THE AQUATIC ENVIRONMENT, FISHES AND FISHERY ROSS LAKE AND THE CANADIAN SKAGIT RIVER

INTERIM REPORT NO. 2

VOLUME 1

MAY 1973

CITY OF SEATTLE · DEPARTMENT OF LIGHTING

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PART 1

INTRODUCTION

1.1 HISTORY OF ROSS LAKE

1.1.1 Original Plans

In 1918, the U. S. Department of Agriculture gave the City of Seattle permission to begin construction of power generating facilities on the Skagit River in north-central Washington State. The Lighting Department of the City proposed a staged development of three dams, called Gorge, Diablo and Ross. Long-range plans included the multi-stage construction of Ross Dam. The impounded waters forming Ross Lake, the principal storage reservoir for the three dams, were to finally reach the approximate elevation now contemplated.

1.1.2 Stages of Development

Construction began on Ross Dam in 1937 and was completed to an elevation of 1365 feet in 1940. Between 1943 and 1947 Ross Dam was raised to elevation 1550 feet. Completion of the dam to its present elevation of 1615 feet was accomplished in 1949.

Present plans include the final step of raising Ross Dam to a height of 1736 feet. The maximum elevation of Ross Lake would thereby be increased to 1725 feet from the present maximum of 1602.5 feet.

1.2 THE PRESENT STUDY

1.2.1 Objectives

An understanding of the condition of the fishes and fishery of the Ross Lake drainage area over the short and long term was the aim of this study. In order to achieve this understanding, a study of the present fish populations and fishery was designed. The results provide much of the data necessary for projections on the future state of the fishery.

1.2.2 Study Area

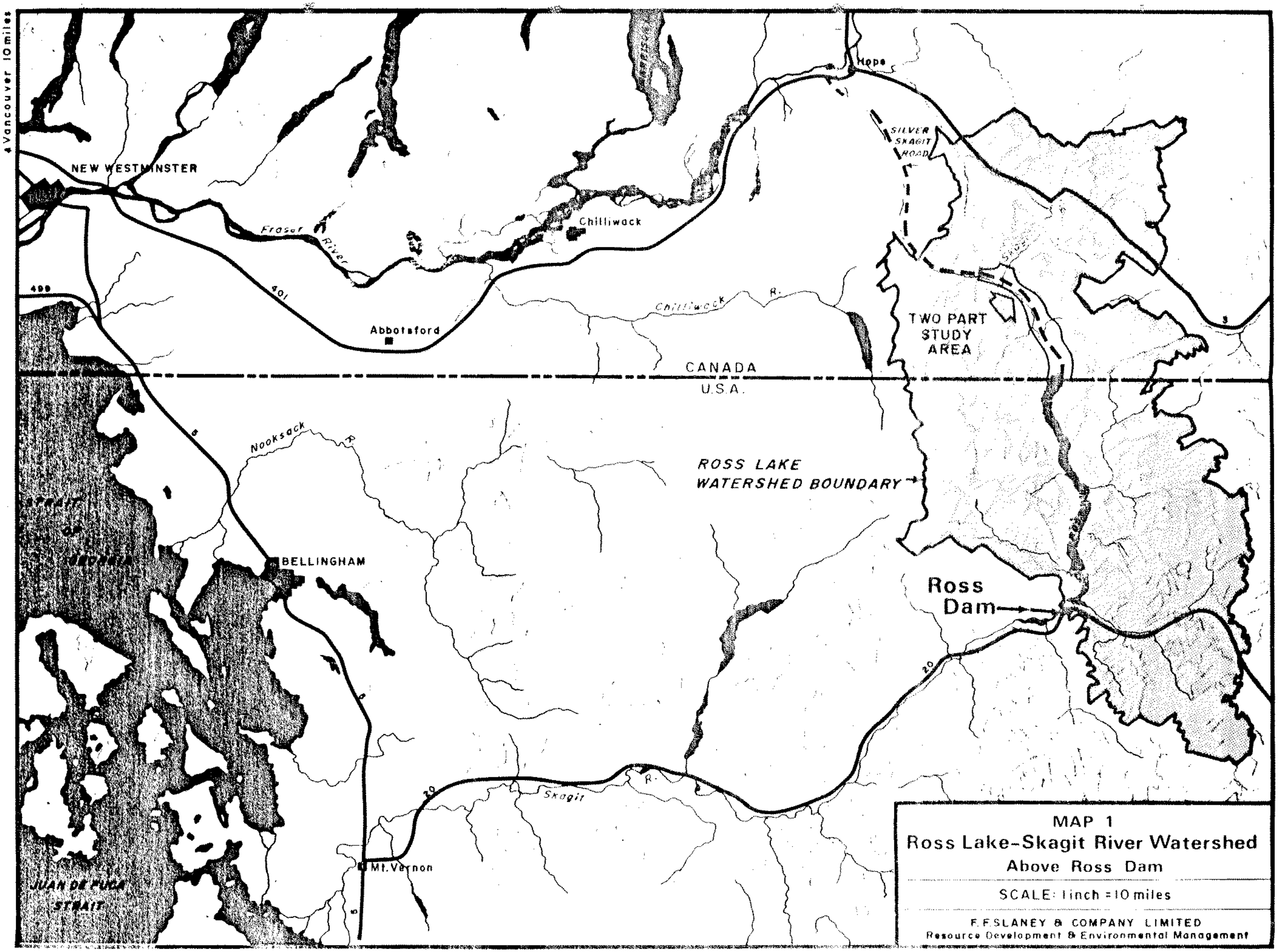
The study area encompasses the Skagit River-Ross Lake watershed above Ross Dam (see Maps 1 and 2). It includes Ross Lake to its maximum elevation of 1602.5 feet and the Skagit River in Canada. The study did not include areas or effects downstream from Ross Dam.

Major political jurisdictions within the watershed include the State of Washington, United States of America, and the Province of British Columbia, Canada.

1.2.3 Administration of Study

Design and co-ordination of this study was carried out under the aegis of the International Skagit-Ross Fishery Committee. Participating agencies included:

British Columbia Fish and Wildlife Branch
Bureau of Sports Fisheries and Wildlife (U.S.)
F. F. Slaney and Company



MAP 1
Ross Lake-Skagit River Watershed
Above Ross Dam

SCALE: 1 inch = 10 miles

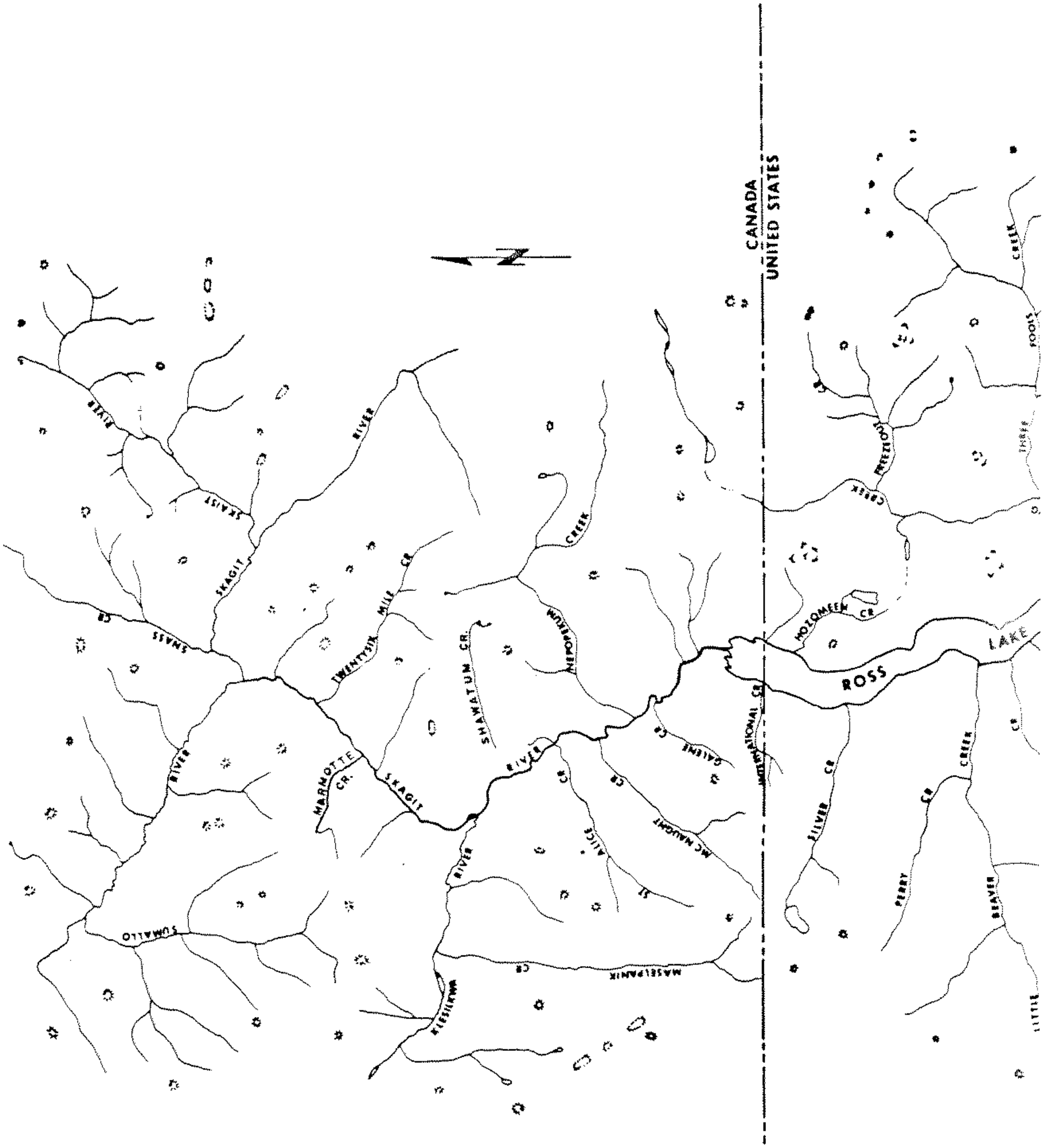
F.E. SLANEY & COMPANY LIMITED
Resource Development & Environmental Management

MAP 2

SKAGIT RIVER

Above Ross

With Ross Lake at Ele



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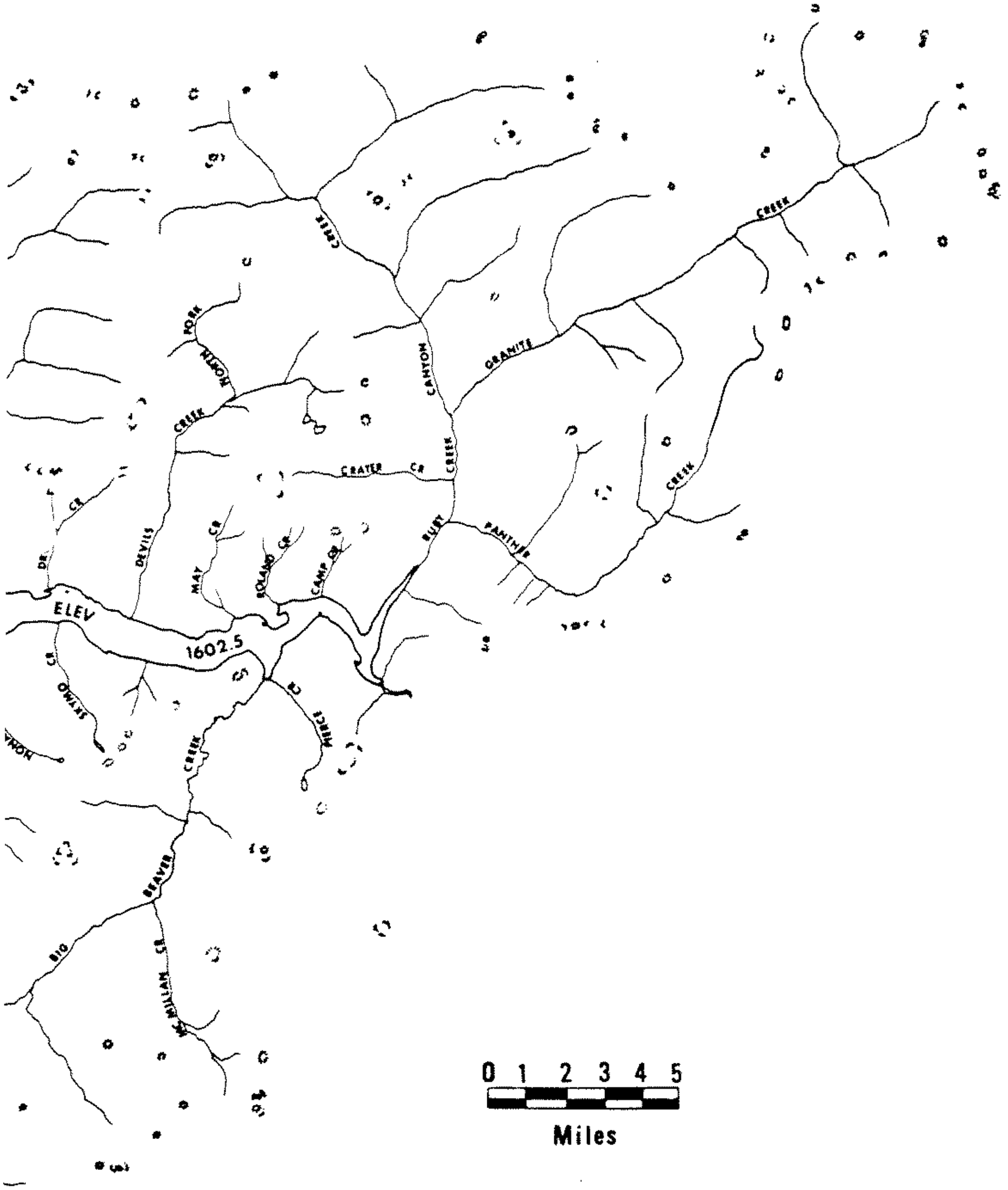

Fisheries Research Institute, University of Washington
National Park Service (U.S.)
Washington Department of Game

Approximately monthly meetings were held during 1971 and as necessary in 1972 to co-ordinate the activities of the various agencies involved.

1.2.4 Funding of Study

The field, analytical and administrative work represented by this report were supported financially through agreements between Seattle City Light and:

F. F. Slaney and Company
Fisheries Research Institute, University of Washington
Washington Department of Game.

1.3 THE REPORT

1.3.1 Volumes I and II

This report is in two portions. Volume I contains the results of the study through 1972 and includes projections of the possible future states of the aquatic environment of Ross Lake watershed, from data available to that time.

Volume II is a supporting volume containing additional data in tabular, diagrammatic and graphical form as well as descriptions of methods used in analysis of the data.

1.3.2 Report Preparation

The report is a result of the combined efforts of the agencies comprising The International Skagit-Ross Fishery Committee. Within the report, however, individual sections have been primarily the responsibility of one or a few agencies. In most cases, these are the agencies that had primary responsibility for implementation of the field program or analysis of the data, as well as the writing of the report, for that section. These agencies are identified by section throughout the report.

1.4 ACKNOWLEDGEMENTS

Individual participants in the deliberations of the International Skagit-Ross Fishery Committee acknowledge with thanks the assistance of colleagues in their respective agencies.

The agencies that had contractual obligations to this project extend their appreciation to the International Skagit-Ross Fishery Committee members who had no such commitment. The advice and assistance of the latter were most helpful.

The field crews were assisted greatly by employees of the National Park Service and of Seattle City Light. Mr. Wayne Dameron and his employees, of Dameron's Resort, also provided assistance.

Finally, with pleasure we thank the many anglers who graciously answered our questions, allowed their fish to be sampled, and in some cases filled out forms, for their co-operation.

PART 2

PRESENT ENVIRONMENT

2.1 ROSS LAKE

(by Fisheries Research Institute)

2.1.1 General Description

Ross Lake, 22 miles in length, is part of a 999 square mile watershed drained by the Skagit River, upstream of Ross Dam and several U.S. tributaries (Maps 1 and 2). The reservoir is located in northern Washington state and extends about one mile into British Columbia when at its highest level. All discharge from Ross Reservoir is by way of the Ross Dam/Powerhouse complex at the southern end of the lake. From Ross Reservoir, the water continues through Diablo and Gorge Reservoirs and 80 miles down the Skagit River into Skagit Bay in Puget Sound.

2.1.2 Reservoir Elevation and Size

The normal full reservoir elevation is 1602.5 feet above mean sea level (msl). Minimum reservoir elevation is 1475 feet above msl. Because of the elevation of the power tunnels at the intake the reservoir cannot be safely drafted below this minimum level without the hazard of the damaging consequences of air being drawn into the tunnels. The minimum level has not been reached since 1952 when the spillway gates were installed.

Surface area of the full reservoir (1602.5 feet msl) is 11,680 acres (18.25 square miles); the area of the reservoir at maximum permissable drawdown (1475 feet msl) is 4400 acres (6.88 square miles); mean depth of the full reservoir is 122.5 feet and the minimum reservoir, 93.6 feet. Reservoir volume at full reservoir is 1,435,000 acre feet and at maximum drawdown elevation (1475 feet), 412,000 acre feet. Lake volumes and surface areas for all lake elevations are presented graphically in Figure 2.1-1.

Shoreline length at full reservoir (1602.5 feet elevation) is 64.5 miles and shoreline development [1] is 4.26, at full drawdown (1475 feet elevation) 37.4 miles and 4.01, and at mean drawdown (1530 feet elevation) 51 miles and 4.07.

Summary physical data including shoreline length, surface area and lake volume at 25 feet elevation intervals are presented in Table 2.1-1.

2.1.3 Drawdown Schedules and Flushing Rates

Lake level fluctuations vary from year to year depending on weather, snow pack and discharge at the dam. Generally the spring runoff begins in mid-April and continues through July (Figure 2.1-2). The rates of filling and drawdown of the reservoir depend on the relative amounts of runoff and water used to generate power. The drawdown schedules for previous years are shown in Figure 2.1-3.

[1] Shoreline development is a quantitative expression which describes the irregularity of shoreline in the form of bays and projections of the shore. It is a ratio of the shoreline length to the circumference of a circle having the same area as the lake and is calculated from the formula:

$$SD = \frac{S}{2\sqrt{\pi A}}$$

where S is the shore length and A is lake area (Reid, 1965)

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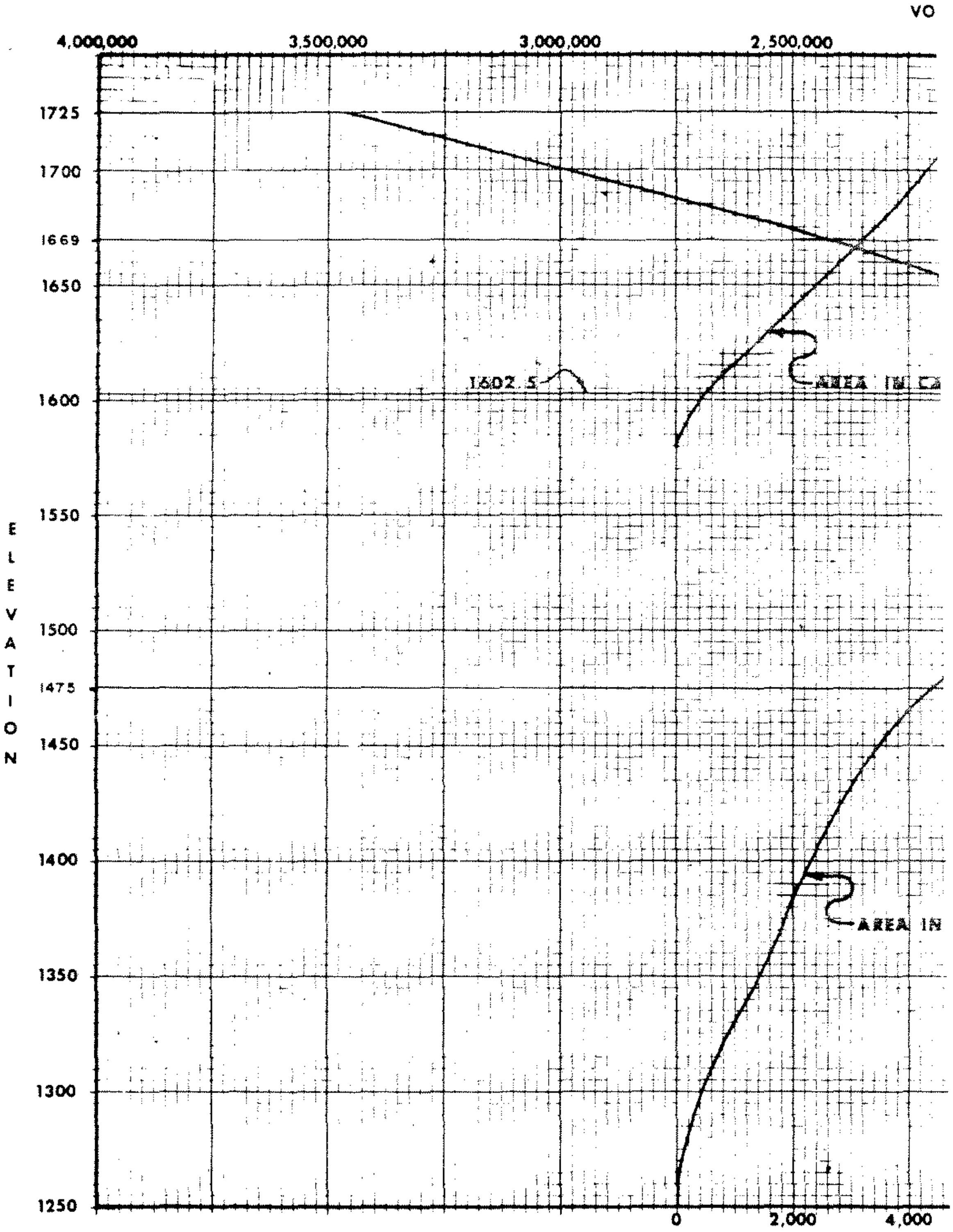
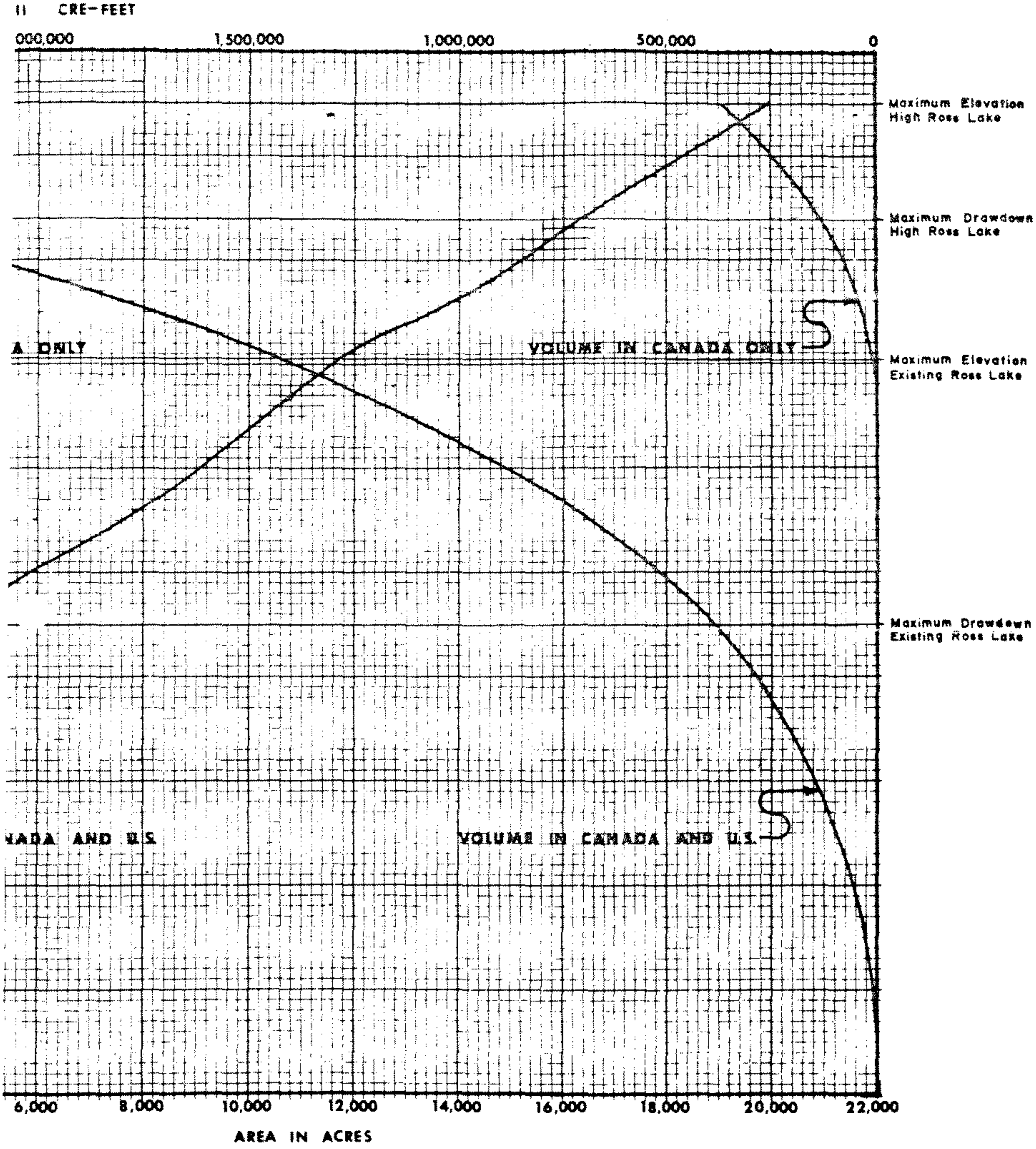
LAKE VOLUMES AND SUR



RE 2.1-1
E AREAS AT ALL ELEVATIONS



NOTE: CURVES DERIVED FROM THE
CITY OF SEATTLE'S "S" SERIES
TOPOGRAPHY OF ROSS RESERVOIR
WITH ADJUSTMENTS PER 1970 SURVEYS.

