 - 145.0

Table 13. Logged length-weight functional regression formulae and condition factors (K) for juvenile trout from the Lardeau River.

Fish Population	Y Intercept	Slope (b)	N	K
Summer 0+	- 5.845	3.511	181	0.91
Fall 0+	- 5.205	3.139	121	1.11
Winter 0+	- 5.540	3.318	76	1.10
Spring 1+	- 4.730	2.888	54	1.17
Summer 1+	- 5.284	3.173	37	1.16
Fall 1+	- 4.918	3.016	10	1.32
Winter 1+	- 4.773	2.933	21	1.20
Spring 2+	- 5.683	3.352	10	1.14
All fish <40 mm	- 6.417	3.888	122	0.87
All fish >40 mm	- 5.264	3.169	388	1.12

Table 14. T test results comparing length frequencies of juvenile trout above and below mile 20.4.

Populations being Tested	t calc.	d.f.	t .05
Summer 0+ above and below	5.99	259	1.65
Fall 0+ above and below	3.38	138	1.66
Winter 0+ above and below	3.90	110	1.66
Spring 1+ above and below	0.85	140	1.66
Summer 1+ above and below	3.35	12.5	1.78
Fall 1+ above and below	1.18	17	1.74
Winter 1+ above and below	0.74	12.4	1.78
Spring 2+ above and below	1.02	17	1.74

has proposed that non-reproductive territoriality evolved as a food supply mechanism. In the Lardeau, yearlings did not increase in condition from spring to summer, and summer fry were in poor condition, suggesting that some environmental factor was limiting during summer. This leads to the hypothesis that high trout densities, the consequence of recent fry emergence, produce relatively small territories making food limiting. From summer through fall, condition factors of 0+ and 1+ groups increased, probably the result of larger territories caused by fry mortality and increased food abundance (especially kokanee eggs). Since underyearling condition factors did not decline between fall and winter, food is probably not limiting during the latter season. High winter drift densities (Table 6) support this conclusion. Other environmental factors (e.g. low temperatures) are probably responsible for the decline in condition of yearlings from fall to winter. From winter until spring, emigration and mortality combine to increase territory sizes. These larger territories (and hence increased food availability), as well as improved environmental conditions are probably responsible for producing the significant increase in condition observed from winter to spring for the younger cohort.

Length-weight data did not vary along the river. However, except for underyearlings during summer, rainbow trout from the upper half of the river were always longer than rainbow trout from the lower half (Table 12). These differences were statistically significant for fall and winter fry, and summer yearlings (Table 14). During August, fry were still adjusting their longitudinal distribution within the Lardeau, and in fact, many were in the process of migrating to Kootenay Lake. It is, therefore, not surprising to find larger fry in the lower portion of the river. Similarly, significant differences are not to be expected during spring because of emigration. Statistically significant differences in length for yearlings are difficult to demonstrate due to small sample sizes. In conclusion, while length-weight relationships remain similar, juvenile trout in the upper half of the river are generally largest, except during periods of emigration; increased size being a consequence of better habitat and increased food abundance.

Species Interactions

During the summer of 1974 kokanee were the dominant salmonid fry at Gerrard until approximately July 20, after which time numbers declined rapidly. Since considerable numbers of these fry were captured by fyke nets in the Lardeau immediately above Mobbs Creek during July, it is assumed that they were of Kootenay Lake origin. Kokanee fry have been noted rearing at Gerrard in other years (Gil Palmer, pers. comm.), but their large numbers in 1974 were probably atypical. Unusually high water levels that summer created an abundance of slack water areas, highly suitable for rearing. Late-emerging kokanee fry may have remained there, utilizing the good habitat provided by the high water, before migrating downstream. Their numbers at Gerrard declined rapidly in the last 10 days of July.

Interspecific competition between kokanee and rainbow fry at Gerrard is likely. Although stomach content analyses of the former showed them to be planktivorous, competition for food is probably not important due to the inexhaustible supply from Trout Lake. More significant is the finite amount of good rearing space. While diving at Gerrard, large numbers of rainbow and kokanee fry were frequently observed cohabiting similar areas and interspecific aggressive behavior was not uncommon. The more aggressive rainbow fry may have partly caused the downstream displacement of the kokanee fry.

At the onset of rainbow emergence, spawning redside shiners (*Richardsonius balteatus)*, and later in the emergence period, young shiners, are abundant along the river edge at Gerrard. No evidence of shiner predation on young trout was found although the opposite relationship was occasionally observed while diving. The net effect of shiners on trout fry is probably minimal. The same is probably true for other cyprinids frequenting the area such as peamouth chub, large scale and longnose suckers, as well as slimy sculpins.

Some species, found at Gerrard and further downstream, do predate on juvenile trout. Cartwright (1961) found 3 of 22 mountain whitefish from the upper Lardeau, 4 of 7 Dolly Varden, and 11 of 65 larger rainbow to have consumed rainbow fry. American mergansers were also found to feed on juvenile rainbow. However, Cartwright (1961) concluded that the predatory impact of these and other species on juvenile trout in the Lardeau was minimal.