TABLE 2.1-1

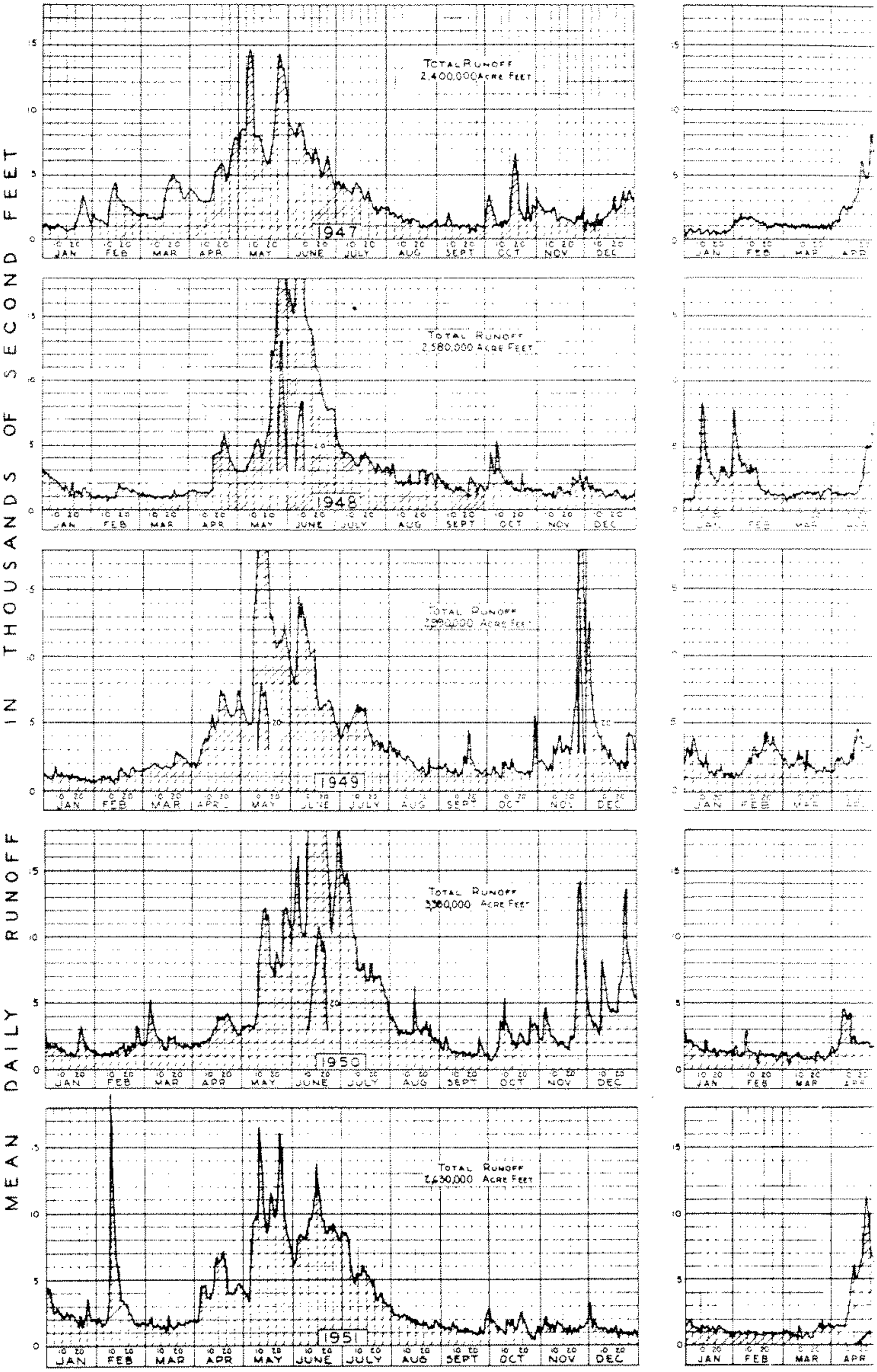
ROSS LAKE PHYSICAL DATA

Drainage Area	999 square miles
Mean lake elevation	1,575 feet
Mean drawdown elevation	1,530 feet

	Maximum Reservoir	Minimum Reservoir
Lake elevation	1,602.5 feet	1,475 feet
Lake volume	1,435,000 acre feet	412,000 acre feet
Surface area	11,680 acres	4,400 acres
Shoreline development	4.26	4.02
Mean depth	122.6 feet	93.6 feet

Lake elevation (feet)	Shoreline length (miles)	Area * (acres)	Lake volume * (acre feet)
1602.5	64.5	11,680	1,435,000
1600	64.3	11,600	1,390,000
1575	58.8	10,280	1,125,000
1550	53.3	9,040	890,000
1525	50.3	7,600	680,000
1500	43.7	5,840	520,000
1475	37.4	4,400	412,000
1450	29.1	3,400	285,000
1425	26.9	2,820	210,000
1400	24.3	2,300	140,000
1375	21.2	1,850	90,000
1350	19.4	1,400	60,000
1325	16.7	900	25,000
1300	13.4	420	10,000

* Values taken from Seattle City Light drawing C-6048



NOTE : Figure provided by City of Seattle
Department of Lighting

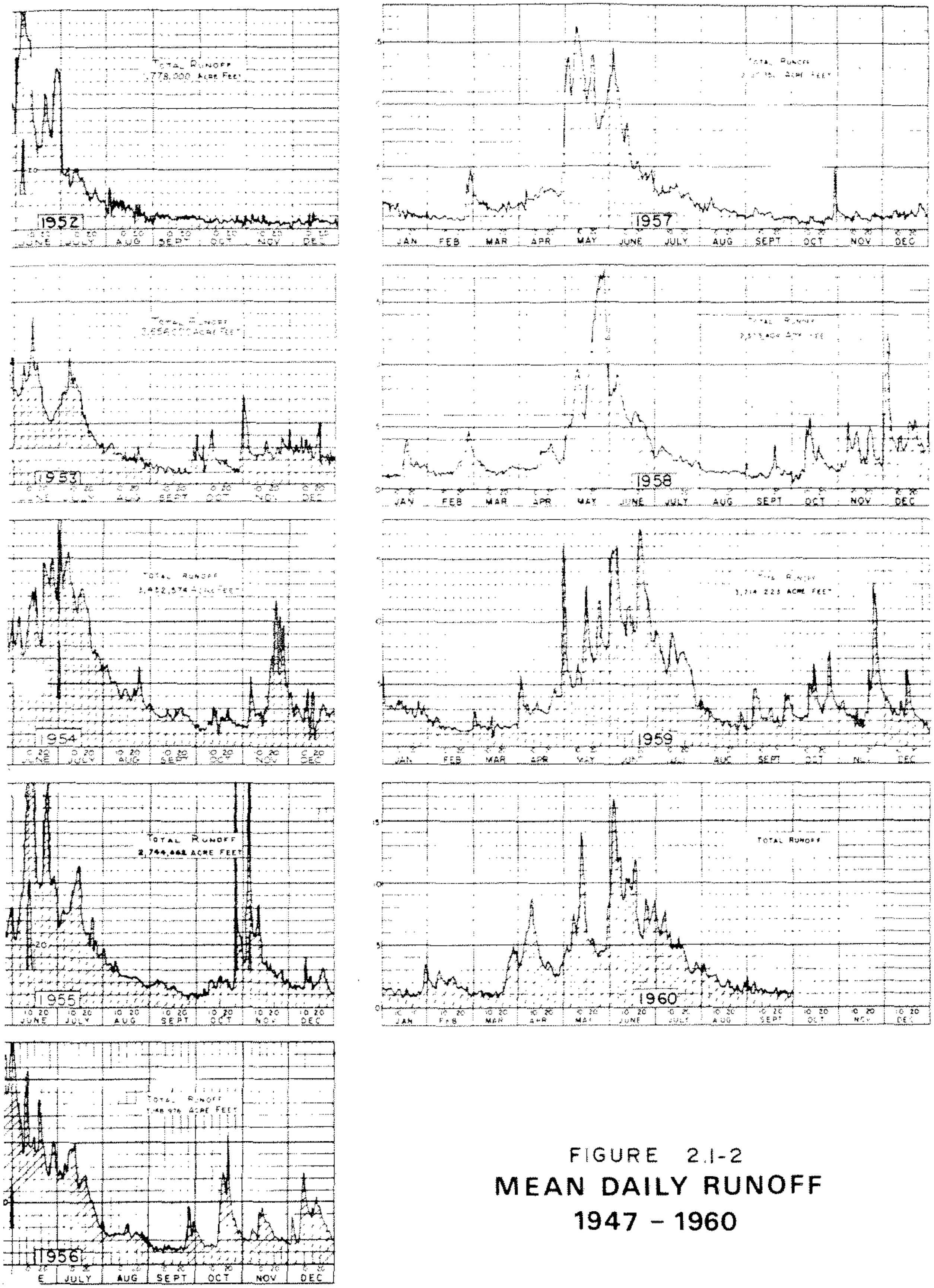


FIGURE 2.1-2

MEAN DAILY RUNOFF
1947 - 1960

FIGURE

MEAN D

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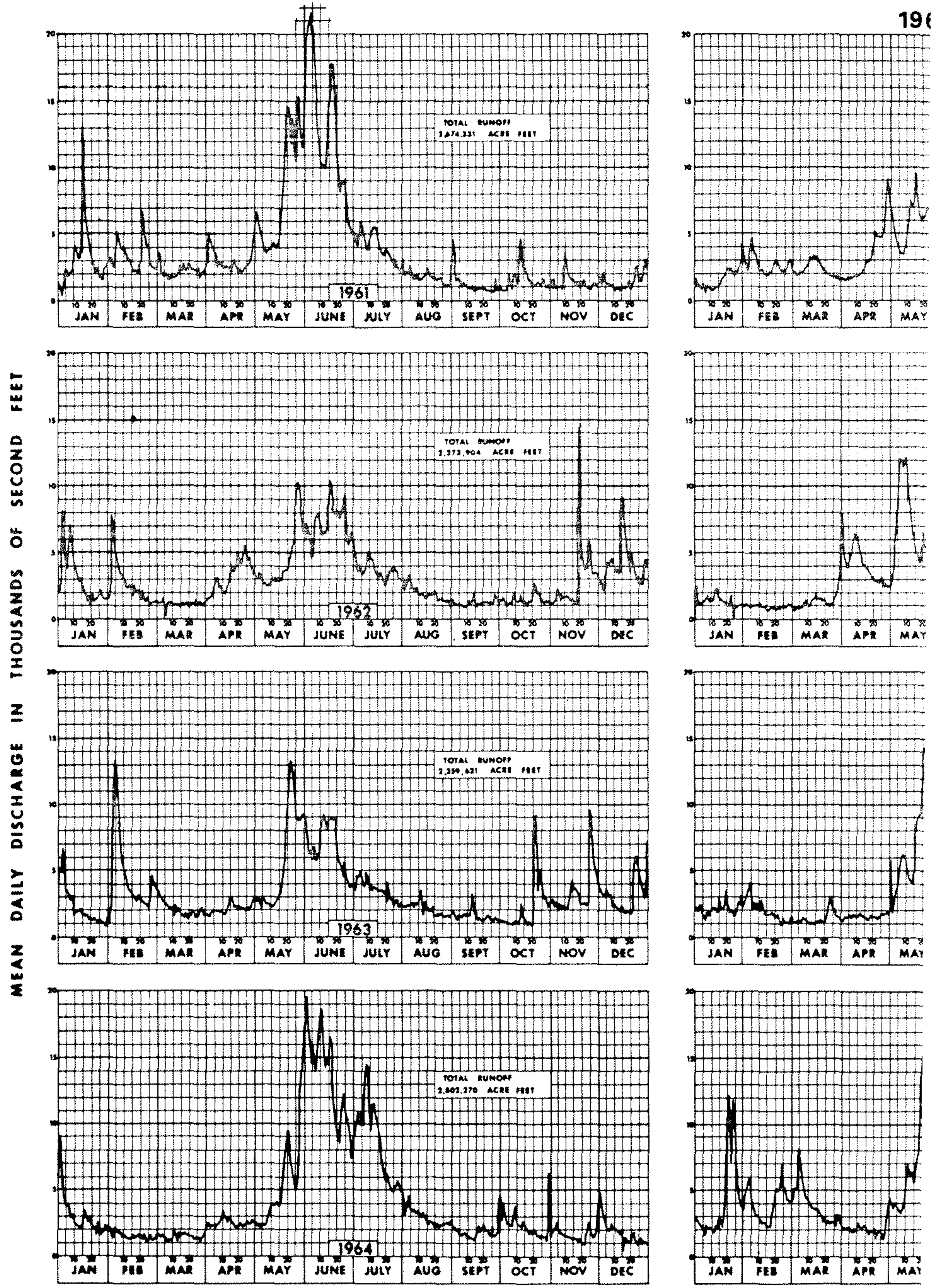
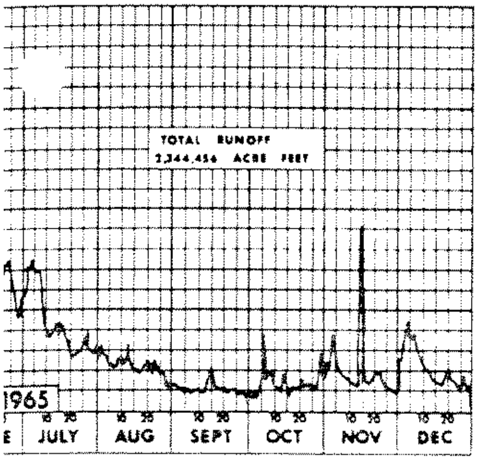
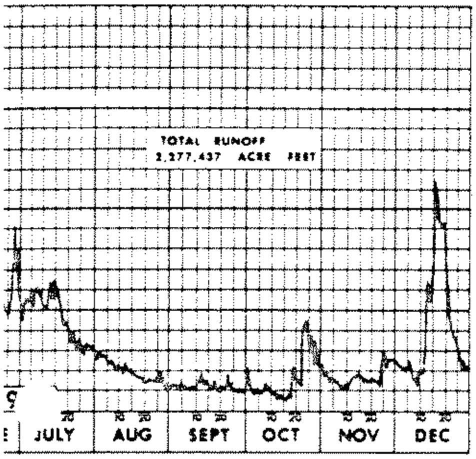


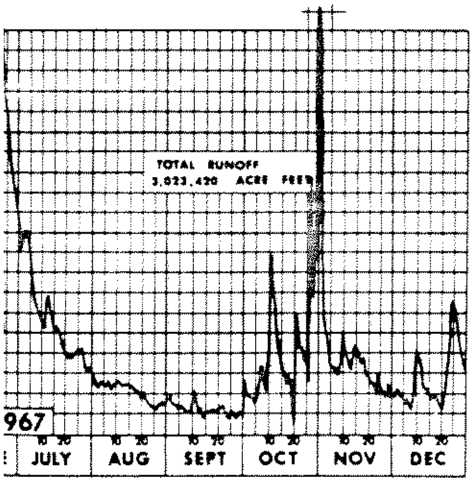
I- 2 (cont'd)

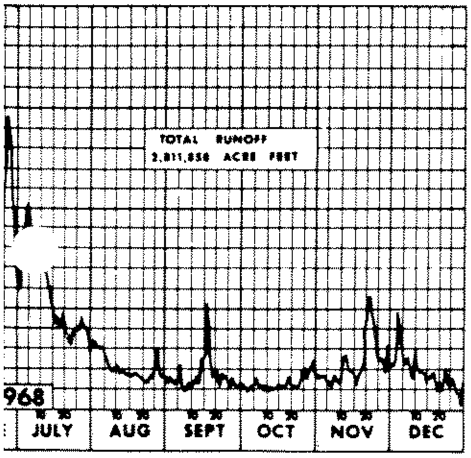
Y RUNOFF

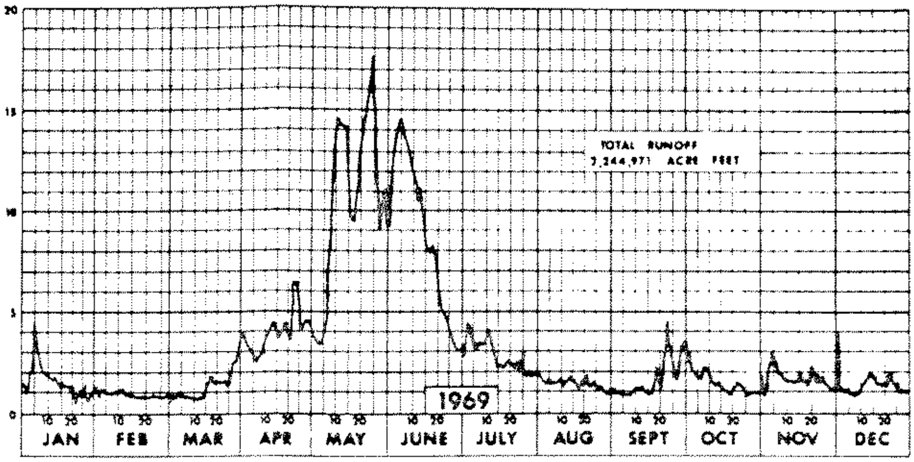
1972

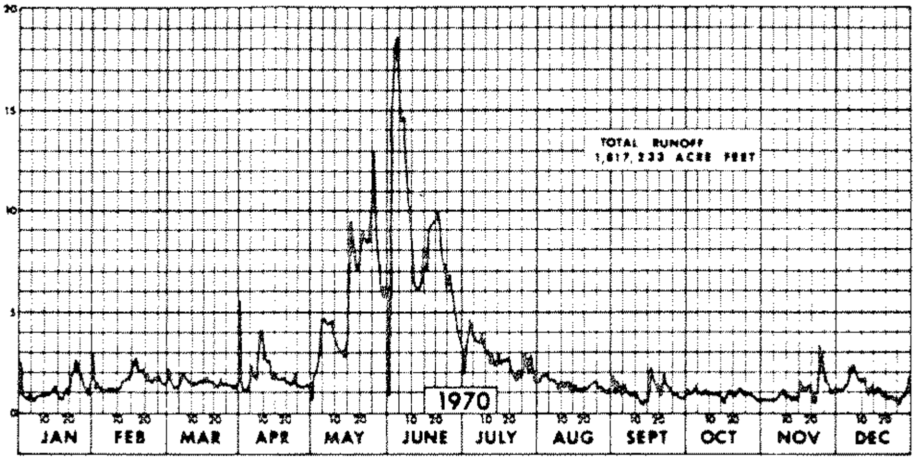


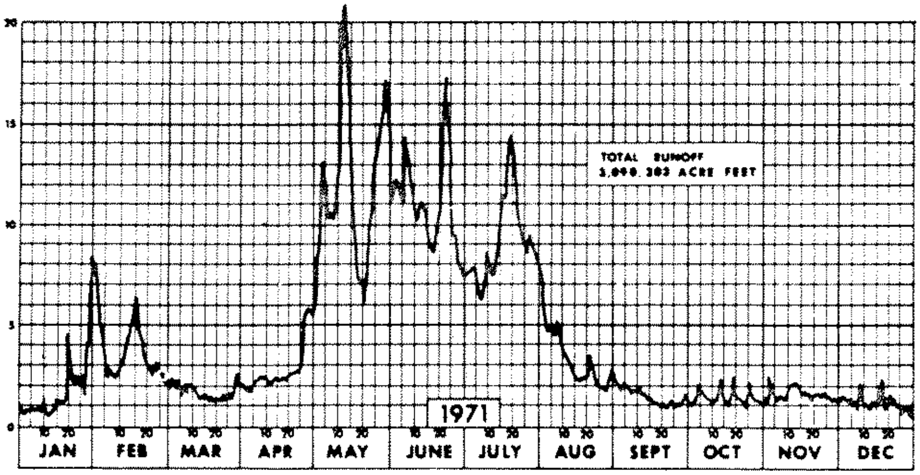


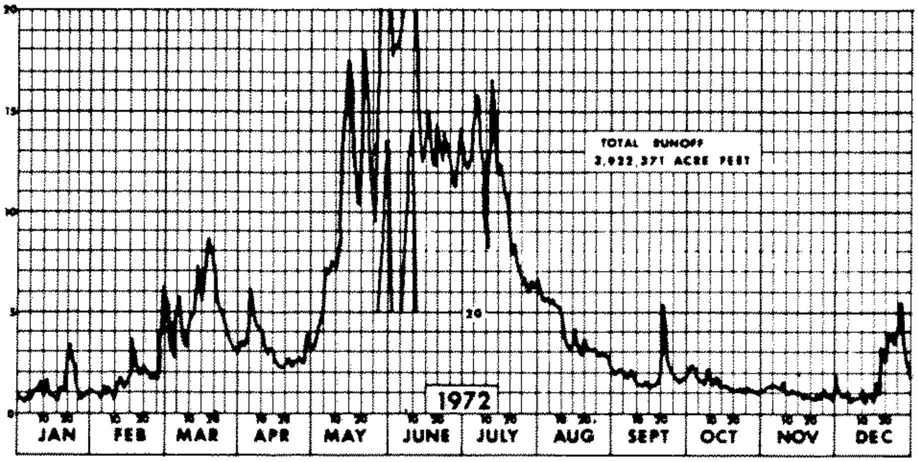












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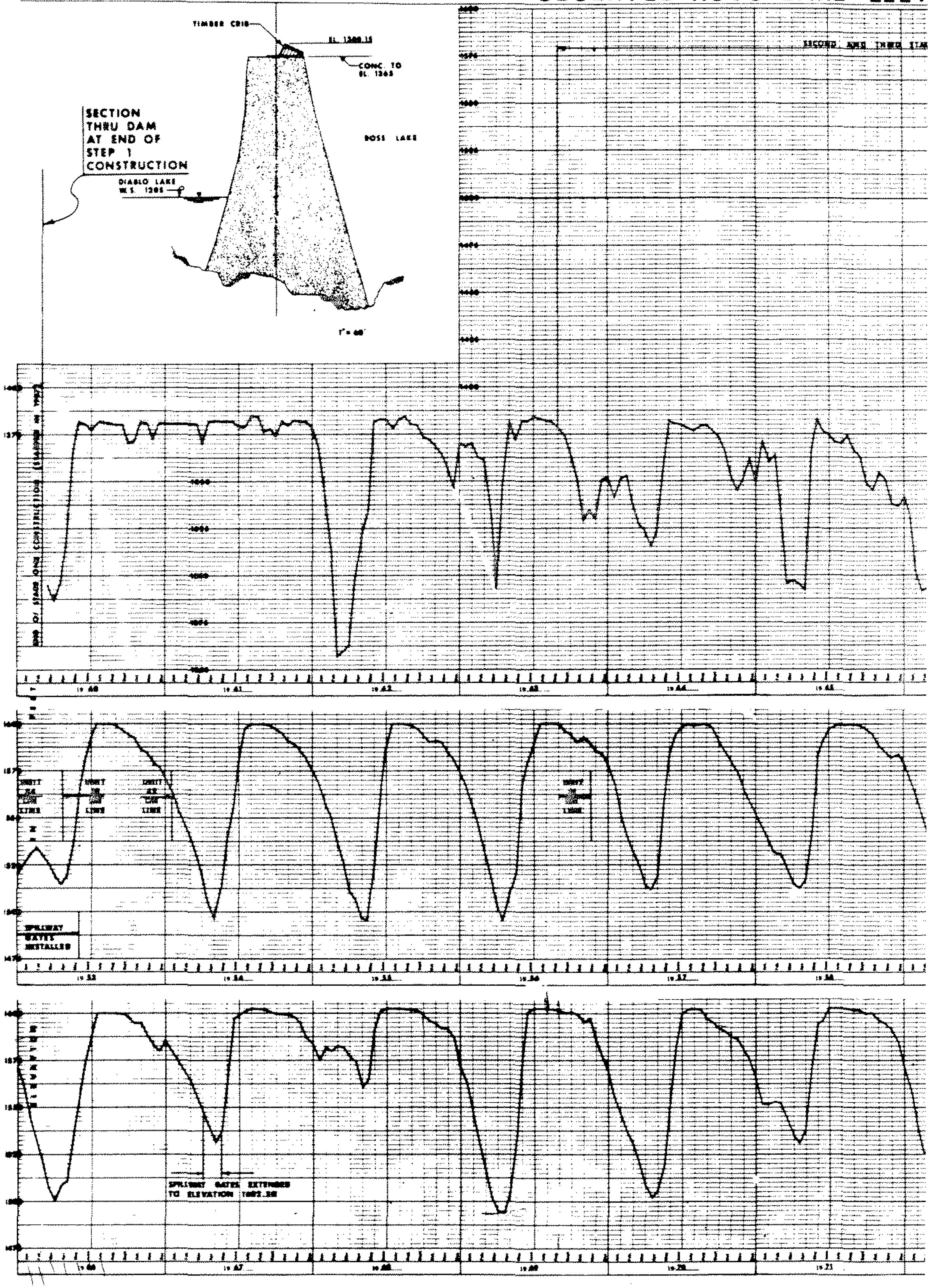
OBSERVED ROSS LAKE ELEV



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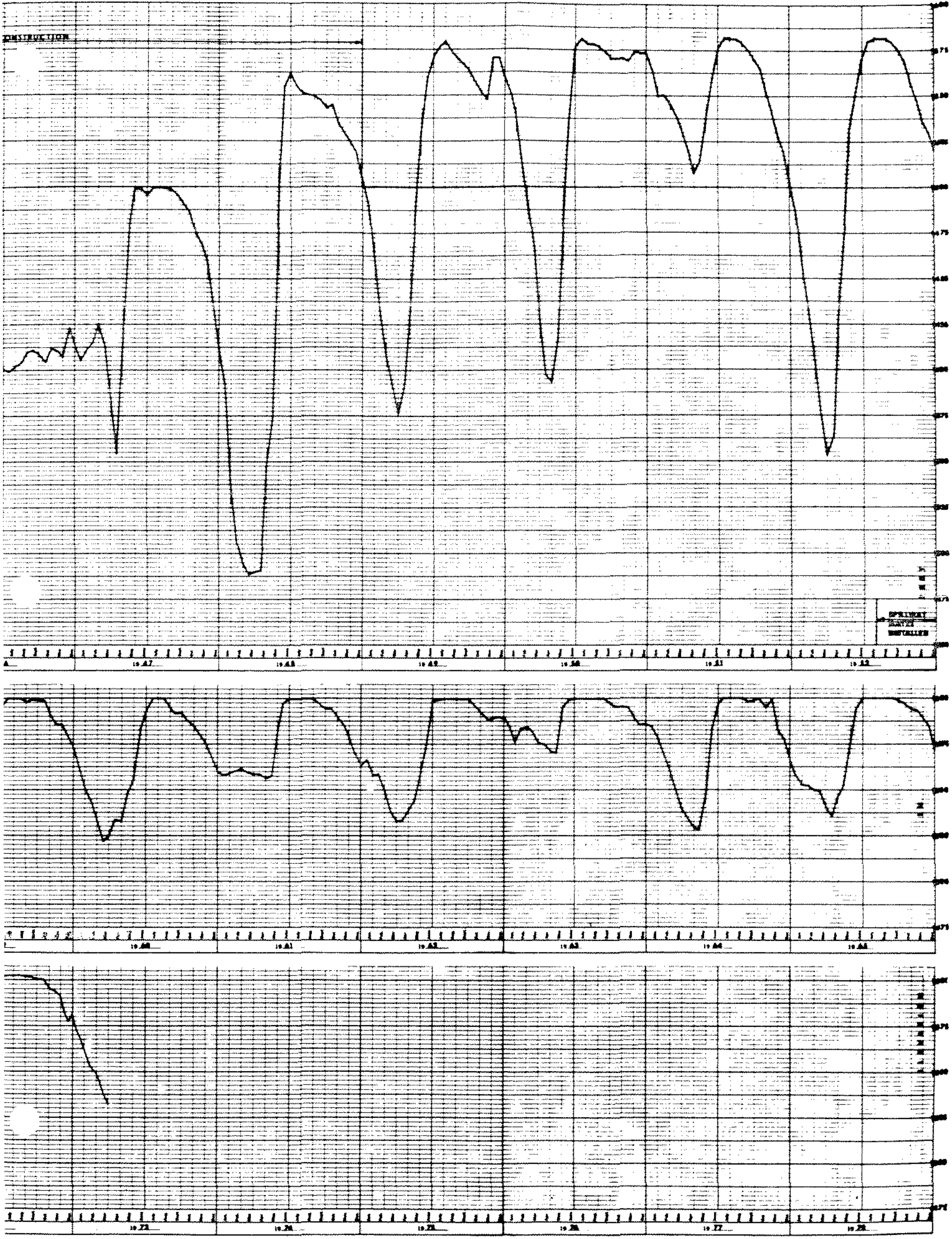
ON FLUCTUATIONS 1940-1971



Monthly inflow [1], discharge, and reservoir volume records for the 17 year period 1953 - 1969 provided a means of calculating flushing rate of the reservoir, that is, the number of times the entire lake volume is replaced by inflow (or the number of times the entire lake volume is removed by outflow) in one year. From July 1 to June 30 the 17 year average flushing rate of Ross Lake based on full reservoir (1602.5) volume was 1.84. Based on average reservoir volume during the year the rate was 2.35. Monthly rates based on monthly average lake volumes are presented in Table 2.1-2.

2.1.4 Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen data were collected by City Light personnel from July 1970 through December 1972 at fixed locations at approximately monthly intervals (Figure 2.1-4). The data show the presence of a well defined thermocline during the summer months. Winter and spring overturns occurred between December 1970 and April, 1971 and between December 1971 and March 1972. A maximum surface temperature in Ross Lake of 24°C (75°F) was recorded at the Hozomeen boat landing on August 1, 1971. Maximum observed surface temperatures of 18.7°C (65.5°F) and 16.9°C (62.5°F) were recorded on August 20, 1971 midlake at Devils Creek, and on August 19, 1970 at the Ross intake, respectively. In 1972 a surface temperature maximum of 18.4°C (65°F) was recorded at the Ross intake on August 9.

Dissolved oxygen (D.O.) concentrations in Ross Lake were generally lowest in early fall (September - November). The lowest surface D.O. concentration was 9 parts per million (ppm) in October, 1970 and 1971 off Devils Creek and

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[1] Estimated from discharge and lake volume data, ignoring loss from evapoation.

TABLE 2.1-2

MONTHLY FLUSHING RATES FOR ROSS LAKE BASED ON THE INFLOW IN ACRE-FEET INTO THE RESERVOIR AS A PROPORTION OF THE RESERVOIR VOLUME FOR EACH MONTH. VALUES ARE BASED ON A 17 YEAR EXPERIENCE RECORD, *1953-1969

Month	Month end elevation	Reservoir volume (acre feet)	Natural inflow (acre feet)	Outflow (acre feet)	Flushing rate (inflow/volume)
January	1,560.3	984,438	137,577	294,504	.1397
February	1,548.3	872,813	120,876	232,501	.1384
March	1,532.2	736,195	108,315	244,933	.1471
April	1,529.5	714,401	185,490	207,284	.2596
May	1,548.3	872,813	486,743	328,331	.5576
June	1,597.1	1,371,367	585,679	87,125	.4271
July	1,602.5	1,434,816	326,422	262,973	.2275
August	1,601.6	1,424,541	134,441	144,716	.0944
September	1,599.0	1,393,811	91,020	121,750	.0653
October	1,594.1	1,336,835	138,990	195,966	.1040
November	1,586.5	1,252,308	167,405	251,932	.1337
December	1,576.1	1,141,365	163,887	274,830	.1436
Year - total			2,646,845	2,646,845	2.3465
average		1,127,975			

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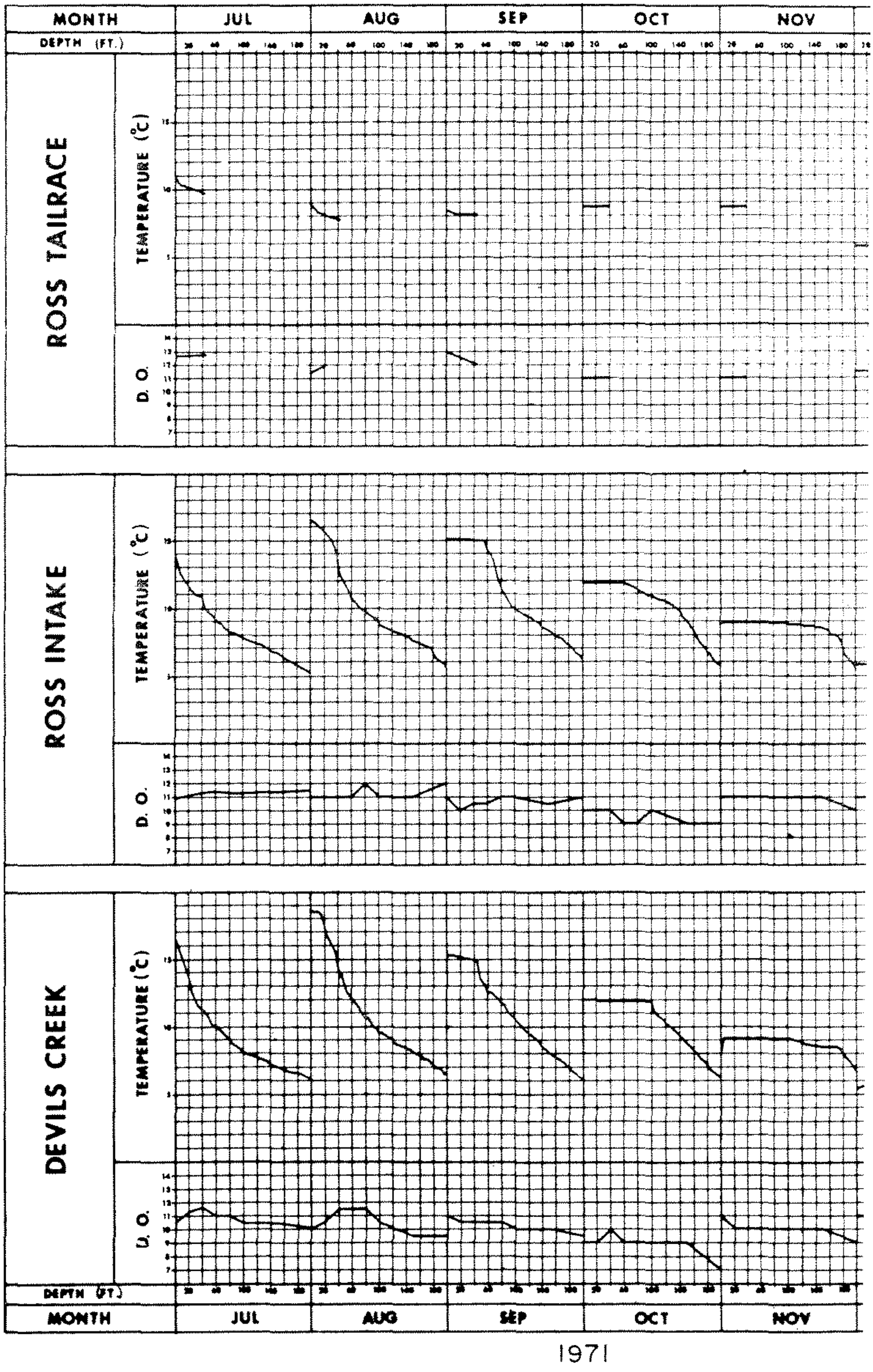
* Experience record is for the existing reservoir with a maximum surface elevation at 1,600 feet (1953-1966) and at 1,602.5 feet (1967-1969). Inflow records do not include October - December, 1969.

FIGUR

WATER TEMPERATURES AND DISSOI



2.1-4

D OXYGEN ROSS LAKE, 1971-1973

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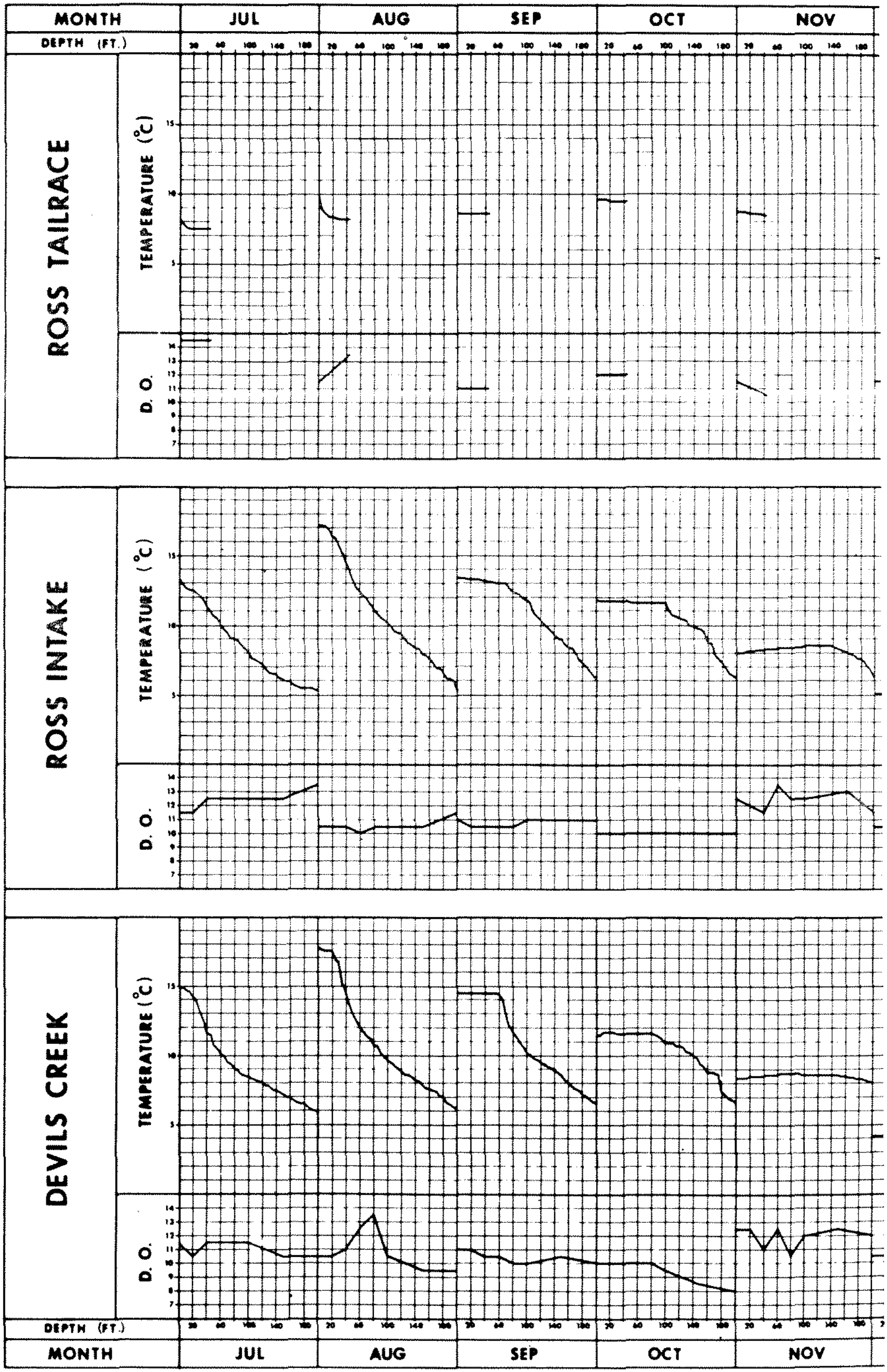

MONTH
JUL
AUG
SEP
OCT
NOV
DEPTH (FT.)
20
60
100
140
180
ROSS TAILRACE
TEMPERATURE (°C)
15
10
5
D. O.
14
13
12
11
10
9
8
7
ROSS INTAKE
DEVILS CREEK

1972

2.1-4 (cont'd)

the lowest D.O. concentrations at 200 feet were 6 ppm in November, 1970 and 7 ppm in October 1971, off Devils Creek; these observations were made at or near the lake bottom. (The depth of the full lake off Devils Creek is 215 feet and at Ross intake is 415 feet). In 1971 concentration of D.O. was highest (13 ppm) from the lake surface to 200 feet in April at both stations; in 1972 D.O. reached 14 ppm from the lake surface to 80 feet in January at Devils Creek station and at the lake surface at the Ross intake in February, 1972. Throughout the period of sampling (July, 1970 - December, 1972) the D.O. concentration at the surface was at or near 100 percent saturation, and in summer months concentration extended above 100 percent saturation.

2.1.5 Turbidity

Turbidity in Ross Lake is influenced considerably by seasonal runoff of silt and glacial flour. An eight inch Secchi disc lowered into the water was used to measure water transparency. The means of the depths at which the disk disappeared from view during descent and reappeared during ascent is given as the Secchi depth. Secchi disc observations were made at two locations on May 27, 1971, at six locations on September 20, 1971 and at 13 locations on Ross Lake in 1972 (Appendix 1). On May 27, 1971 Secchi depth was 17 feet at the south end of the lake and 14 feet at the north end. On September 20, 1971 Secchi depths ranged from 30 to 45 feet at the six locations.

In early May, 1972 Secchi depth at the south end of the lake was 41 feet. A general decline in Secchi depth occurred during May until May 24 when it reached 8 feet. During the following week Secchi depth rapidly increased to 24 feet (May 30). In June, the month of peak runoff, Secchi depth gradually decreased until June 30 when it reached 4.5 feet. Following this date the Secchi readings gradually increased until late August when the last reading was 46 feet.

At other locations in Ross Lake Secchi depth during May and June varied according to distance of the stations from sources of runoff. In Ruby Arm Secchi depths as low as 1.5 feet in early June were due to heavy spring runoff and erosion due to highway construction activities in the Ruby Creek drainage. A Secchi depth of three feet was observed in Big Beaver Bay in mid-June, a result of the spring runoff and the glacial flow from Big Beaver Creek.

Generally, Secchi depth at all stations was lowest in late May and late June, 1972. The lake waters gradually cleared in July and August.

2.1.6 Water Chemistry

Water samples collected from Ross Lake on May 27, 1971 were analysed by the Seattle Water Department. Results are given in Appendix 2. Measurements of specific conductance, which closely approximates residue in solution in ppm (Reid, 1965) were continued in 1971 and 1972 by project personnel. The values for specific conductance are reported as micromhos per centimeter at 25°C (American Public Health Association, 1965). In 1971, values were as follows:

Date	Location	Depth (ft)	μ mhos/cm
May 27	South end	25	64
		100	68
	North end	25	70
		100	64
August 26	South end	Surface	55
	North end	Surface	77

In 1972 readings were taken at six locations (Appendix 1).

At the south end of the lake specific conductance ranged from 55 to 69 μ mhos/cm (mean = 61). In Ruby Arm the range was 45 to 67 μ mhos/cm (mean = 58); in Lightning Arm the readings ranged from 65 to 81 μ mhos/cm (mean = 72); specific conductance was determined once in mid-June near Cat Island (75 μ mhos/cm), and in mid-lake off Silver Creek in early June (69 μ mhos/cm).

2.1.7 Obstructions

The surface of Ross Lake is relatively free of obstructions such as submerged trees and rocks when the lake level is above 1555 feet in elevation. Boat travel is generally unrestricted except near the shore, where tree stumps are near the water surface. When the reservoir elevation falls below 1555 feet areas in the vincity of the inlets of Big Beaver and Devils Creeks and the entire north end of the lake above Lightning Creek become hazardous for boat operation.

2.1.8 Access

Ross Lake is part of the 107,000 acre Ross Lake National Recreation Area administered by the U.S. National Park Service. A system of lakeshore and back country trails provides access for hikers, packers, anglers and campers. Access to Ross Lake on the American side is by trail or by boats operated by Seattle City Light from Diablo Lake to the base of Ross Dam. From the Canadian side Ross Lake is reached by road from Hope, B.C. Lodging and rental boats for visitors to the area are available at a resort at the south end of the lake. A campground at the north end of the lake and primitive campsites around the lake are available.

2.2 ROSS LAKE TRIBUTARY STREAMS

(by Fisheries Research Institute)

2.2.1 Major American Tributaries

Measurements of stream length (horizontal distance along stream bed from stream mouth to stream source) and gradient (rate of stream slope per unit of stream length) were made with the use of U.S. Geological Survey topographic maps and a map measurer for distance measurement (Appendix 3.) In order to obtain representative measurements of stream gradient, the slope of each stream was determined for the section from the stream mouth to a point near the stream source where gradient increased abruptly. For streams in which gradient did not change abruptly near the stream source, gradient for the entire stream from mouth to source is given (see Table 2.2-1). Streams flowing into Ross Lake were arbitrarily described as major or minor tributaries based

TABLE 2.2-1

CHARACTERISTICS OF THE MAJOR ROSS LAKE TRIBUTARY STREAMS

	TRIBUTARY					
	Ruby Creek	Big Beaver Creek	Devils Creek	Lightning Creek	Little Beaver Creek	Canadian Skagit River
Drainage Area (square miles)	186.32	62.86	29.80	142.00	53.40	389.16
Length (miles)	3.36	18.45	9.85	11.01 (to U.S./ Canada Border)	14.35	20.2
Gradient (percent)	1.56	0.61 (lower 8.95 miles to MacMillan Creek)	4.71 (lower 8.52 miles)	2.89 (to U.S./ Canada Border)	2.21 (lower 13.70 miles)	0.38
Discharge (cfs)						
Average	714 (1948-56, 62-69	414 (1940-48, 63-69	No information	237 (1943-48)	No information	See Section 2.3.3.4
Maximum	8640 (27 Nov./49)	4420 (22 Oct./63		2500 (30 May/45)		
Minimum	46 (10 Feb./49)	64(each day 7-12 March/69)		49 (both days 7-8 March/44)		

TABLE 2.2-1 - Page 2

	Ruby Creek	Big Beaver Creek	Devils Creek	Lightning Creek	Little Beaver Creek	Canadian Skagit River
Substrate	BO, R CGR	SD, ST, FGR-lower 7 mi BO, R, CGR-next 6 mi	Variable-BR, BO, CGR - lower 1 mi	BO, R, CGR, FGR	BR, BO - lower 2 mi, BO, R, GR-upper 12 mi	See Section 2.3.3.3
Character	Rapids, deep riffles, a few pools	Meanders - lower 7 mi, rapids and riffles - next 6 mi turbid in summer months	Variable - falls, rapids, pools - lower 1 mile	Rapids, deep and shallow riffles, pools	Falls, rapids - lower 2 mi, rapids, riffles meanders - upper 12 mi	Many log jams, no water falls or other fish migration blocks
Accessibility of stream areas above stream mouth to fish from Ross Lake	Accessible	Accessible after mid-May for about 7 miles	Not accessible	Accessible after early May for about 1/4 mile	Not accessible	Accessible

on drainage area, stream length, and gradient (Tables 2.2-1, 2.2-2). For example, Skymo Creek is considered a minor Ross Lake tributary because it drains a small area (5.10 square miles), and it is a short stream (3.4 miles) flowing over an extremely steep gradient (20.48 percent slope). Its discharge at times other than during spring runoff is relatively low. Other tributaries flowing into streams which empty into the reservoir are included as minor tributaries on this basis alone.

The characteristics of the major American tributaries to Ross Lake are discussed by Eggers and Gores (1971). In addition, notes on stream character and substrate were made during foot surveys of the streams and overflights of the area in 1971.

Substrate symbols used in Table 2.2-1 are as follows:

BR - bed rock
BO - boulders (diameter 12 inches)
R - rubble (3 - 12 inches)
GR - gravel
CGR - coarse gravel (1 - 3 inches)
FGR - fine gravel (.125 - 1 inch)
SD - sand
ST - silt

(Eggers and Gores, 1971).