Numbers Using River for Rearing

A crude estimate of the number of rainbow trout overwintering in the Lardeau can be calculated by extrapolating from density estimates obtained during the sampling program. Since downstream juvenile migration was well underway by the spring period, fall results are more pertinent to this discussion. Approximate densities are known for a variety of habitat types. Unfortunately, it was impossible to accurately estimate the amount of each type of rearing habitat in the river. However, an estimate of the total area of river used can be made. Diving observations demonstrated that juvenile trout (especially underyearlings) were generally confined to the river margins in strips averaging 1.5 meters. Water velocities in more central river regions were generally too fast. The Lardeau flows approximately 65 river kilometers from Trout to Kootenay Lake. Assuming only a 1.5 meter strip is used alongside both banks for rearing, 195,000 m^2 are available for this purpose. This is undoubtedly an underestimate, not accounting for the river's numerous side and back channels. Densities in these strips are approximately equal to the average of densities of the three major habitat types: runs, riffles, and pools. The average October fry density estimate for these three habitats was 0.33/m^2 while the corresponding yearling density estimate was 0.03 fish/m^2. Since fish were able to escape without being seen during sampling, a more reasonable total density estimate is 0.5 fish/m^2. Therefore, approximately 97,500 juvenile trout (195,000 m^2 x 0.5 fish/m^2) utilize the Lardeau for rearing in October.

LAKE LIFE HISTORY

Distribution

Although information is meager, large rainbow trout within Kootenay Lake apparently are distributed throughout the north and south arms. Since the fishery on them has historically been concentrated in the north arm, it has been assumed the majority live in that portion of the lake. However, since construction of the Duncan and Libby Dams, catches of large rainbow in the north arm have declined significantly, while south arm catches have increased. The speculation has, therefore, been made that the large trout of Kootenay Lake may have redistributed themselves in response to changes in temperature, water currents, and/or food distribution, arising out of the operation of the Duncan Dam (Andrusak, M.S. 1974; Andrusak and Crowley, M.S. 1976).

Feeding

Food habits of Kootenay Lake rainbow have been discussed by Northcote (1973) although more recent unpublished data are available. Terrestrial insects are the most important food item among small (< 30 cm) fish, and equally important with kokanee to intermediate (30-45 cm) sized trout although for the latter, aquatic insects and mysids are of some importance. With larger trout, kokanee are the major food type during summer and winter and surface insects, during spring (H. Andrusak, pers. comm.). Small sample sizes from earlier years (1928-29) made it difficult to demonstrate shifts in feeding habits over time (Northcote, 1973).

DISCUSSION

SURVIVAL ESTIMATES

Reproduction statistics for Gerrard trout (Table 15) and survival estimates (Table 16) provide an approximate description of the population dynamics of the Gerrard trout. The mean number of spawners (574) is the average of the two estimates for the years 1967-1976 (Table 3). Sex ratios and hence numbers of female spawners were obtained from early hatchery records. Values for fecundity, egg retention, total egg deposition, and egg loss due to displacement and whitefish predation were obtained as discussed previously. The number of fry migrating to Kootenay Lake during their first summer was obtained by Acara (M.S. 1969) and the number of October river rearing fry extrapolated from fall density estimates. Since other workers have demonstrated substantial declines in mortality after the first few months following fry emergence (Allen, 1951; LeCren, 1965; Mortensen, 1977), it was assumed that two-thirds of the fry surviving until October smolted in the spring. Assuming these smolts constitute the majority of those individuals surviving to spawn at Gerrard, these figures imply that the most profitable means of population enhancement is the reduction of early fry mortality within the Lardeau. Therefore, it may not be worthwhile to expend effort to improve spawning conditions or egg-to-fry survival. The substantial numbers of trout emigrating to Kootenay Lake during their first weeks probably do so in response to density dependent factors operating in the river. Mortality and emigration rates among fish rearing in the river are likely very high for the first several months after emergence until fish numbers approximate the river's carrying capacity. Mortality after this period is probably reduced. Within Kootenay Lake natural and fishing mortality combine to reduce survival. The former is very difficult to control and reduction of the latter could have adverse sociological repercussions. The results of this study indicate increasing the rearing capacity of the Lardeau River as the best means of enhancing the Gerrard population.

RECOMMENDATIONS

Habitat Protection

Throughout this document the importance of the Lardeau River as a nursery area for Gerrard trout has been stressed. It is strongly recommended that every possible effort be made to preserve its rearing capabilities. This can be accomplished, in part, by better public education. The local news media should be more efficient in advertising the importance of the rearing stream and the value of the fishery resource. As well, improved educational display facilities at Gerrard should be provided.

Table 15. Population statistics for Gerrard trout.