Ruby Creek, 3.36 miles in length (from the confluence of Granite and Canyon Creeks to Ross Lake) is the largest of the American tributaries to

TABLE 2.2-2

CHARACTERISTICS OF MINOR TRIBUTARIES OF ROSS LAKE WATERSHED

TRIBUTARY

	Granite Creek	Canyon Creek	Crater Creek	Panther Creek	McMillan Creek	Three Foo's Creek	Freezeout Creek
Tributary to:	Ruby Creek	Ruby Creek	Ruby Creek	Ruby Creek	Big Beaver Creek	Lightning Creek	Lightning Creek
Length (mi.)	17.05	16.10	4.92	13.07	5.70	10.30	6.16
Gradient (percent)	3.29	3.84 (lower 13.26 mi.)	24.04	4.59 (lower 12.34 mi.)	3.48 (lower 4.51 mi.)	4.05 (lower 3.17 mi.)	10.90 (lower 5.66 mi.)
Character	rapids, swift flow over bouldery bottom	rapids, riffles, pools, BO, R, GR	steep falls and rapids	steep rapids and falls, pools, BR, BO, R	variable-rapids, riffles, pools, BO, R, CGR	riffles, rapids, falls swift flow through gorge	---
Accessibility of stream areas above stream mouth for fish from Ross Lake	Accessible for 6.06 miles	Accessible for 9.18 miles	Very limited accessibility	Accessible for .41 miles	Not accessible	Not accessible	Not accessible

TABLE 2.2-2 - Page 2

CHARACTERISTICS OF MINOR TRIBUTARIES OF ROSS LAKE WATERSHED

TRIBUTARY

	Perry Creek	North Fork Canyon Creek	Slate Creek	Mill Creek	Roland Creek	May Creek	Skymo Creek
Tributary to:	Little Beaver Creek	Canyon Creek	Canyon Creek	Canyon Creek	Ross Lake	Ross Lake	Ross Lake
Drainage area (sq.mi.)					4.76	3.84	5.16
Length (mi.)	5.45	5.59	8.95	6.91	2.65	3.84	3.17
Gradient (percent)	8.90	11.40	8.02	8.99	39.13	25.08	17.59
Character	---	rapids, falls and pools, R,BO,BR substrate, limited GR areas	rapids, falls and pools, BO,BR substrate limited GR areas	rapids and falls, few pools, R,BO, BR substrate, little GR	steep falls and rapids	steep falls and rapids	steep falls and rapids
Accessibility of stream areas above stream mouth for fish from Ross Lake	Not accessible	Accessible for 0.62 miles	Accessible for 0.47 miles	Accessible for 1.23 miles	Accessible for .31 mi.	Not accessible	Not accessible

TABLE 2.2-2 - Page 3

CHARACTERISTICS OF MINOR TRIBUTARIES OF ROSS LAKE WATERSHED

TRIBUTARY

	Noname Creek	Arctic Creek	Dry Creek	Silver Creek	Hozomeen Creek	Pierce Creek
Tributary to:	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake
Drainage area (sq.mi.)	6.75	13.68	6.35	17.00	6.75	3.64
Length (mi.)	4.00	5.50	3.79	6.20	4.35	3.26
Gradient (percent)	10.62	8.26	20.56	7.62(lower 5.07 mi.)	6.70	17.51
Character	steep falls and rapids	steep falls and rapids	steep falls and rapids, pools	rapids and falls	---	steep falls and rapids
Accessibility of stream areas above stream mouth for fish from Ross Lake	Not accessible	Not accessible	Accessible for .20 mi. in S.fork, .28 mi. in N. fork	Accessible for .49 mi.	Accessible for .05 mi.	Very limited accessibility

Ross Lake in terms of average discharge (714 cfs) and drainage area (186 square miles). It is characterized mainly by rapids interspersed with deep riffles and occasional pools. The substrate of Ruby Creek is mainly boulders, rubble, and coarse gravel. The gradient (slope) of Ruby Creek, 1.56 percent, is second lowest of the American tributaries to Ross Lake.

Big Beaver Creek, the longest American tributary (18.45 miles) meanders through a deep channel in its lowest two miles. Substrate in this section is silt and fine gravel. From two miles to seven miles upstream from the lake (1725 feet elevation) Big Beaver Creek meanders through the valley alternating between shallow and deep riffles. Substrate in this stream section is mainly fine gravel with some silt. The remainder of Big Beaver Creek flows through rapids and riffles over a boulder, rubble and coarse gravel substrate. Stream gradient is low in the lower seven miles of the stream, (0.32 percent). From this point the stream gradient abruptly increases (1.63 percent from 1725 feet elevation to the confluence of McMillan Creek). The overall gradient from the stream mouth to McMillan Creek is 0.61 percent, the lowest of the American tributaries to Ross Lake.

Devils Creek is an extremely precipitous stream; its gradient is the steepest (4.71 percent) of the major American tributaries. Rapids interspersed with falls and pools typify the lower one mile of stream (from full pool to approximately the 1800 foot elevation). Substrate in this section is bedrock, boulders, rubble and coarse gravel.

Lightning Creek (gradient 2.89 percent) flows over a stream bed varying from boulders to fine gravel. Stream flow is generally through deep and shallow riffles with some rapids and pools. Only one fall of significance exists above the full reservoir (1648 foot elevation, 1/4 mile upstream from the lake) on Lightning Creek.

Little Beaver Creek in its lower two miles (from full pool to approximately the 1825 foot elevation) is similar to Devils Creek in its lower mile. The stream in this section is mainly rapids and falls with substrate of bedrock and boulders. Above this two mile section the stream character changes abruptly to meandering sections and riffles for nearly 12 miles with some rapids near the stream source. Substrate in the upper 12 mile section is boulders, rubble and gravel.

Big Beaver and Little Beaver Creeks, which enter Ross Lake from the west, are fed by glacial melt. In spring and summer 1971 they were generally more turbid than Ruby, Devils and Lightning Creeks, which enter Ross Lake from the east.

In 1972, Ruby and Lightning Creeks were more turbid than Big Beaver Creek for about two weeks in late May and early June. This was due to earth slides in the Lightning Creek drainage and highway construction activities in the Ruby Creek drainage during the runoff period. As the runoff subsided in July and August, Ruby and Lightning Creeks became clear (visibility > 15 ft) while Big Beaver Creek remained turbid (visibility generally 3-5 ft) during these months. In September, Big Beaver Creek gradually cleared (visibility 12-15 ft).

In late August, 1971 specific conductance in Big Beaver and Little Beaver Creeks (17 and 18 μmhos/cm, respectively) was much lower than in Ruby, Devils and Lightning Creeks (54, 41, and 75 μmhos/cm, respectively).

Average specific conductance in 1972 in Big Beaver and Little Beaver Creeks (21 and 17 μmhos /cm respectively) was considerably lower than in Ruby, Devils and Lightning Creeks (49, 49, and 69 μmhos/cm respectively, See Appendix 4). Turbidity caused by glacial melt apparently does not contribute greatly to total dissolved solids (TDS) in Big Beaver and Little Beaver Creeks.

The stream temperatures of Big Beaver and Little Beaver Creeks which enter Ross Lake from the west were very similar from May to October, 1971 (Figures 2.2-1 and 2.2-2). Water temperatures in Ruby and Lightning Creeks which enter Ross Lake from the east were similar and were warmer than Big Beaver and Little Beaver Creeks. Mean stream temperatures of Ruby and Lightning Creeks from May to mid-October were 45.6 and 45.3° F respectively; the mean temperatures for Big Beaver and Little Beaver Creeks in the same period were 43.4 and 43.3° F respectively. Mean stream temperatures in the period June to mid-August are of particular interest because this is the approximate period of incubation of trout eggs in the system as will be discussed later. In Ruby and Lightning Creeks these means were 46.0 and 45.7° F, respectively; in Big Beaver and Little Beaver Creeks the means were 43.9 and 43.3° F, respectively. The plots of stream temperature over time (Figures 2.2-1 and 2.2-2) show that all the streams in early spring were at nearly the same temperature but Ruby and Lightning Creeks reached much higher temperature maxima in the summer than Big Beaver and Little Beaver Creeks. Temperature means for Devils Creek were 44.0° F (May to mid-October) and 44.6° F, (June to mid-August). Its temperature curve over the summer was also somewhat different than the other streams, as it began warming later and cooling earlier.

FIGURE 2.2-1

WEEKLY STREAM TEMPERATURES

1971

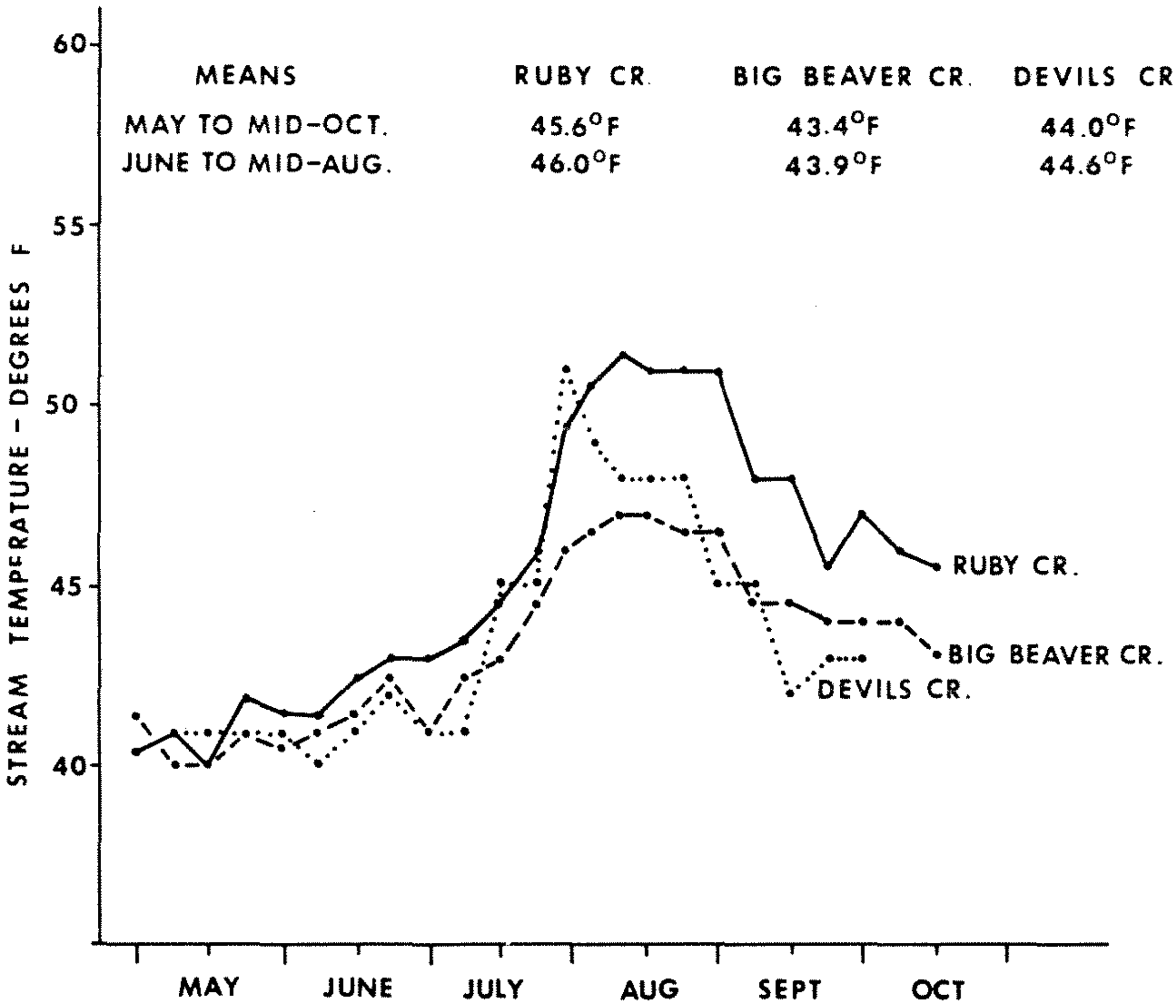
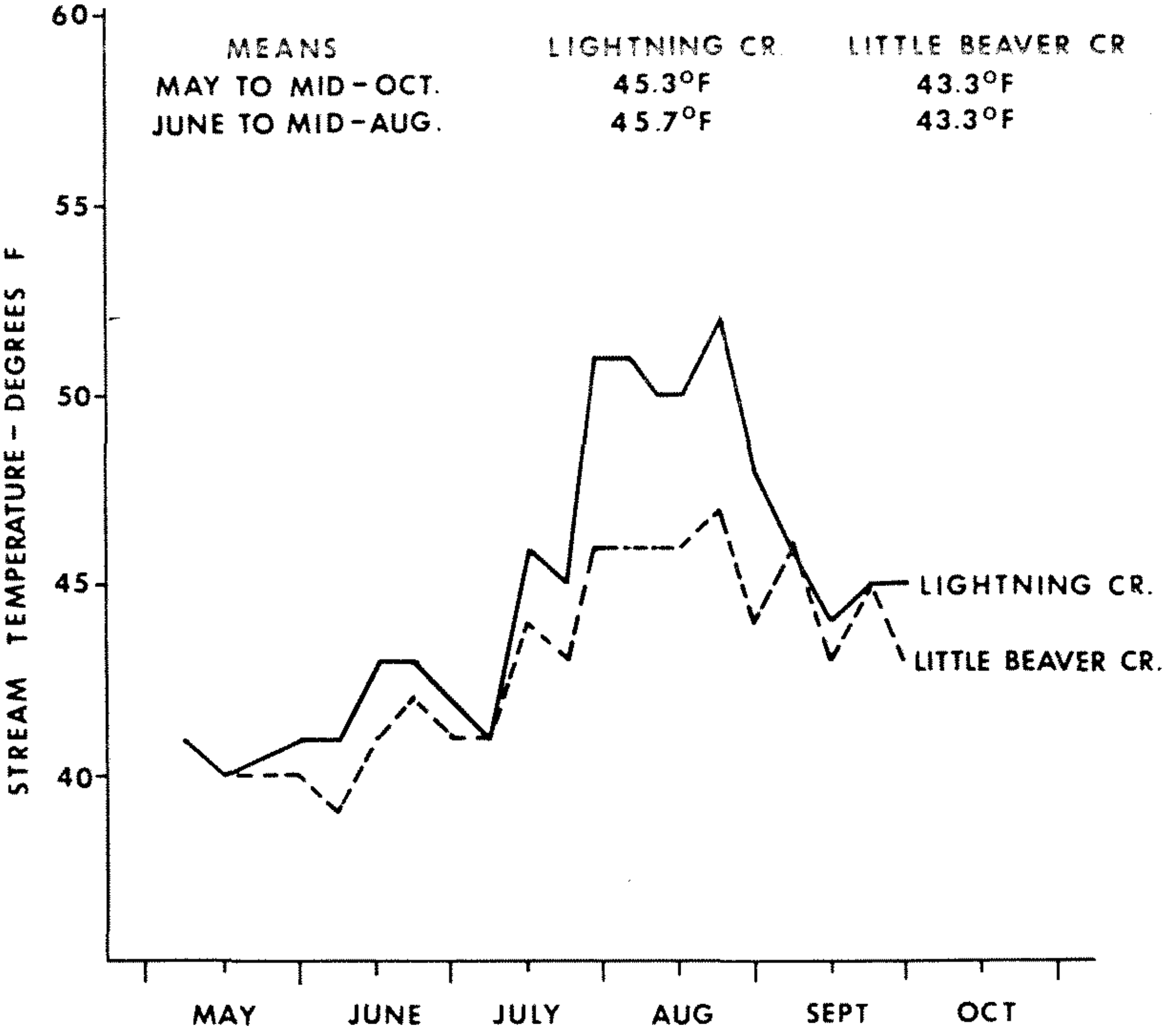


FIGURE 2.2-2

WEEKLY STREAM TEMPERATURES

1971



Stream temperature data for 1972 are presented in Figures 2.2-3 and 2.2-4. The mid-April through September temperature means for Ruby, Big Beaver, and Lightning Creeks were 43.4° F, 44.1° F, and 44.1° F, respectively. During the June to mid-August time period mean temperatures were 44.0° F, 45.8° F, and 45.0° F. The 1971 and 1972 temperature data show considerable difference in temperature means during the trout egg incubation period between the two years. Ruby and Lightning Creek mean temperatures for June to mid-August were 2.0° F and 0.7° F lower in 1972 than in 1971. The June to mid-August mean for Big Beaver Creek in 1972 was 1.9°F higher than in 1971. The temperature curves in Fig. 2.2-3 show that in early spring 1972, the streams were at approximately the same temperature. A comparison of the 1971 and 1972 temperature data (Figures 2.2-1 to 2.2-3) show that temperature maxima between the two years also differed somewhat in magnitude. In Ruby Creek the maximum temperature, 51° F, in 1971 occurred in early August. In 1972 the maximum of 49° F occurred about three weeks later. In Big Beaver Creek, 1971 maximum temperature of 47° F occurred in mid-August; in 1972 the temperature reached 48° F about one week earlier. In Lightning Creek the 1971 temperature maximum of 52° F occurred in late August; in 1972 the stream temperature reached 49° F also in late August.

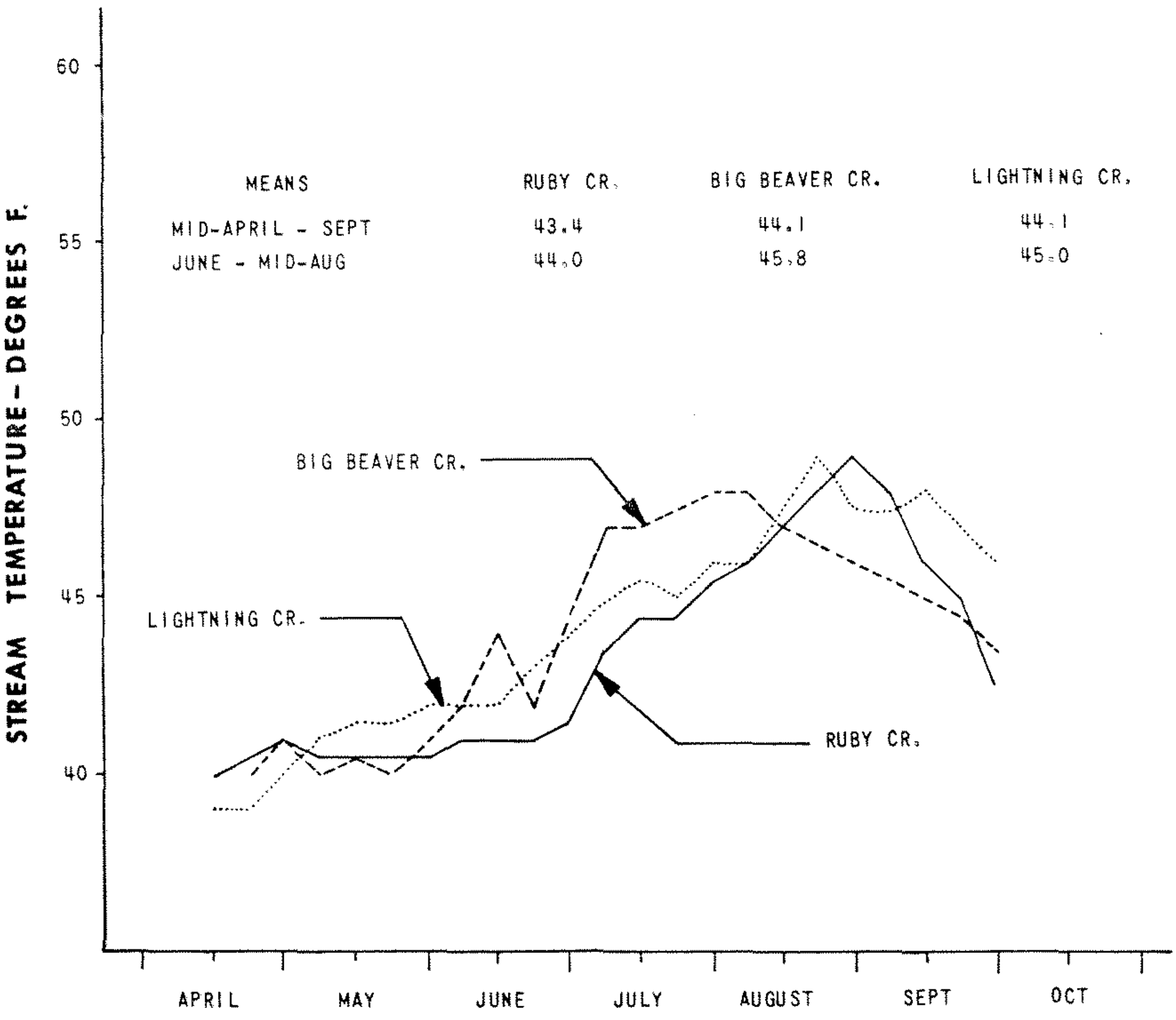
2.2.2 Minor American Tributaries

Minor tributary streams of the Ross Lake watershed are listed and described in Table 2.2-2. Generally, the minor tributaries to Ross Lake are short steep streams with relatively low discharge. The streams which flow into major Ross Lake tributaries generally are longer and not as steep as the minor streams flowing directly into the lake. Important tributaries in the Ruby Creek drainage are Granite and Canyon Creeks. Granite Creek, nearly 16.5 miles long is a

FIGURE 2.2-3

WEEKLY STREAM TEMPERATURES

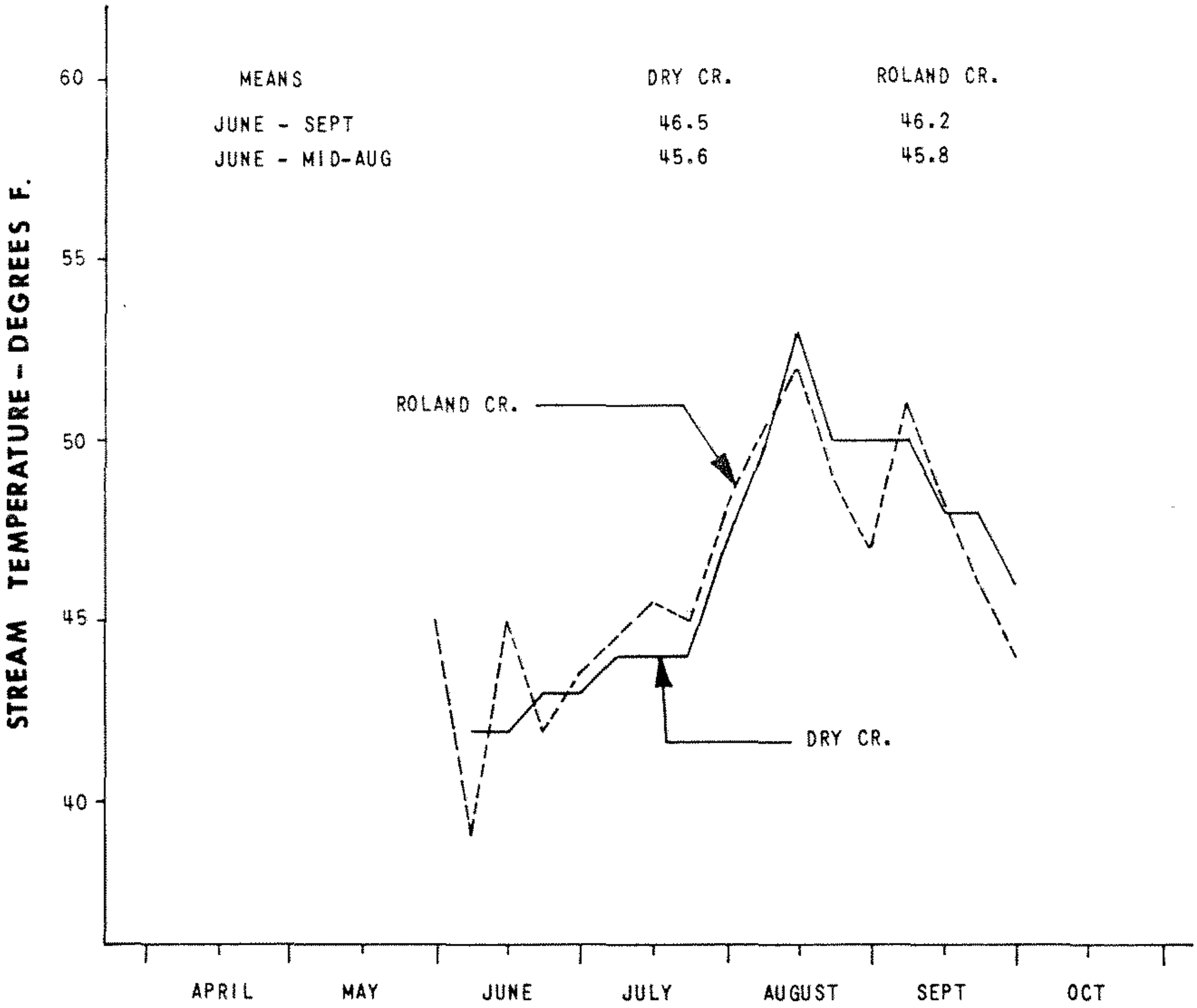
1972



MEANS	RUBY CR.	BIG BEAVER CR.	LIGHTNING CR.
MID-APRIL - SEPT	43.4	44.1	44.1
JUNE - MID-AUG	44.0	45.8	45.0

FIGURE 2.2-4

WEEKLY STREAM TEMPERATURES
1972



relatively precipitous stream (3.64 percent gradient) characterized by swift flowing rapids and deep riffles over a boulder and rubble bottom. Pools and gravelly areas are rare (Eggers and Gores, 1971). The North Cascades Highway parallels the stream for its entire length to Rainy Pass. During the spring runoff in 1971 and 1972 soil erosion due to the road construction drastically reduced visibility in the stream. Canyon Creek is also a somewhat precipitous stream (3.95 percent gradient in the lower 13.0 miles), however its character is more variable than Granite Creek. Pools are interspersed with rapids and riffles over boulder, rubble and gravel substrate. Gravel areas are limited but not as rare as in Granite Creek. Three tributaries of Canyon Creek, North Fork, Slate, and Mill Creeks are accessible to Ross Lake fish for short distances. Their gradients (11.4, 8.02, and 8.99 percent respectively) are indicative of their precipitous nature. Gravel areas are limited in the North Fork of Canyon and Slate Creeks and are rare in Mill Creek.

Three Fools Creek is an important tributary of Lightning Creek. It is a stream of variable nature with rapids, deep and shallow riffles, falls and some pools. Its flow is rapid through a gorge about 3/4 miles upstream from its confluence with Lightning Creek. Substrate is boulders, rubble, and gravel (Eggers and Gores, op cit).

Generally, the remainder of the minor tributaries not flowing into Ross Lake are considered unimportant because they are inaccessible to fish from Ross Lake (See Table 2.2-2). This will be discussed later.

Stream temperatures in Roland and Dry Creeks, which are utilized for spawning by Ross Lake trout, were measured periodically from June through September, 1972 (Figure 2.2-4). The means were 46.2 and 46.5° F, respectively. June - mid-August means were 45.8 and 45.6° F. Temperature maxima occurred in both streams in mid-August (Roland Creek, 52°F and Dry Creek, 53°F).

2.3 SKAGIT RIVER AND TRIBUTARY STREAMS

(by F.F. Slaney & Company)

2.3.1 Definitions

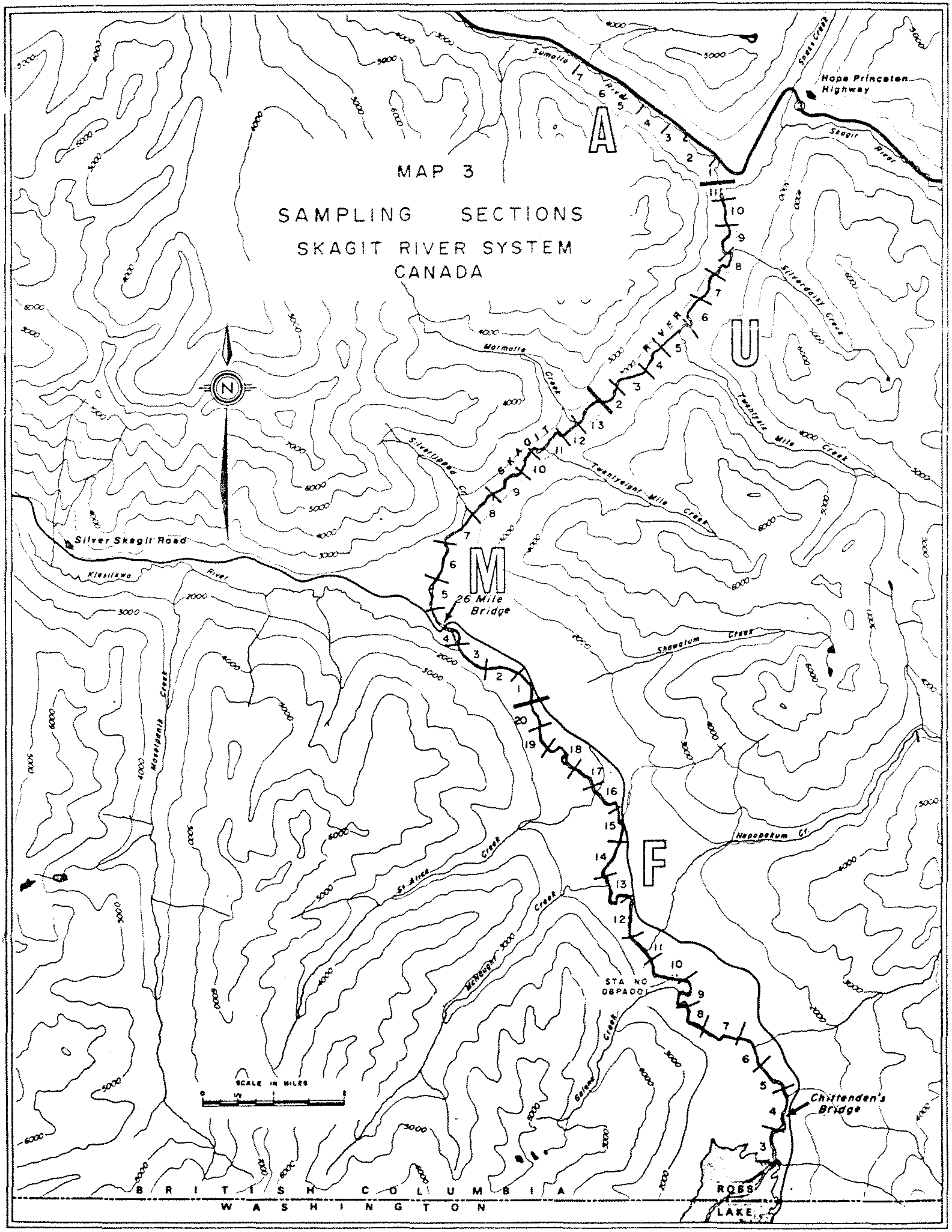
The portion of the Skagit River system referred to in this report is that upstream of Ross Lake. Primary emphasis is placed on the Skagit River itself between the elevation of Ross Lake and the 2011.8 foot elevation (at the confluence with the Sumallo River). The Skagit River below Ross Dam was not considered. Those portions of the Skagit River which are alternately river or lake depending on the level of Ross Lake will be referred to as "drawdown river" throughout this report.

The 1725 foot elevation used throughout this report refers to the location on the river where the 1725 foot contour crosses the stream bed at its lowest point. It is approximately one mile upstream from the location of the 1725 foot contour on the bank of the river.

2.3.2 Study Sections

The divisions of the Skagit River system used throughout the sampling program are shown in relation to the Skagit and its tributaries on Map 3. Four major areas (F,M,U, and A) are each divided into shorter, approximately one-half mile, sections as shown.

These divisions were determined on small scale maps before the detailed mapping of the river at a large scale was completed. They have been retained in their original form for consistency. This accounts for the slight differences in length of various sections, and for the fact that the 1725 foot elevation, originally intended to be at the F-20/M-1 boundary, is actually very close to the


MAP 3

SAMPLING SECTIONS

SKAGIT RIVER SYSTEM

CANADA

M-2/M-3 boundary approximately 11 river miles from the U.S./Canada border and 10 miles from the 1602.5 foot elevation on the river. Map 11, Appendix 5, shows the precise location on the large scale river map.

2.3.3 Skagit River

2.3.3.1 General Description

Table 2.2-1 summarizes the characteristics of the Skagit River and provides a comparison between it and the other major tributaries of Ross Lake. Some of the physical characteristics of the river are considered in more detail in the following sections.

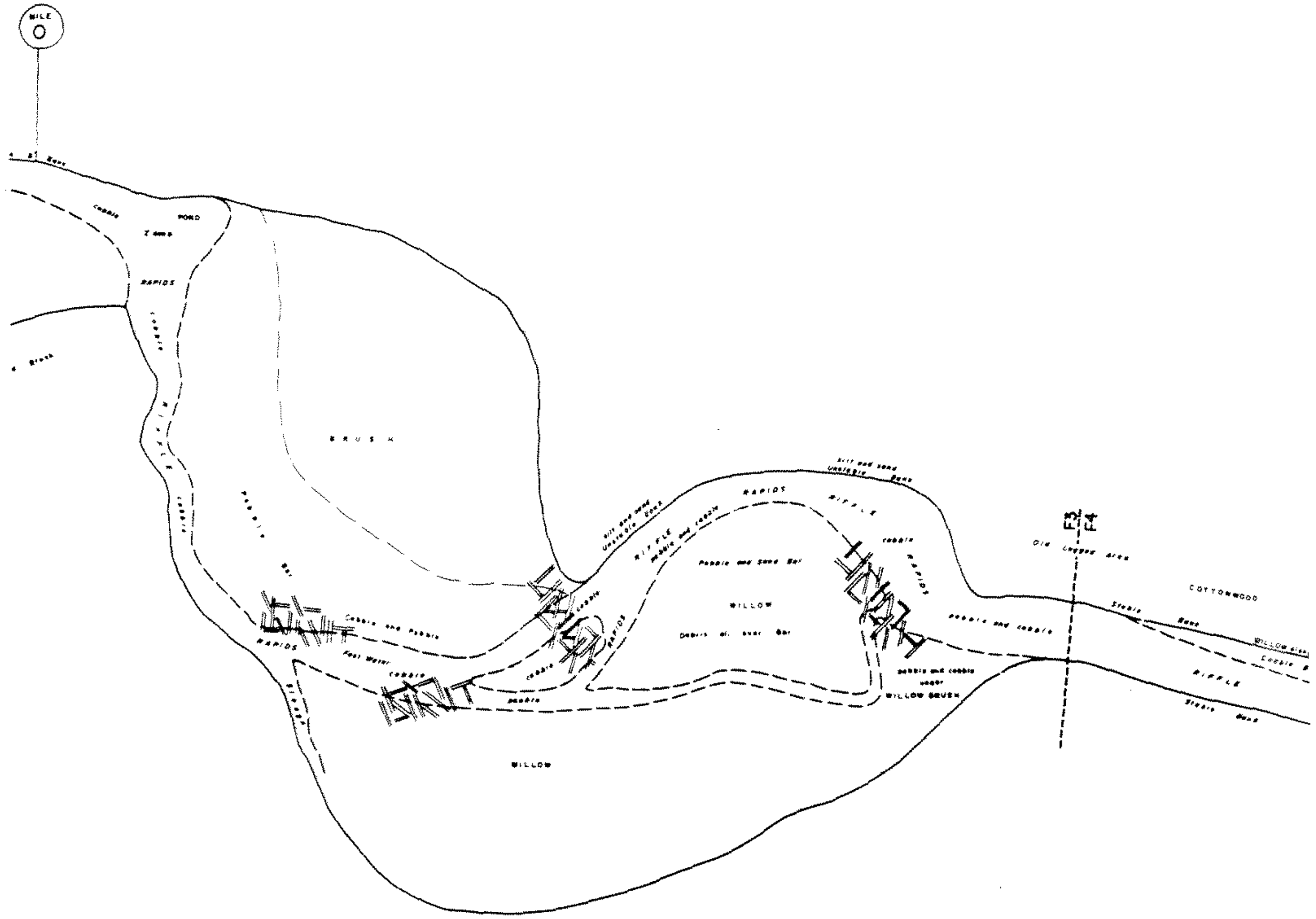
Complete maps to a scale of 100 feet to one inch were made of the Skagit River between elevations 1602.5 and 2011.8 feet during this study. Two portions of the map are shown, considerably reduced in size, in Figure 2.3-1. The entire map is presented, similarly reduced in size, in Appendix 5.

The map provides a detailed description of the Skagit River, its substrate, and surrounding areas. Distances in miles from the 1602.5 foot elevation as well as the sampling sections shown on Map 3 are also presented on the large scale map.

2.3.3.2 Profile and Gradients

The profile of the Skagit River between elevation 1602.5 feet and 2011.8 feet is shown on Figure 2.3-2. The gradients of various portions of the river along its length are also shown on the figure.

Elevations shown on the profile were determined at the highest point on the river bed in each location. The 1725 foot elevation is located on the profile by its distance along the river from the 1602.5 foot elevation on the river.


MILE
0
Bank
cobble
POND
Z one
RAPIDS
cobble
Brush
RIFFLE
cobble
Pebble
Bar
BRUSH
Cobble and Pebble
RAPIDS
Fast Water
cobble
Slough
pebble
cobble
cobble
RAPIDS
Silt and sand
Unstable Bank
RIFFLE
pebble and cobble
RAPIDS
Silt and sand
Unstable Bank
RIFFLE
Pebble and Sand Bar
WILLOW
Debris of. over Bar
cobble
RAPIDS
pebble and cobble
pebble and cobble
under
WILLOW BRUSH
WILLOW
F3
F4
Old Logged Area
COTTONWOOD
Stable Bank
WILLOW
Cobble
RIFFLE
Stable Bank

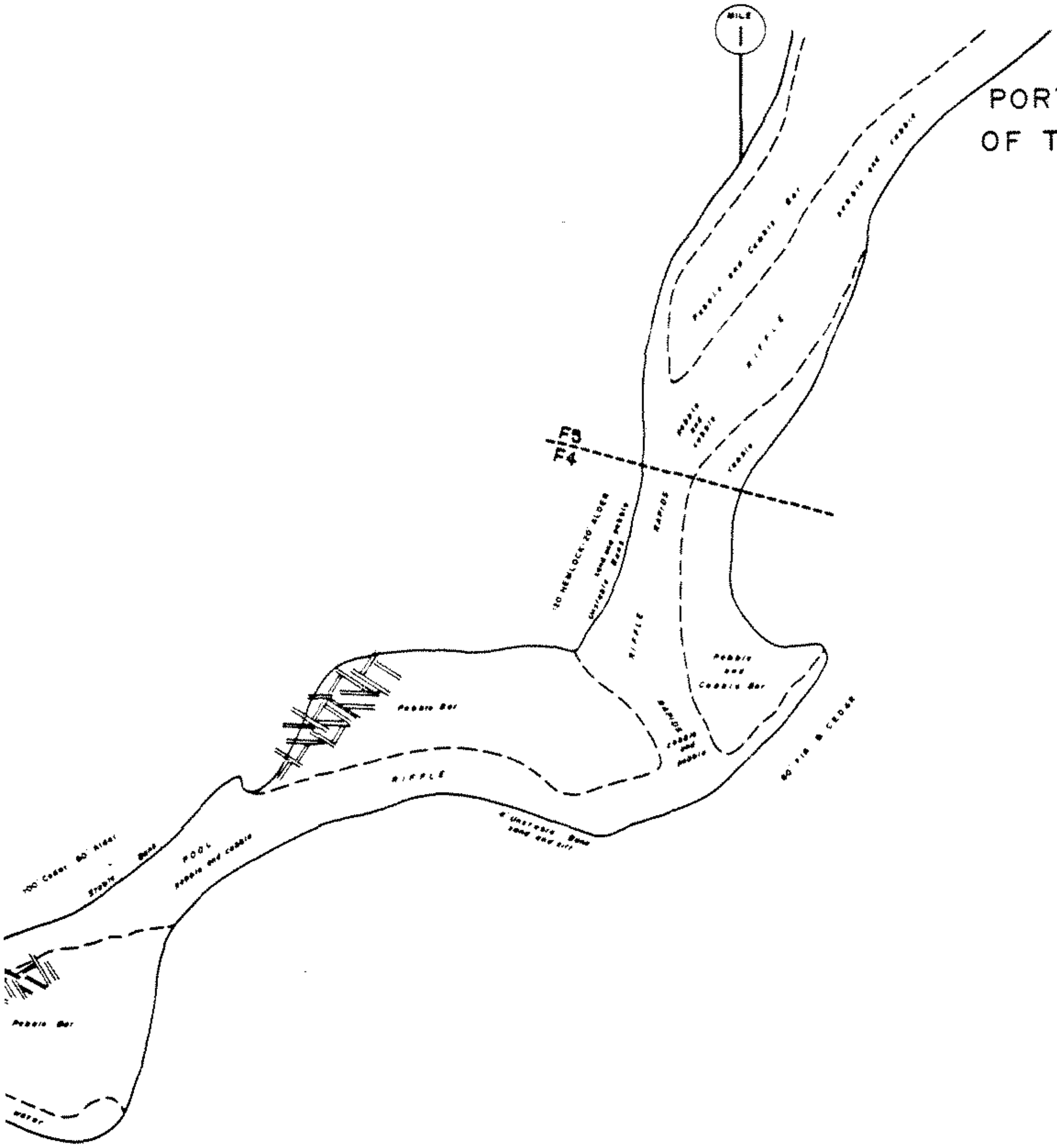


FIGURE 2.3-1
PORTION OF 1"-200' MAPS
OF THE CANADIAN SKAGIT
RIVER

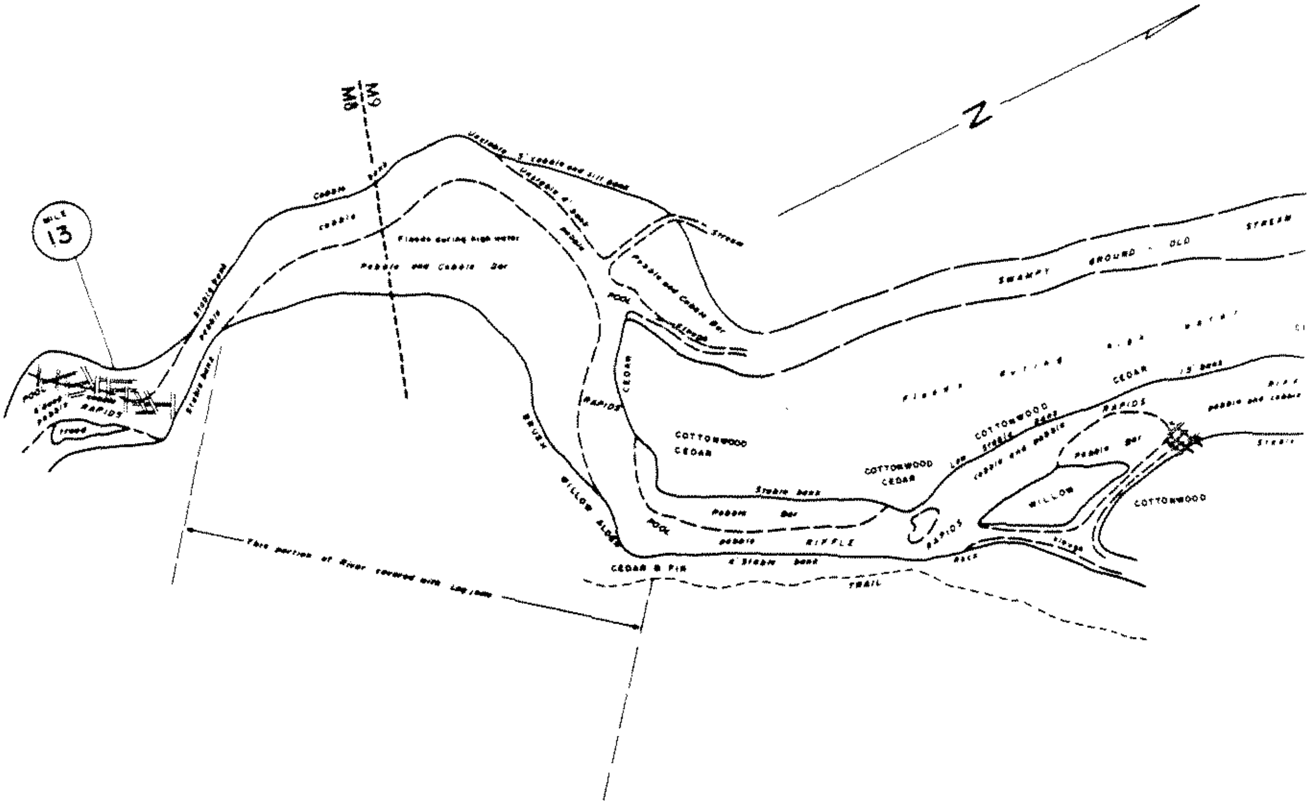
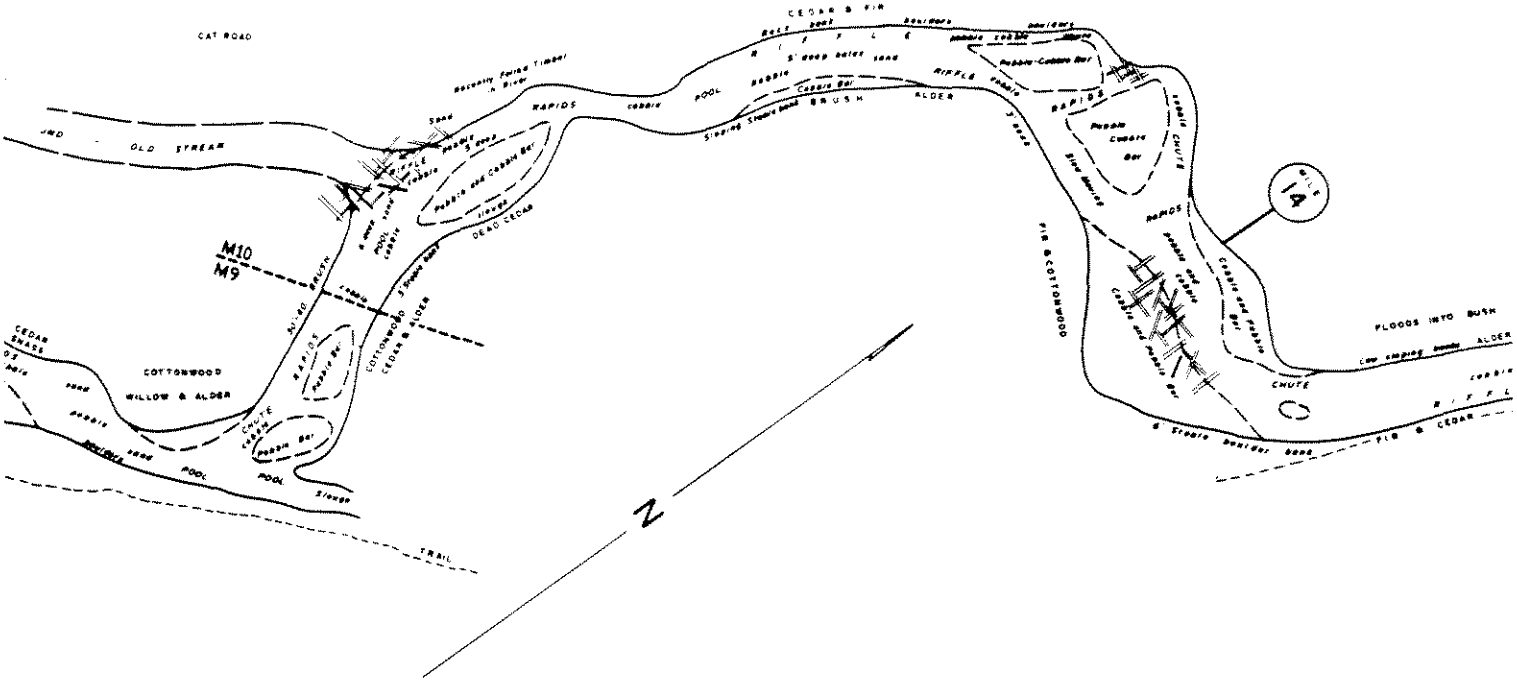

MILE
13
M9
M8
N
Cobble bank
cobble
Floods during high water
Pebble and Cobble Bar
Unstable 5' cobble and silt bank
Unstable 4' bank
pebble
Stream
Pebble and Cobble Bar
POOL
Slough
Stable bank
pebble
Stable bank
POOL
4' sand
pebble
RAPIDS
Trees
CEDAR
RAPIDS
BRUSH
WILLOW ALDER
COTTONWOOD
CEDAR
Stable bank
Pebble Bar
POOL
pebble
RIFFLE
4' Stable bank
CEDAR & FIR
TRAIL
This portion of River covered with Log jams
SWAMPY GROUND - OLD STREAM
Floods during high water
CEDAR
15' bank
COTTONWOOD
COTTONWOOD
CEDAR
Low Stable bank
cobble and pebble
RAPIDS
Pebble Bar
WILLOW
RAPIDS
Rock
Slough
COTTONWOOD
Riff
pebble and cobble
Stable