Mean number of spawners (1967 - 1976)	574
Sex ratio (♂ : ♀)	1.3:1
Number of female spawners	274
Fecundity	8,076
Egg retention	808
Total egg deposition	1,795,000
Egg loss due to displacement and whitefish predation	226,000
Remainder	1,569,000
Number of fry emerging (assuming 50% survival)	785,000
Number of fry leaving Lardeau system for Kootenay Lake within first 2 months after emergence	108,000
Number of fry rearing in river in October	97,500
Number of smolts leaving system in spring	65,000

Table 16. Calculated survival rates for Gerrard trout.

Period	Per cent Survival
Egg to emergent fry	44
Emergent fry to October fry	12.4
Egg to October fry	5.4
Emergent fry to spring smolt	8.3
Egg to spring smolt	3.6
October fry to spring smolt	66.7
Spring smolt to spawner	0.92
Egg to spawner	0.03

Logging operations in the Lardeau's tributaries and road maintenance along it affect the rearing potential of the system. Both can produce very turbid water reducing fry survival rates and should be monitored closely.

Research and Management

Serious gaps in our knowledge of the biology of the Gerrard trout should be apparent from this report. For example, virtually nothing is known about these fish once they enter Kootenay Lake. It is proposed that work be initiated which would establish the importance of the Lardeau as a rearing area and at the same time provide much useful information on the basic biology of the population. A tagging operation of juvenile trout within the river should take place, preferably using a magnetic nose-tagging machine (in conjunction with fin clips). At a later date, trout entering the sport fishery in Kootenay Lake, as well as fish spawning at Gerrard, would be examined for the presence of these markings. In addition to establishing the importance of the Lardeau system for rearing, this technique would also provide valuable information pertaining to migration patterns, fish growth rates, and stock abundance.

A detailed examination of scales from known Gerrard spawners (or at least large Kootenay Lake trout) is needed. The early circuli pattern should be examined, and compared to scales from Lardeau River juveniles for further information on their early life history. In addition to obtaining important growth data, it may become possible to distinguish between river resident trout and juvenile stream rearing Gerrard fish. Alternatively, electrophoresis could be done on alevins taken from the spawning gravel at Gerrard and compared with electrophoretic results from juveniles rearing in the river.

Before it is possible to make educated regulatory recommendations, more accurate information on stock size and fishing mortality is needed. As discussed previously, average duration periods of spawners at Gerrard should be obtained annually to more accurately estimate total spawner counts. Following this, additional information could be collected by the Kootenay Lake creel census. All large trout captured should be examined to determine if they would have spawned the following spring. The ratio of the number of large trout exhibiting these natural marks over the total number should be equivalent to the number of fish spawning at Gerrard over the total number in the population (Mottley, 1946) and could be used, as follows, in determining stock size:[1]

$$\frac{\text{no. ripe fish in fishery } (> 7\text{ kg})}{\text{total no. fish in fishery } (> 7\text{ kg})} = \frac{\text{no. fish spawning at Gerrard}}{\text{total no. fish in population } (> 7\text{ kg})}$$

$$\therefore \quad \text{total no. fish in population } (> 7\text{ kg}) = \frac{\text{total no. in fishery} \times \text{no. spawners at Gerrard}}{\text{no. ripe fish in fishery}}$$

[1]I thank A.D. Martin for suggesting this technique to me.

From the scale work described previously, the age composition of the catch should be determined over a number of years, and then, as described by Beverton and Holt (1957) and Ricker (1975), used to determine rates of fishing and natural mortality from catch and effort statistics. Estimates of stock size could then be obtained by combining this information with recruitment estimates.

Enhancement

Cost benefit analyses should be performed to determine the feasibility of artificially enhancing the rearing capacity of the Lardeau. Reviews of possible enhancement techniques are available (e.g. Parkinson and Slaney, 1975) and from these an artificial rearing channel seems most feasible. Three potential locations are the upper river near Gerrard, the lower river near the Duncan Dam outlet, or as part of the kokanee spawning channel complex at Meadow Creek. The first two locations have the advantage of being immediately adjacent to a plankton rich lake which could be used as a water source. The chief disadvantage of the Gerrard site is isolation; depending on the nature of the rearing development, some upkeep and consequently manpower may be required. This would not present a problem at the Meadow Creek location due to ongoing Fish and Wildlife activities there. Results obtained in this study describing habitat preferences of juvenile trout should be used, in combination with results from similar studies to determine optimum substrate sizes and water velocities. If costs are not prohibitive, some of Mundie's (1974) suggestions, including supplementary feeding and attraction of aerial insects by artificial illumination should be incorporated into the design. Alternatively, it should still be possible to produce substantial numbers of fry in more natural rearing channels by providing abundant cover, overhanging vegetation, and suitable substrate and velocity in a meandering sequence of riffles and pools. At minimum, a further development of the rainbow trout rearing operation at Meadow Creek, described by Andrusak and Fleck (1977), is suggested. More trout, both Gerrard and Duncan stocks should be reared, but throughout the winter, being released during their normal spring smoltification period. Returning spawners would be trapped, stripped, and their eggs artificially incubated and reared.

Considering the economic importance of the Gerrard trout, it is imperative that the above proposals be given serious consideration. Research towards Lardeau River enhancement should be begun immediately.

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