FIGURE 2.3-1
PORTION OF 1"- 200' MAPS
OF THE CANADIAN SKAGIT
RIVER



S14-SR15

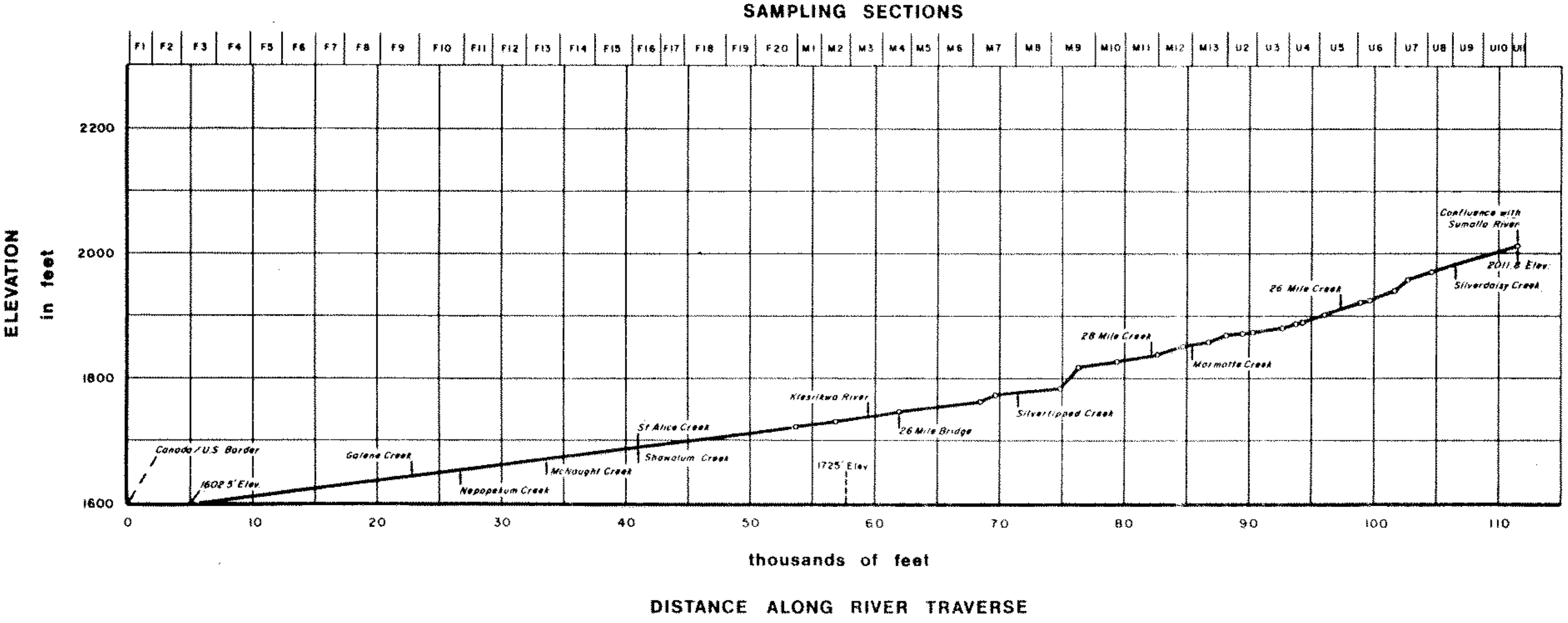
FIGURE 2.3-2

PROFILE OF CANADIAN SKAGIT RIVER

Elevation 1602.5 ft. to 2011.8 ft.

RIVER GRADIENTS

Elevations	Distance	Gradient	Elevations	Distance	Gradient
1602.5 feet to 2011.8 feet	20.18 miles	0.38%	1602.5 feet to 1725 feet	9.99 miles	0.23%
1783.7 feet to 1817.7 feet (M-9)	0.24 miles	2.78%	1725 feet to 2011.8 feet	10.19 miles	0.53%



The mean gradient across the total distance is 0.38 percent. The maximum gradient is 2.78 percent for a short distance in Section M-9. There are no waterfalls or other migration blocks that might interfere with fish movements throughout the total distance.

2.3.3.3 Substrate

The types of substrate in the Skagit River were described by a modified Wentworth classification. The size range of each type used is shown on Table 2.3-1.

The substrate of the river between elevations 1602.5 feet and 2011.8 feet was mapped by type on the 100 foot to one inch maps as illustrated in Figure 2.3-1. (See also Appendix 5).

The amounts and percentages of the various substrate types were also determined. A summary of the results is shown in Figure 2.3-3. Amounts are given in tabular form in Appendix 6.

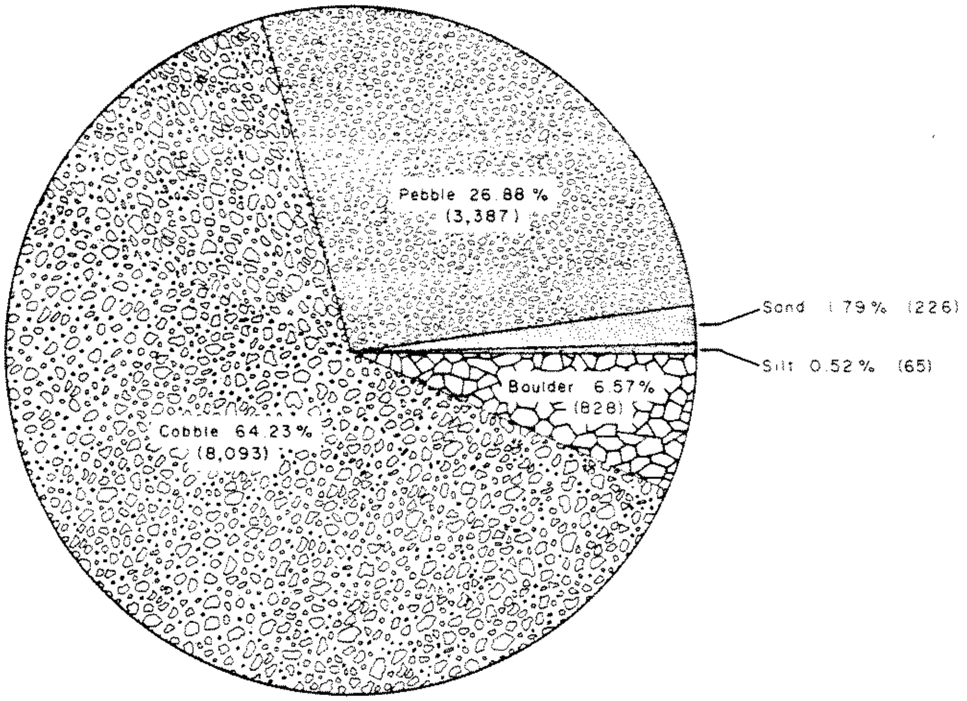
The diagram shows amounts of gravels below both high (spring) and low (fall 1970) water levels.The areas of the circles are proportional to the total amount of substrate below water at the given time.

Pebble and cobble account for approximately 90 percent of the substrate at both times of year. The absolute amounts of these gravels range from approximately 7,421,000 to 11,480,000 square feet. Boulders comprise about six to eight percent of the total or about 720,000 to 828,000 square feet. Sands and silt make up the remainder.

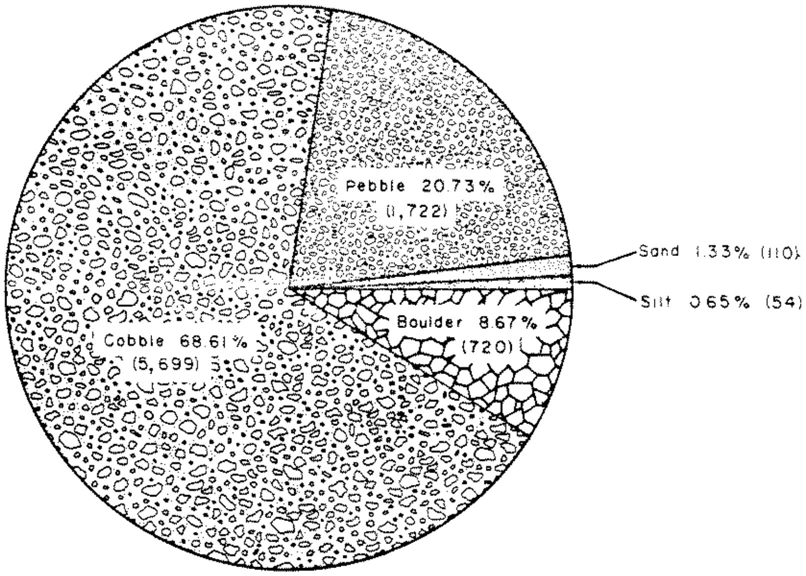
FIGURE 2.3-3

SKAGIT RIVER SUBSTRATE

Elevations 1602.5 ft. to 2011.8 ft.



High (Spring) Water Levels



LEGEND

( ) Bracketed numbers in thousands of square feet

Low (Fall, 1970) Water Levels

TABLE 2.3-1

MODIFIED WENTWORTH CLASSIFICATION OF GRAVEL SIZES

PARTICLE	LIMITING DIMENSIONS (mm)	APPROXIMATE DIMENSIONS (inches)
Silt	< 1	< .04
Sand	1 - 4	.04 - .16
Pebble	4 - 64	.16 - 2.5
Cobble	64 - 256	2.5 - 10
Boulder	> 256	> 10

2.3.3.4 Discharge

1971 and 1972

Discharge of the Skagit River was determined in cubic feet/second at Chittenden's Bridge (Section F-4, see Map 3) throughout this study. Velocity was determined at the surface by measuring the length of time a wood chip took to travel a 50 foot distance. Three determinations were made each day and the average value used. The cross sectional area of the river at the station was surveyed in each year. A stream gauge was used to indicate river level. From the level of the stream on a given day the cross sectional area was determined. Multiplication of a cross sectional area by the velocity in feet per second yields discharge in cubic feet per second.

Discharge of the Skagit River at this station is plotted by day in Figure 2.3-4 for 1971 and Figure 2.3-5 for 1972. Mean monthly discharge values are also shown for both years.

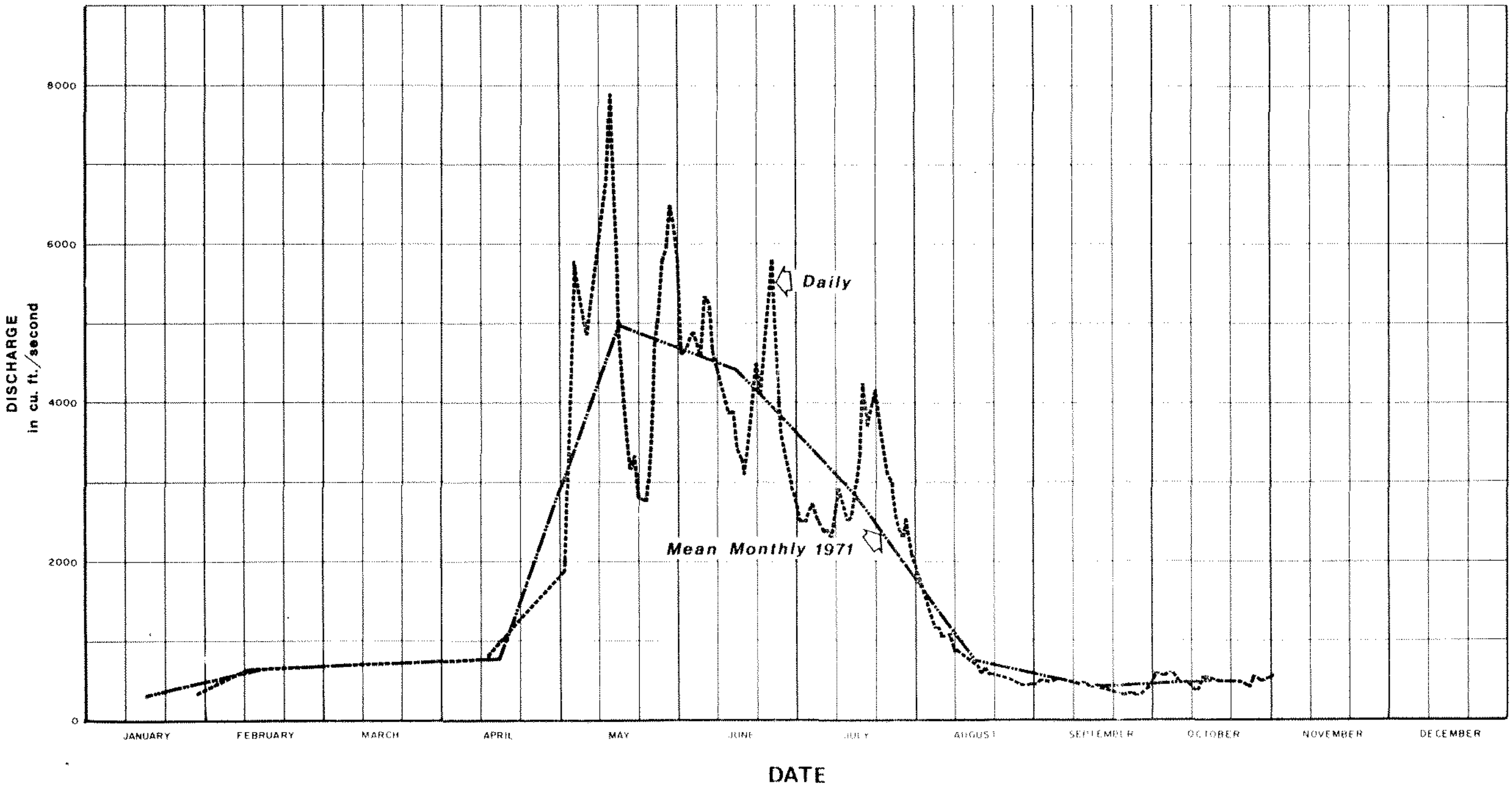
It should be noted that peak daily discharges in 1972 could not be accurately measured, since flooding around Chittenden's bridge occurred above the 8 foot mark on the stream gauge. This means that peak discharges shown in Figure 2.3-5 are underestimations of actual discharge.

Previous Years

During 1954 and 1955 water elevation readings were taken at the Chittenden's Bridge location by the Inland Waters Branch of the Government of Canada. These elevation figures have been converted to discharges using the relationship determined between elevation and discharge at Chittenden's

FIGURE 2.3-4

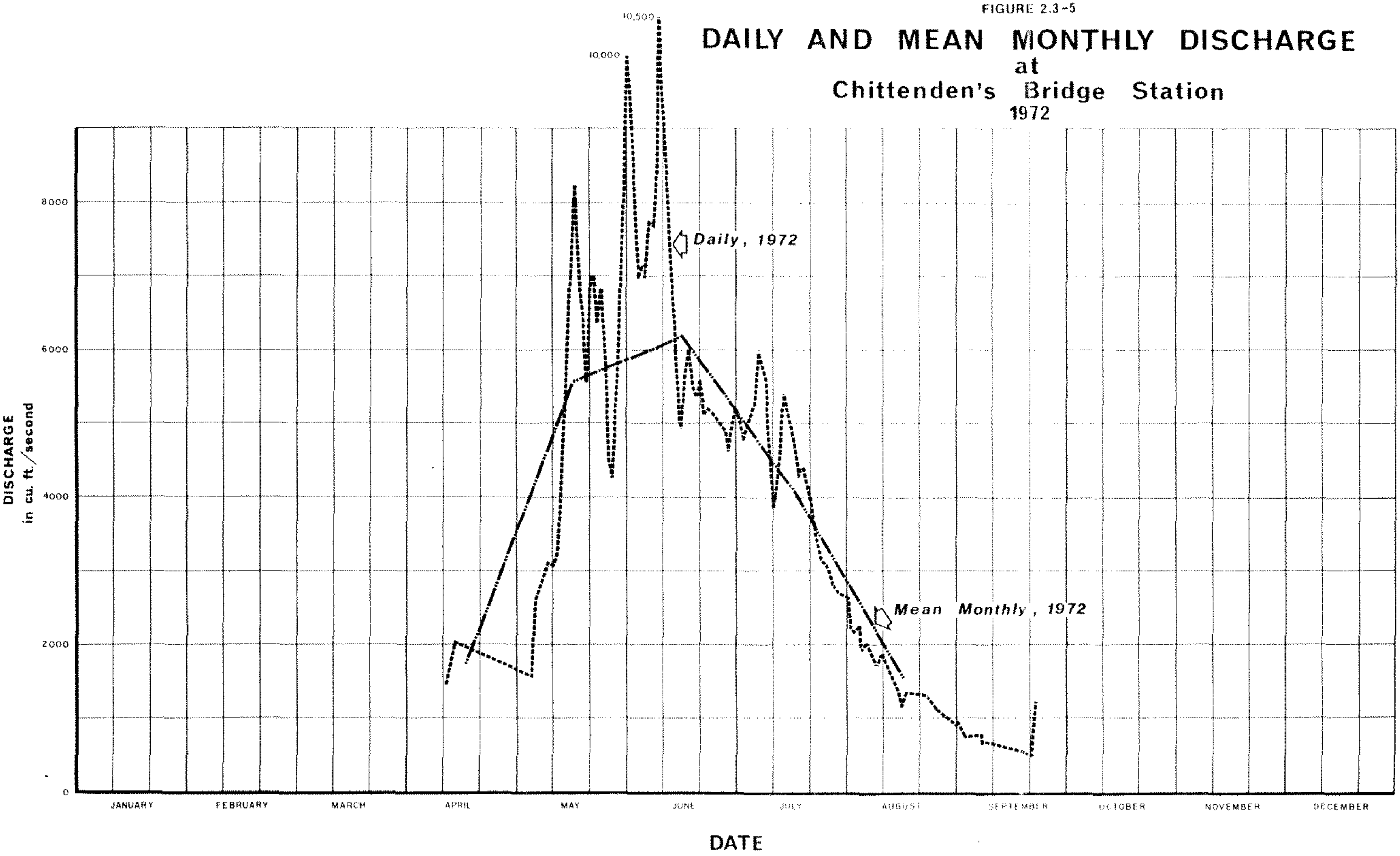
DAILY AND MEAN MONTHLY DISCHARGE at Chittenden's Bridge Station 1971



574-C63

FIGURE 2.3-5

DAILY AND MEAN MONTHLY DISCHARGE at Chittenden's Bridge Station 1972



Bridge in 1971. (The graph of this relationship is illustrated in Appendix 7). The assumption was made that no significant change in the cross sectional area of the river at this station had occurred between 1954-55 and 1971.

Mean monthly discharges at the Chittenden's Bridge station for 1954 and 1955 are plotted on Figure 2.3-6. Also shown are 1954 and 1955 mean monthly discharges at Inland Water Branch Station 08PA001 as provided by the Branch. The location of this station is shown on Map 3.

It can be seen that although discharges were higher at the Chittenden's Bridge Station, as would be expected, the timing of peak discharges is quite similar at the two station for the two years.

These similarities allow some comparisons to be made with 25 complete years of discharge data from station 08PA001 provided by the Inland Waters Branch. The 25 years between 1917 and 1954 for which complete data were available are 1917-21 and 1935-54 inclusive.

On Figure 2.3-7 the mean monthly discharge for the 25 years of data at station 08PA 001 are plotted on the same graph with the mean monthly discharge values for 1971 and 1972 at Chittenden's Bridge Station (originally shown on Figures 2.3-4 and 2.3-5). Since the two stations have different amounts of discharge, as demonstrated in Figure 2.3-6, no direct comparison between amounts of the 1971 and 1972 discharges and the 25 year average discharge can be made. The timing of the peak discharges can be compared, however.

FIGURE 2.3-6

MEAN MONTHLY DISCHARGE OF THE SKAGIT RIVER

1954 – 55

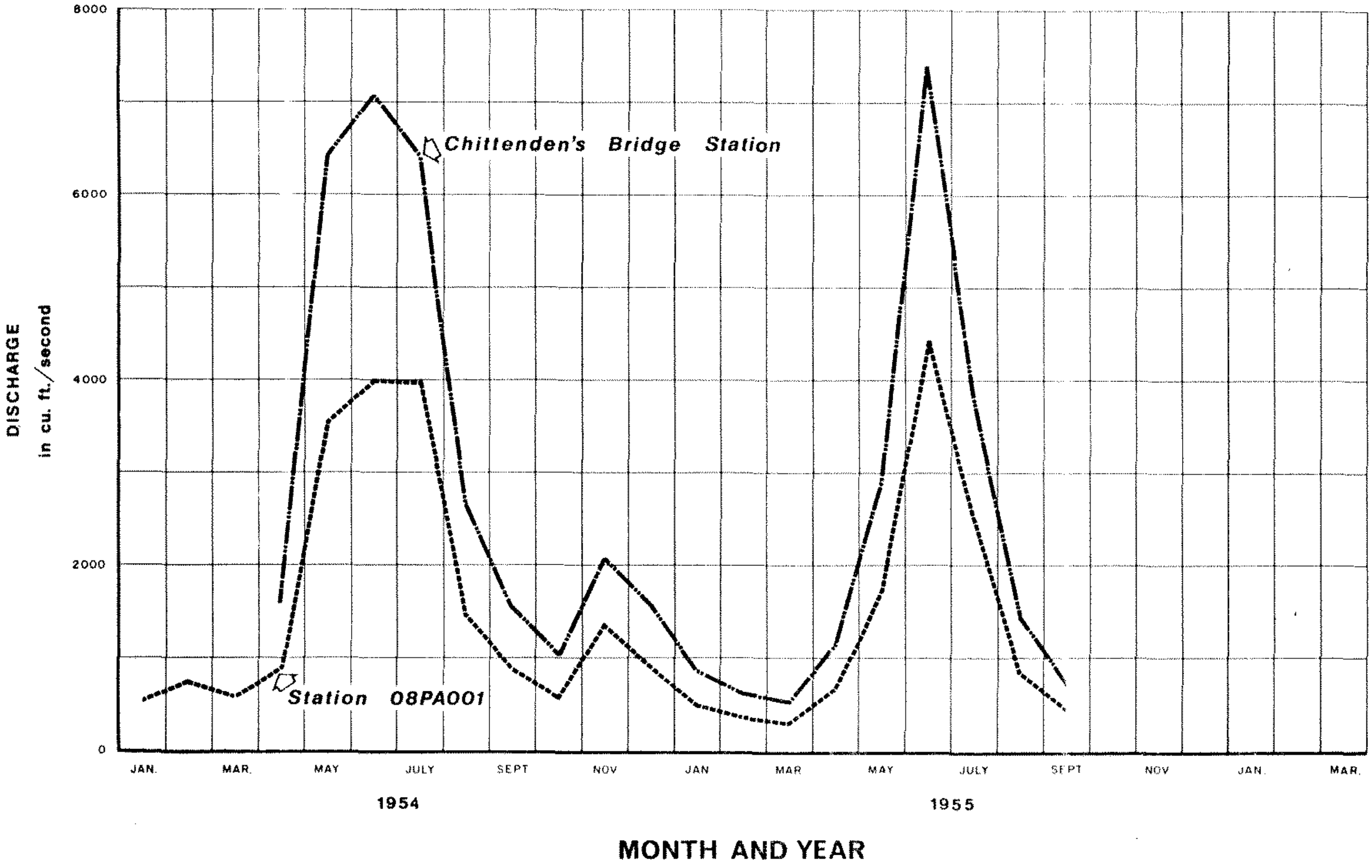
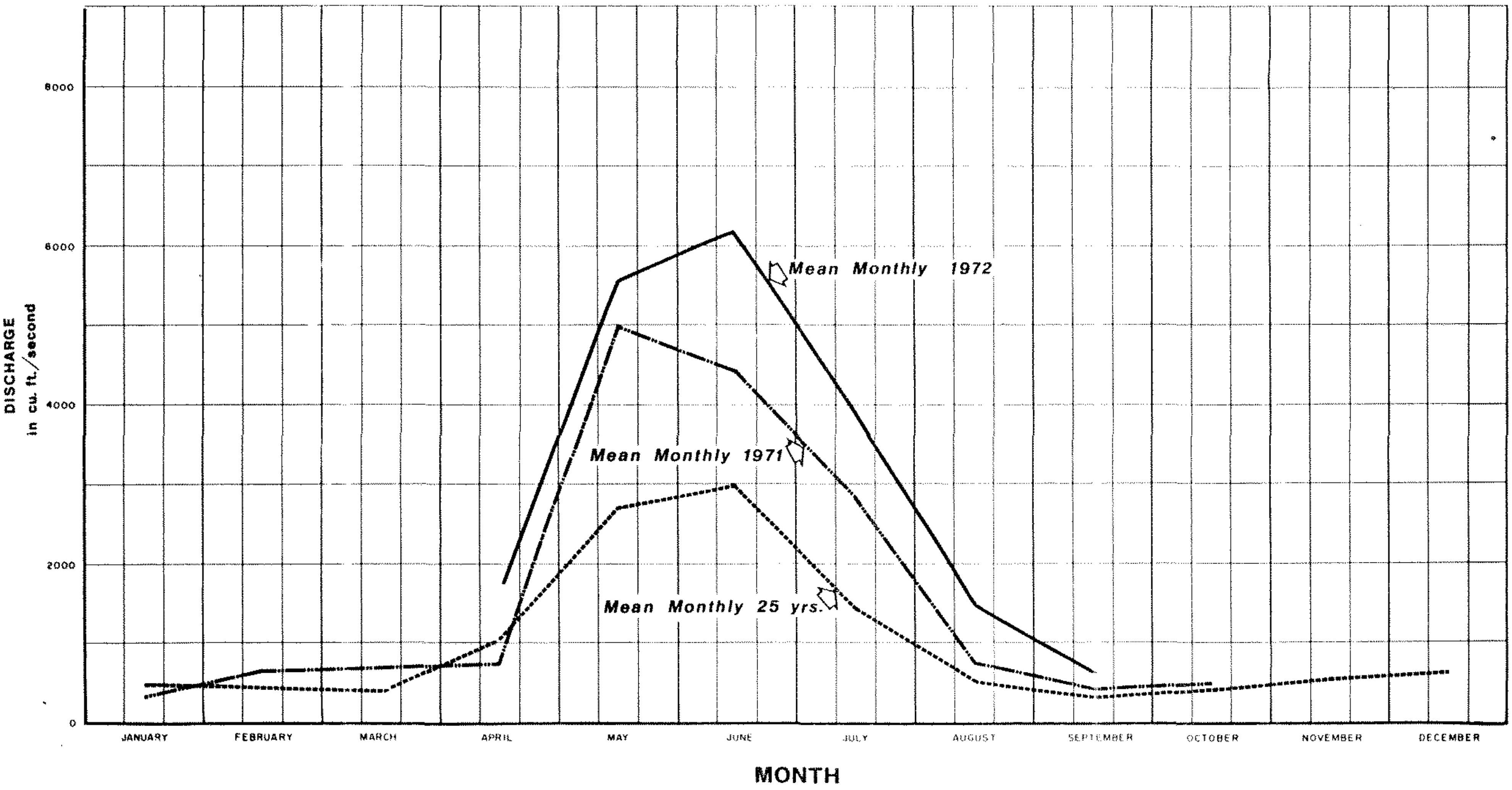


FIGURE 2.3-7

MEAN MONTHLY DISCHARGE OF SKAGIT RIVER



519-C68

Figure 2.3-7 indicates that the timing of the 1971 peak discharge was slightly earlier than the 25 year average, while 1972 was quite similar. In terms of peak discharge time, then, neither 1971 nor 1972 were unusual years on the Skagit.

2.3.3.5 Temperatures

The temperature of the Skagit River was recorded in degrees Centigrade at approximately the same time each morning at the Chittenden's Bridge Station (F-4). These temperature readings are plotted on Figure 2.3-8 for 1971 and Figure 2.3-9 for 1972. Past temperature records are quite limited. They are listed in Appendix 8.

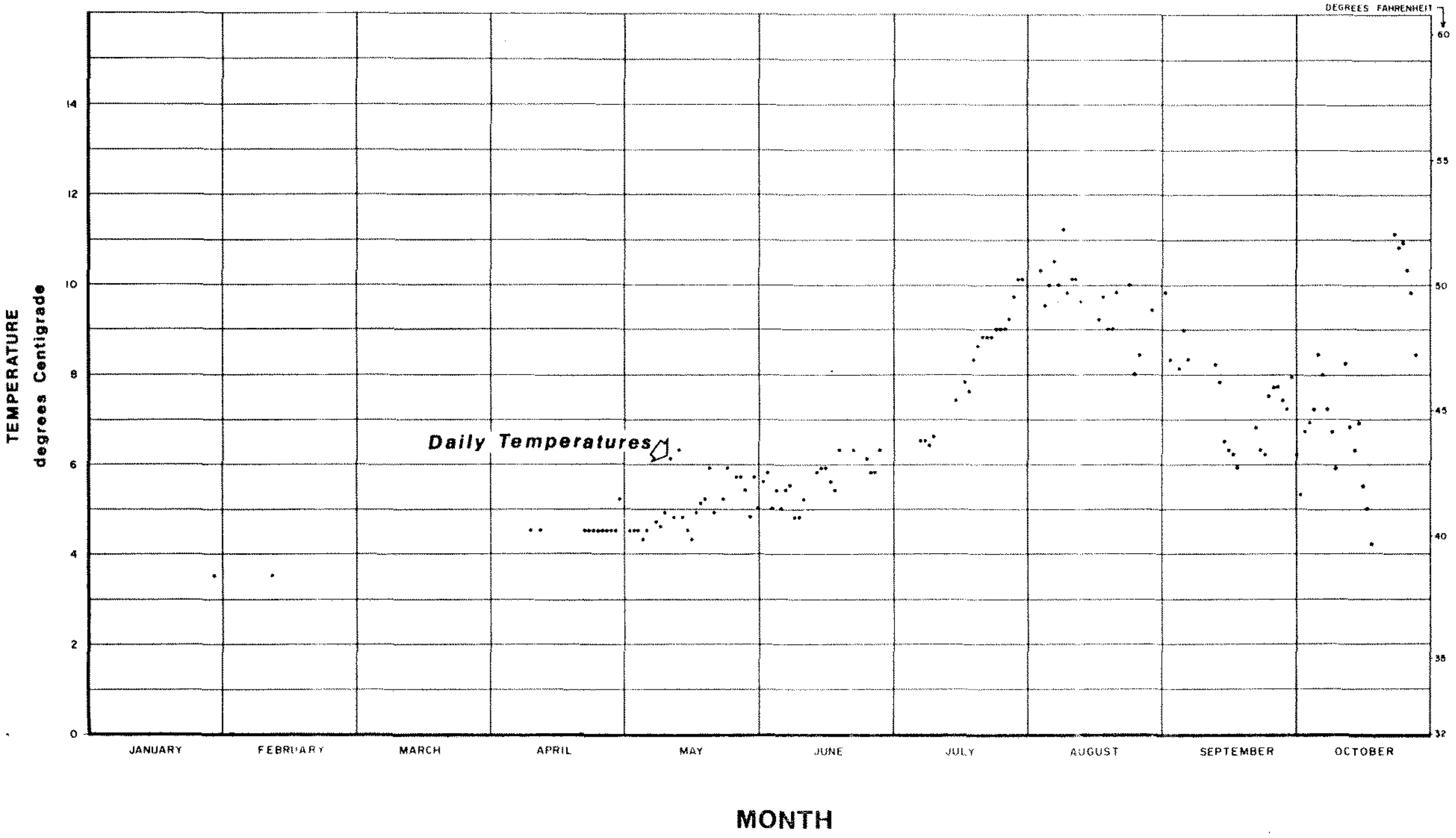
2.3.4 Skagit River Tributary Streams

The principal features of streams tributary to the Canadian Skagit River are listed in Table 2.3-2. Comparison can be made with the tributaries of Ross Lake described in Tables 2.2-1 and 2.2-2.

The Klesilkwa River is an important tributary of the Canadian Skagit River. Its gradient, (shown in Figure 2.3-10), averages 0.6%, for the first 1.5 miles above the stream mouth over a predominantly boulder substrate. The next 8 miles meanders through a boggy area with occasional gravel patches in the mostly silt, sand and organic substrate. The stream is covered in some parts of the bog by debris jams up to 300 feet long, much of it logging slash. The Klesilkwa is rarely turbid, since most silt settles out in the boggy area. Above the bog, gradients are more steep, and substrate is large gravels and boulders. The largest tributary to the Klesilkwa is Maselpanik Creek.

FIGURE 2.3-8

DAILY TEMPERATURE READINGS OF SKAGIT RIVER
at
Chittenden's Bridge Station
1971



3/4-588

FIGURE 2.3-9

DAILY TEMPERATURE READING OF SKAGIT RIVER
at
Chittendens Bridge Station
1972

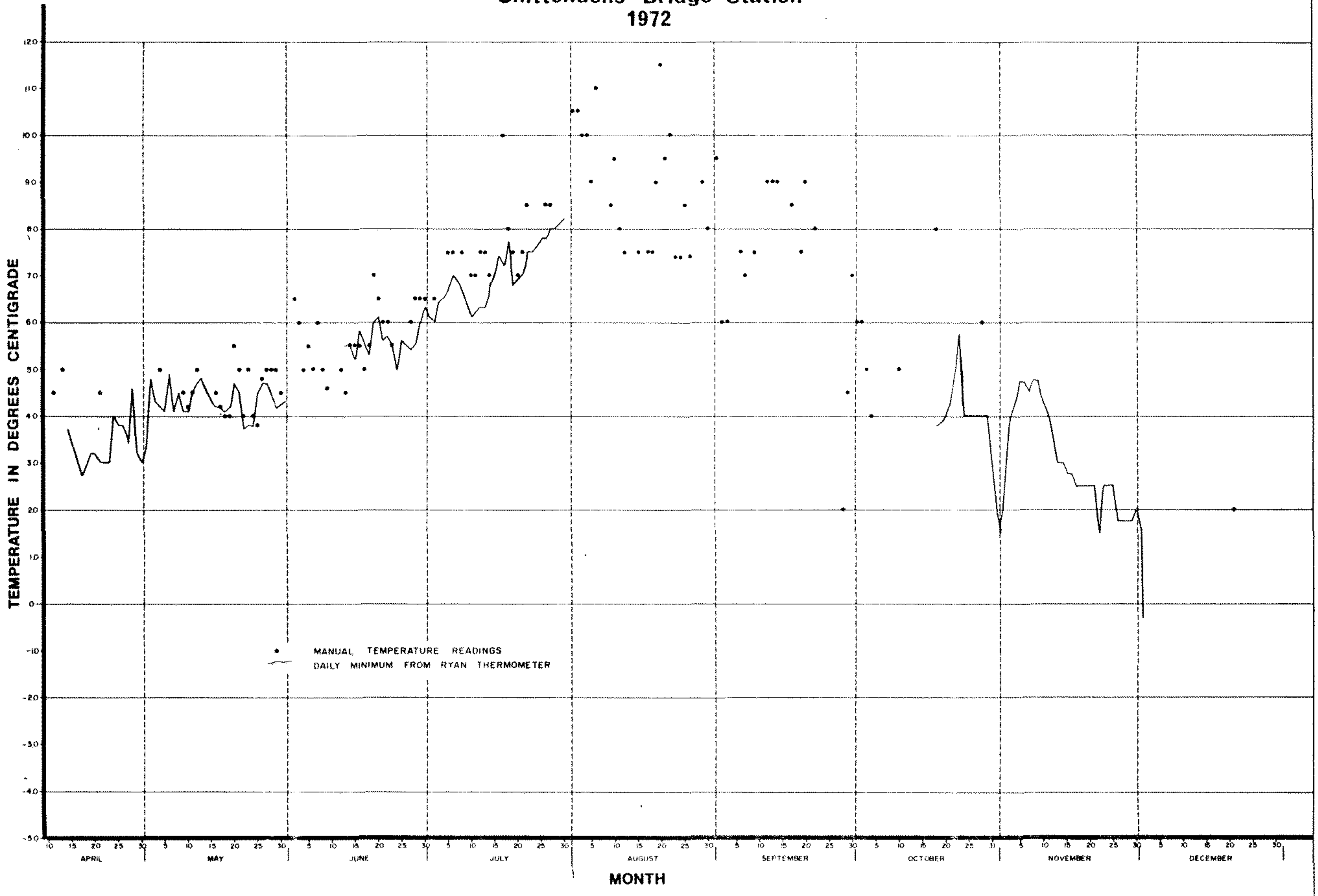


TABLE 2.3-2

CHARACTERISTICS OF TRIBUTARIES TO CANADIAN SKAGIT RIVER

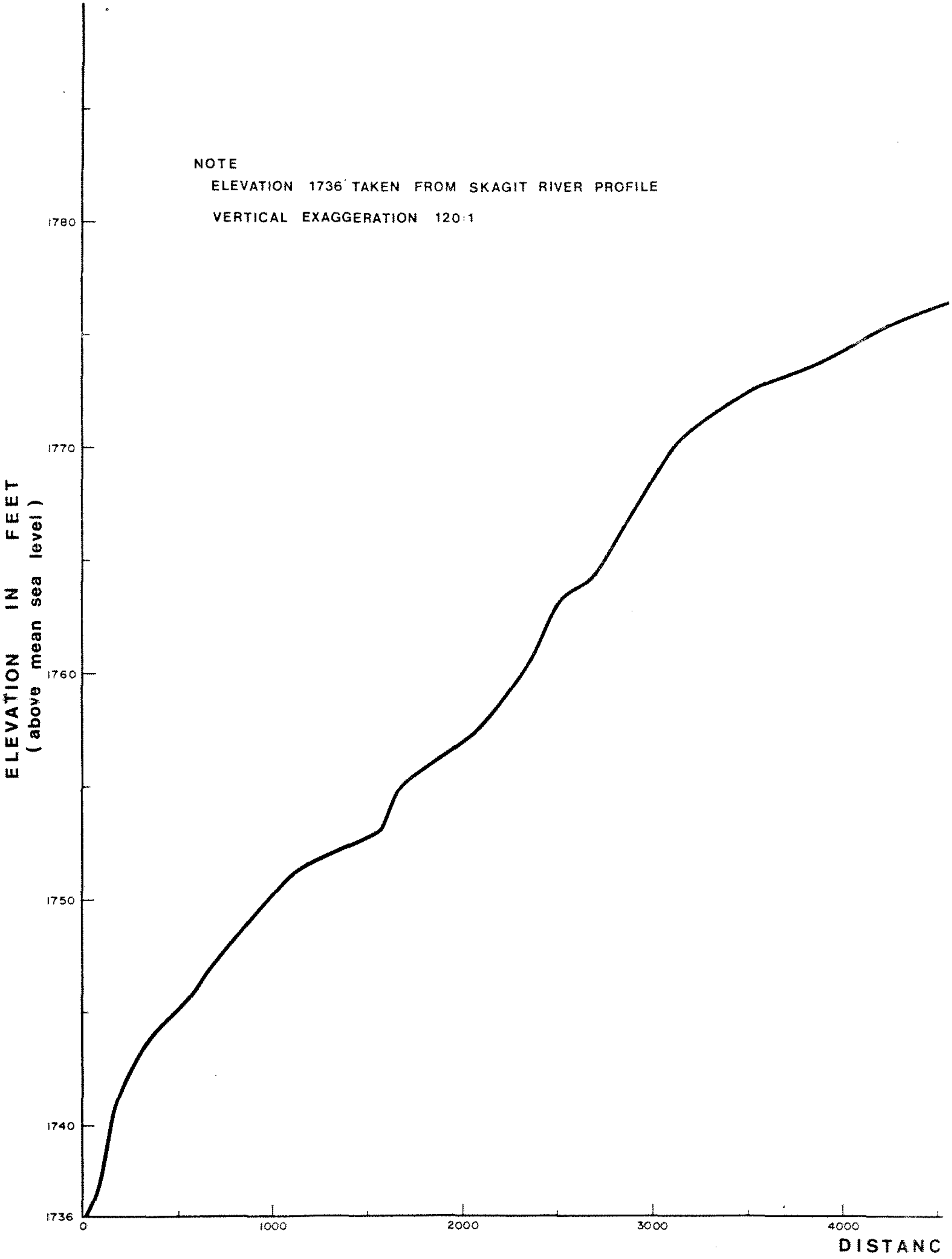
Name	Present Draw-down River.	International Creek	Galene Creek	Nepopekum (Muddy) Creek	McNaught Creek	St. Alice Creek
Tributary to: (Location)	(1475 - 1602.5 elevation)	Ross Lake (At boundary)	Skagit River (F - 9)	Skagit River (F - 11)	Skagit River (F - 13)	Skagit River (F - 16)
Length (Mi)	8.98	3.22	3.35	12.20	5.91	6.30
Gradient (%)	0.27	24.7	20.37	4.5	8.98	8.42
Drainage Area (Sq. Mi)	-	3.0	2.96	32.47	12.57	11.22
Accessibility to Fish (from Ross Lake)	Accessible	For .5 miles	Doubtful	Accessible	For .5 miles	Not accessible
Character	Flat, meandering, occasional pools; Log jams; gravels, silty.	Shallow riffles, gravel for 300 feet; steep with boulders above. No spawning gravel above 1st 100 yds.	Variable course over gravelly alluvial fan. Steep with boulders above falls 120' from mouth.	Pools and riffles; large gravel and boulders; subject to high turbidity.	Shallow riffles over good gravel across alluvial fan; steep boulders above.	Mouth diffuse, blocked with jams; above valley bottom steep with boulders.

TABLE 2.3-2 - Page 2.

Name	Shawatum (10 Mile Creek)	Klesilkwa River	Maselpanik Creek	Silver Tipped Creek	28 Mile Creek	Marmotte Creek
Tributary to: (Location)	Skagit River (F - 16)	Skagit River (M - 3)	Klesilkwa River (Mi. 5.5)	Skagit River (M - 7)	Skagit River (M - 11)	Skagit River (M - 12)
Length (Mi)	6.69	12.4	11.02	1.97	2.76	3.35
Gradient (%)	10.75/0.3	4.12	6.36	22.12	21.98	11.31
Drainage Area (Sq. Mi)	7.80	49.78	20.94	2.75	4.11	6.44
Accessibility to Fish (From Ross Lake)	1 mile	Accessible	.5 miles	.5 miles	Not accessible	200 - 300 yds.
Character	Steep, boulders from source; goes under ground into porous gravel; reappears along old Skagit River Channel. See Text.	Source steep with boulders; 8 miles silt and sand some gravel; Boulders, fast to mouth. See Text.	Moderate gradient from source; rapids, pools and riffles; logging in area; steep, boulders to alluvial fan; pools, riffles; frequent gravel. See Text.	From source steep, boulders to alluvial fan; coarse gravel, variable course, crossed by logging road.	Mouth blocked by debris. Steep falls, rapids.	Steep with large boulders.

TABLE 2.3-2 - Page 3.

Name	26 Mile Creek	Silver Daisy Creek	Sumallo River	Sumallo River	Upper Skagit River
Tributary to: (Location)	Skagit River (U - 5)	Skagit River (U - 8)	Skagit River (A1 - A8)	Skagit River (A8 to source)	Skagit River above elevation 2011 feet.
Length (Mi)	8.66	3.15	3.0	14.8	14.0
Gradient (%)	6.78	22.83	0.3	4.0	4.3
Drainage Area (Sq. Mi)	4.52	2.75	24.4	55.6	97.4
Accessibility to fish (From Ross Lake)	200 yards	.25 miles	Accessible	Accessible	Unknown
Character	Steep, boulders log jams, few pools.	Slow, good gravel to 40' falls; occasional mining.	Slow meandering with silt and sand, occasional rapids; adjacent to Hope-Princeton Highway.	Same as A1 to A8 for 2 miles, steeper with large gravel above. Course modified by developers.	For ½ mile: pools and riffle, good gravels, large log jams. Above gorge: very fast, bedrock. At headwater, pools and riffles, large gravels.



NOTE
ELEVATION 1736 TAKEN FROM SKAGIT RIVER PROFILE
VERTICAL EXAGGERATION 120:1

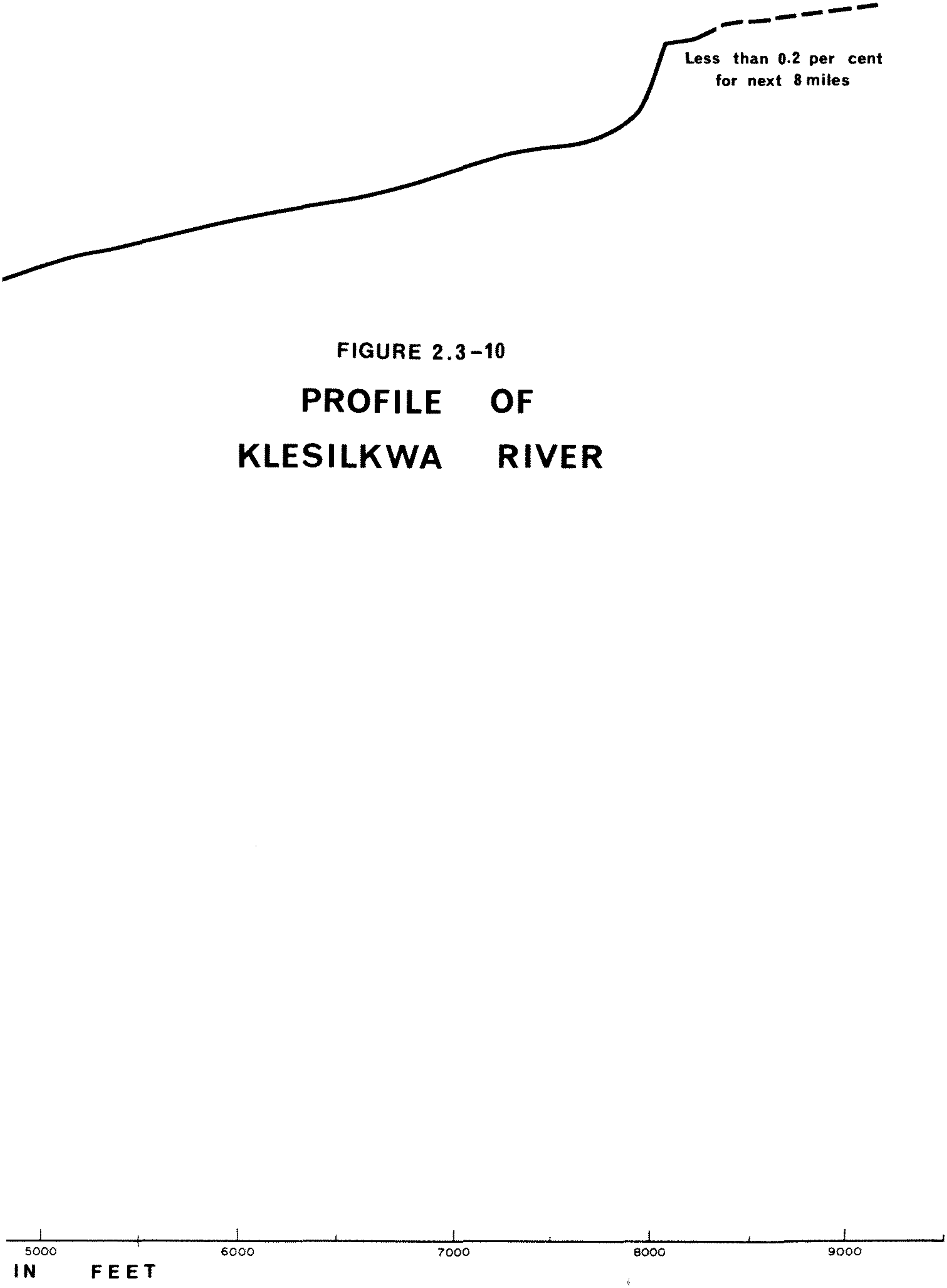


FIGURE 2.3-10

PROFILE OF
KLESILKWA RIVER

Nepopekum (Muddy) Creek is the largest Canadian tributary to be partially inundated. Its profile and gradients are shown in detail in Figure 2.3-11. Gradients average 4.3% for the lower 12 miles where the substrate is boulders with gravel near occasional small log jams. Nepopekum Creek becomes very turbid during the spring freshet; Secchi disc visibility was less than 0.5 inches on several dates in June 1972.

Maselpanik Creek is the largest tributary to the Klesilkwa River. The lower ½ mile runs at approximately 5% gradient across an alluvial fan with frequent pools and gravel substrate. The next mile has a gradient of approximately 20% with some small pools distinguishable from white water in late summer. Above these rapids, the stream consists of shallow riffles and pools, gravel and boulders for substrate, and the course is stable with no sign of bank erosion. There was a logging operation and associated road building activities in this drainage during 1972.

Shawatum Creek originates in a hanging valley and runs in increasingly steep gradients to the Skagit Valley floor. There, it disappears into porous gravels to reappear as a series of springs along a previous Skagit River channel. This channel, paralleling sections F-16 and F-17, has a gravel bottom covered with a thin layer of organic debris from beaver dams, is not subject to freshet, and runs clear all year.

2.3.5 Drawdown River

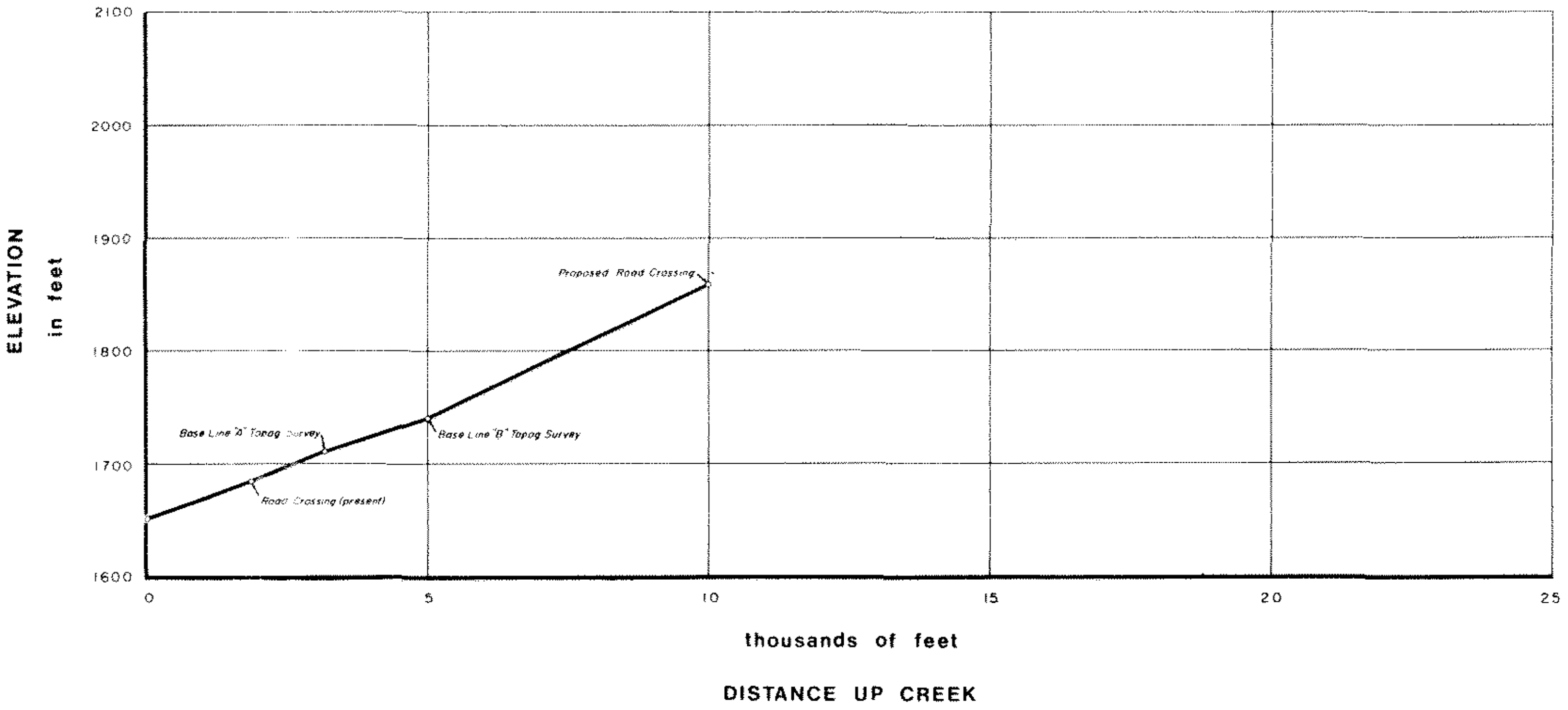
The characteristics of the drawdown river are also shown on Table 2.3-2. These figues apply to the maximum possible length of drawdown river below elevation 1602.5 feet. The reservoir has never been drawn down to 1475 feet elevation since the installation of the spillway gates in 1952.

FIGURE 2.3-11

PROFILE OF NEPOPEKUM (MUDDY) CREEK

CREEK GRADIENTS

Elevations	Distance	Gradients	Elevations	Distance	Gradients
1651 feet to 1683 feet	1850 feet	1 73 %	1710 feet to 1740 feet	1850 feet	1 62 %
1683 feet to 1710 feet	1300 feet	2.08 %	1740 feet to 1858 feet	5000 feet	2.40 %
			1651 feet to 1858 feet	10000 feet	2.07 %



514-C87

PART 3

PRESENT STATE OF FISHES AND FISHERY

3.1 INTRODUCTION

3.1.1 Species Present

(by F.F. Slaney & Company)

Fishes found in the Skagit River-Ross Lake system include rainbow trout, brook trout, Dolly Varden char and cutthroat trout. Golden trout and steelhead trout have been introduced to the system, as have rainbows, brook and cutthroat (see Section 3.1.2).

Table 3.1-1 summarizes the morphological, life history and other characteristics of the four major species of fish found in the system. The Table is compiled from several literature sources (Calhoun, 1966; Carl et al, 1967; McPhail and Lindsey, 1970; and Paetz and Nelson, 1970) and presents the characteristics of the species throughout their ranges.

Hybridization between the cutthroat and rainbow trout populations appears to have occurred in the Skagit-Ross system. Individuals showing the characteristics of both species as well as intergrades between the two have been sampled. The two species may perhaps more properly be referred to as a "rainbow - cutthroat complex".

TABLE 3.1-1

CHARACTERISTICS OF FISH SPECIES FOUND IN SKAGIT RIVER - ROSS LAKE SYSTEM

Name					
Common	Scientific	Description	Distinguishing Characters	Distribution	Notes
Rainbow trout	*Salmo gairdneri* Richardson	Body trout-like; color variable (silver to bluish green or brown); up to 45" long and 52 lbs.	Lack of teeth at base of tongue; absence of red "slash" under jaw	Native: Pacific and Bering slopes (Mexico to Alaska). Introduced: world wide	Cool water fish; found in lakes and streams; spawning: late spring and early summer; few native populations; anadromous=steelhead
Coastal cutthroat trout	*Salmo clarki clarki* Richardson	Body trout-like; dark green above, silvery below; small dark spots on back and sides; up to 30" long and 17 lbs.	Red slash beneath lower jaws; small teeth at base of tongue	Northern California to S.E. Alaska on Pacific slopes	Cool water fish; lake and stream resident; spawning: late spring and early summer
Dolly Varden char	*Salvelinus malma* (Walbaum)	Body trout-like; color variable: olive-green with many round light spots; up to 50" and 32 lbs.	Small round spots (yellow, orange or pink) on back and sides	Northern California to Northwestern Alaska to Japan	Cool water fish; some anadromous populations; spawn in fall (August to November)

TABLE 3.1-1 - Page 2

Name					
Common	Scientific	Description	Distinguishing Characters	Distribution	Notes
Brook trout	*Salvelinus fontinalis* (Mitchill)	Body deep, trout-like; color variable: olive-green above, lighter below; many small greenish spots with red centers and blue border	Red spots with blue halos; dark green marbling on back and dorsal fin	Native: streams and lakes of N.E. North America. Introduced: Western North America and world wide	Cold, clear streams preferred; spawn in fall

3.1.2 History of Stocks

3.1.2.1 Washington

(by Washington Department of Game)

Cognizance of Washington fish and wildlife resources is historic and surely dates back to the earliest explorations of the territory. The first law pertaining to wildlife was passed by the Washington Territorial Legislature in 1853.

But not until 1889, the year Washington attained statehood and the State Department of Fisheries and Game was created, were formal records kept. Unfortunately, little of what was known of fishes native to particular areas of the State including the present Ross Lake area, prior to introduction of fishes from other locales, exists today.

Henry Custer, in a report dated May, 1866, (National Archives, 1866) provides the earliest known record of fishes residing in the upper Skagit River. Engaged in boundary survey work, Custer's party visited the Skagit River in the vicinity of the international boundary early September, 1859. About the fishing activity of the Indian guides, Custer wrote, "..... the result was a fine mess of black speckled trouts, which seem to be in abundance in the river wherever its waters are deep and the currents low. These fish are truly delicious and firm and a very acceptable addition to our meal .....". This was the only mention of fish in Custer's report.

The first of several recorded artificial introductions to the Skagit River or its tributaries, upstream from the present site of Ross Dam, occurred in 1916.

A publication of the United States Forest Service (Forest Service, 1916) describes a plant of 20,000 trout to Big Beaver Creek "far above the falls in barren waters that never before had known the trout". These fish, planted by Forest Service personnel, were transported 35 miles by pack mules "with a total loss of less than 50 fish". The variety of trout planted was not given nor was there direct mention of the several small lakes or ponds in the Big Beaver Valley, at least one of which is presently inhabited by rainbow and cutthroat trout. The falls mentioned are probably those located near the present entrance of Big Beaver Creek to Ross Lake. State records also list a plant in 1916 to Big Beaver Creek of 27,000 cutthroat trout (Fish Commissioner, 1915, 1916) from a State hatchery as well as a plant of 20,000 cutthroat trout from a County hatchery to a Beaver Creek (Chief Game Warden, 1915, 1916) also in Whatcom County. No details are available from the State records which could ascertain if these were all related to a single introduction or, if there were two or more separate plants made, or if waters other than those of the upper Skagit were involved. In any case, in 1916, there were at least 19,950 trout, no doubt cutthroat, planted in Big Beaver Creek.

Over the succeeding years, 17 other introductions of rainbow, steelhead, cutthroat and golden trout have been made to waters tributary to the upper Skagit and/or Ross Lake including several lakes lying within and draining to the Ross Lake Basin. These are summarized in Table 3.1-2.

Brook trout, currently found in Ross Lake, Hozomeen Lake and reported in Sourdough Lake (Walcott, 1965; Washington State Game Department, no date) were introduced sometime prior to 1933, since they are not indigenous to Western North America (Schultz and DeLacy, 1965; Carl et al, 1959) and no plants of this species to the Ross Lake Basin were made after that time. State

TABLE 3.1-2

TROUT INTRODUCTIONS TO ROSS LAKE, OR THAT PORTION OF THE SKAGIT RIVER WHICH IT PRESENTLY OCCUPIES, AND WATERS TRIBUTARY THERETO WITHIN WASHINGTON STATE LISTED IN STATE RECORDS OR FILES OF THE WASHINGTON STATE GAME DEPARTMENT

YEAR	WATER	SPECIES	NUMBER
1916	Big Beaver Creek	Cutthroat	27,000
	Beaver Creek	Cutthroat	20,000
1919	Big Beaver Creek	Rainbow	10,000
1920	Hozomeen Lake[1]	Steelhead	40,000
1935	Slate Creek [2]	Rainbow	10,000
1936	Ruby Creek	Rainbow	2,000
	Slate Creek [2]	Rainbow	2,000
	Slate Creek, South Fork [2]	Rainbow	2,000
1938	Slate Creek, South Fork[2]	Rainbow	5,000
	Slate Creek, North Fork[2]	Rainbow	5,000
1952	Ross Lake	Cutthroat	25,104
1953	Ross Lake	Cutthroat	25,761
1954	Ross Lake	Cutthroat	50,861
1960	Willow Lake [3]	Cutthroat	7,200
1961	Willow Lake [3]	Cutthroat	5,000
	Silver Lake (Glacier Lake) [4]	Golden Trout	5,000
1967	Willow Lake [3]	Cutthroat	2,250
	Jerry Lakes (upper) [5]	Cutthroat	3,450
	Jerry Lakes (lower) [5]	Cutthroat	3,450

[1] Hozomeen Creek Drainage

[2] Ruby Creek Drainage

[3] Lightning Creek Drainage

[4] Silver Creek Drainage

[5] Devils Creek Drainage

and U. S. Forest Service records prior to 1933 do not contain facts regarding the original or subsequent introductions of this species. The first shipment of brook trout into Washington occurred in 1894 (Fish Commissioner, 1902).

Apparently, anadromous forms of rainbow trout and Dolly Varden did not frequent the Skagit River upstream from Ross Dam prior to construction of Gorge Dam in the early 1920's at least according to a biological survey of the area made in 1921 (Smith and Anderson, 1921). In that report, the Skagit River between the mouth of Ruby Creek and the town of Newhalem was characterized as follows: "Through this region, the Skagit boils and foams for the greater part of the distance. While no single fall or rapid observed would form an insurmountable barrier to the upward migration of salmon," (this would probably include steelhead as well since during this period, steelhead were arbitrarily placed in the salmon class (Chief Game Warden, 1915, 1916) and were often referred to as "steelhead salmon")..."the continued series of low falls and rapids seem to have proved effective in stopping the run of salmon through this part of the river. Those living in this region ... have never seen salmon more than one mile above the city of Seattle camp" (the present location of the town of Newhalem).

Smith and Anderson's 1921 report noted further that the Skagit River, from Ruby Creek to the Canadian border, was "well stocked" with rainbow trout and Dolly Varden. It is not clear if their usage of the term "stocked" was literal or figurative. Ruby Creek, termed, "... an excellent trout stream throughout the greater part of its length", was also inhabited by rainbow trout according to Smith and Anderson, although, "At the mouth of the creek, where it empties into the Skagit River, much larger fish (rainbow) were found." A 25 foot high diversion dam was located on Ruby Creek which was formerly used to supply water to a hydraulic mining project. At the time of their survey (1921), Smith and Anderson noted this structure was located four miles upstream from the Skagit River and was no longer in use. A dam of this height would be a barrier to any upstream trout movement. Though not specifically stated, Smith and Anderson's report indicated that rainbow trout were found above and below this structure. If this were the case, and lacking records of rainbow trout introductions to Ruby Creek, it can only be assumed that they were native to this area and, consequently, to the main Skagit. The dam was removed by U.S. Forest Service personnel in 1949. Again, lacking records of Dolly Varden introductions, it must be assumed they were also native to the upper Skagit drainage.

3.1.2.2 British Columbia

(by British Columbia Fish and Wildlife Branch)

The B.C. Fish and Wildlife Branch has no records of non-native eggs, fry, or adult introductions into the Skagit system.

3.2 GENERAL PROCEDURES OF FISH SAMPLING

(by Fisheries Research Institute and F.F. Slaney and Co.)

3.2.1 Introduction

In order to obtain the data necessary to ascertain species composition, age, growth, condition, sexual maturity, and to tag fish for assessment of their movements and population abundance in Ross Lake and its tributaries, a fish sampling program was conducted in Ross Lake and the Canadian Skagit River during the periods of March through October, 1971, and April through September, 1972 (see Appendix 9 for dates and location of fish sampling). Since it was necessary to capture, process, tag, and release a large number of fish, various means of capture were attempted to find the most successful method. Generally, areas of the reservoir which yielded the most fish were sampled most extensively.

The Canadian Skagit River System was sampled throughout where water levels, flow and accessibility permitted.

3.2.2 Fish Collection and Processing Methods

3.2.2.1 Sampling Gear

Lake

Gear, including bait (clustered and single salmon eggs and worms), various lures-spinners, spoons, artificial flies, and gang trolls (multiple spoons and spinners with salmon eggs or worms) were used in 1971 and 1972. Generally the bait and single spinners or spoons were effective when fished near the shore or at stream inlets. No angling gear was very effective in the open water zone of the reservoir; however, a 300 foot long by 30 foot deep 2-½ inch mesh (stretched measure) gill net was used in this zone in 1971 with moderate success. In 1972, sinking monofilament gill nets (1, 1-1/2 inch mesh - stretched measure, 50 ft long by 8 ft deep) were fished in overnight sets along the lake shore with excellent success. Fish captured by the 1 and 1-1/2 inch mesh gill nets ranged in size from 94 to 387 mm. The larger fish were invariably caught by the jaws while the smaller fish were usually caught behind the operculum. Baited traps constructed of 1 x 2 inch wire mesh with a conical fyke were placed on the lake bottom in approximately 40 feet of water in and near stream arms in 1971 only. Sets varying from one day to four days in length produced small catches (generally 1-2 fish). Electrofishing was employed in the areas of stream inlets in 1971. The shocker, a gasoline powered generator with a variable voltage pulsator (VVP) producing pulsed direct current (DC) with voltages ranging from 100-700 volts, was operated from an aluminum boat. The hull of the boat served as the negative electrode. A grid (positive electrode) lowered into the water (electrolyte) completed the circuit. Recovery from the shocking was usually rapid and the fish were swimming normally within three minutes.

Effectiveness of angling and 1971 gill net methods of fish capture in terms of number of fish caught per gear hour, e.g. catch per unit of effort (CPUE), by date and location is shown in Appendix Table 10.

River

Gill nets, fry nets, seining, electrofishing, and angling were used to capture fish in the Canadian Skagit River system. A detailed account is given in Section 3.3.3.2.

3.2.2.2 Sample Processing

Lake

Before processing, live fish were placed in a 4 x 3 x 2 foot holding box filled with fresh water and allowed to recover from the stress of capture until they were swimming normally. The fish were then placed in a solution of tricaine methanesulfonate (MS-222) until they showed no response to being touched. The fish were then measured from tip of snout to tail fork (fork length) to the nearest millimeter (mm) and weighed with a single beam balance to the nearest five grams (g) to obtain data on size, growth rate and condition. A scale sample for age determination and growth studies was taken from the left side of the fish from scale row 2, 3, or 4 midway between dorsal and adipose fins. At first, a knife was used to scrape the scales off the fish; the scales were then placed in an envelope for later mounting on gummed cards. This method was soon replaced by a method whereby four scales were removed by forceps from each fish and placed directly in position on gummed cards with sculptured side up. Each scale sample taken was carefully identified by code number as was each fish so that scale patterns for each fish could be related to species, age, size, growth rate, and location of capture.

Fish in apparently good condition were then tagged with color coded and numbered 2-1/2 inch long anchor tube tags. A Dennison tagging gun was used to apply the tags (Dell, 1968). A sterilizing agent (95 percent ethanol) was used to clean the needle of the gun prior to tagging in order to prevent infection of the wound. The tag was inserted into the flesh just below the dorsal fin on the left side of the fish. The tag color codes used to identify location of tagging in the event of later tag sighting or recovery were as follows:

Blue	Ruby Creek Area
Green	Roland Point Area
Yellow	Devils Creek Area
International Orange	Lightning Creek Area
Red	Little Beaver Creek Area
White	Hozomeen Area

The numbers on the tags allowed identification of individual recaptured fish, thus minimum distance of movement between locations of tagging and recovery could be determined.

After tagging the fish were squeezed ventrolaterally in an anterior-posterior direction to express running sex products if fish were ripe and ready to spawn. This procedure allowed positive identification of spawning fish. The fish were then placed in fresh water in the holding boxes, where they remained until recovery from the anesthetic was complete. Upon recovery they were released at the location of capture.

Some of the fish died shortly after handling. In addition, a few fish were sacrificed to provide needed information on sexual maturity and stomach contents. The stomachs and gonads were removed from the dead fish, labelled and preserved in a 10 percent solution of formalin for later analysis of food habits and maturity stage.

Criteria for determining sexual maturity of females from egg size were as follows:

Egg size (diameter in mm)	Maturity Stage
eggs indistinguishable in ovary	0
1 mm	1
1 - 2 mm	2
2 - 3 mm	3
3 - 4 mm (tight skein)	4
3 - 4 mm (eggs loose in body cavity)	5 (ripe fish - ready for spawning)
a few loose eggs (3 - 4 mm) or remains of ovary in body cavity	6 (spent - spawned out fish)

For males the criteria were more subjective; sexual maturity was based on appearance of the testes as follows:

Testes appearance	Maturity Stage
barely distinguishable	0
thin clear membranes	1
small pinkish organs	2
large pinkish organs with many blood vessels	3
testes large, turgid, white with many blood vessels, no running milt	4
testes exuding milt with little or no pressure	5 (ready for spawning)
part or all of testes deflated, no running milt	6 (spent - spawned out fish)

River

Gill net and seine net catches from the Canadian Skagit River system were sacrificed to obtain stomach samples and data on sexual condition. The fish were also weighed (to the nearest five g), and measured (to the nearest mm). Scale samples were taken as described above for the lake sample.

Fish captured by electrofishing and by angling were also weighed and measured. Scales were taken and the fish were tagged and released. Anaesthetic was not used since maintaining position in the river was difficult and quick processing was necessary. The tags used were the Dennison type described in the lake tagging program and tagging procedures were similar. The river color code was brown/white.

Criteria used for maturity stages of captured fish were the same as outlined above for lake sampling.

3.2.2.3 Sport Catch

Anglers' catches from lower Ross Lake were sampled to provide information on species composition of the catch, additional length and weight data (many fish had been dead for several hours therefore only a few fish were weighed), scales for age determination and sexual maturity information. Stomach samples were also taken.

Creel census samples from the north end of Ross Lake and the Skagit River System were processed in the same way as gill net catches with length and weight recorded and scales, stomachs and gonads taken and preserved if possible.

3.3 SPAWNING TIME AND LOCATION

3.3.1 Introduction

Determination of the timing of spawning and the spawning areas utilized by trout and char in the lake-stream complex is an essential part of the study to evaluate the potential impact of raising the reservoir level. Information on timing of spawning relative to present and predicted reservoir drawdown schedules aids in determining what areas are available now and likely to be utilized successfully in the future by spawning fish. Data on the amount and nature of presently available spawning areas, the location of migration blocks relative to present and predicted lake levels, and the amount and nature of new areas above blocks inundated at the higher lake elevation are necessary in predicting the changes in spawning.

3.3.2 Ross Lake and American Tributary Streams

(by Fisheries Research Institute)

3.3.2.1 Methods

Location and time of spawning was determined by direct observation of spawning activity, capture of sexually mature fish and by observation of the location of newly emerged fry.

During the spring runoff, from May through June, visibility in the streams is reduced, making fish sampling by angling and particularly visual observations of spawning difficult. High water levels and swift flow make foot surveys at this time very slow and hazardous. Granite and Ruby Creeks were obscured further from early May through June by erosion from the construction of the North Cascades Highway. Big Beaver Creek is generally turbid during the spring and summer and difficult to reach by foot due to the thick brush on each bank. Periods of cold weather in mid-June of 1971 and 1972 resulted in clearing of Big Beaver Creek for several days. This allowed the float surveys (discussed later) to be made. A float survey was also made in late April 1972. Otherwise visual observations were difficult to make. For these reasons, much of the results of time and location of spawning rely on methods other than direct observation of spawning activity. As will be shown later, time of trout spawning occurs during the runoff when observations are most difficult.

The sampling of sexually mature fish in Ross Lake has been previously described. Fish sampling during the stream spawning surveys involved the use of angling gear with lures (spoons and spinners) in potential spawning areas such as riffles and pools. Sex and maturity were determined as described earlier. Some visual observations of activity related to spawning (nest building in gravel and fish pairing) were made in Lightning, Dry, Roland, and Canyon Creeks. Emergent fry observations were made along 50 to 300 foot sections of the lake shore in the vicinity of all stream inlets to Ross Lake in 1971. Fry observations in the stream were made at selected short stream bank sections where areas of quiet water were present (trout fry, following emergence from the gravel, seek areas of quiet water along stream banks for protection). Counts were made of fry observed at each location. In addition, small fyke nets (described in 3.2.2.1) were set for 12 to 24 hour periods (usually overnight) in Ruby, Big Beaver, Roland, Devils, Dry, Lightning, and Silver Creeks in September 1971, and August and September 1972. The nets were placed midstream in riffles with the opening facing upstream.

To estimate time of spawning by Ross Lake trout, two methods were used. The first involved plotting the distribution of maturity stages of captured trout over time. (Figs.3.3-1;3.3-2). Sample sizes of mature fish from the south end of the lake in 1971 were pooled to give estimates of spawning time there. Therefore, 1971 samples from all areas from Lightning Creek south were combined (Lightning, Devils, Roland Point, Ruby areas. This procedure was also followed with the 1972 samples. The second method employed to estimate time of earliest spawning incorporated a back-calculation from the time fry were first observed in each stream area to the time of spawning (Figs. 3.3-3;3.3-4). This method is based on the use of temperature units as discussed by Embody (1934). A temperature unit (TU) represents one degree Fahrenheit above 32°F for one day (24 hours). Thus a temperature of 40° F for one day would represent eight temperature units. Embody (op. cit.) found that during egg development, the sum of the temperature units is relatively constant at all temperatures normal to the eggs. According to Embody (op. cit.) and Donaldson (1971, oral personal communication) the period of development from spawning to hatching averages between 580 and 600 TU. Another 400 to 500 TU are required for the fry to emerge from the gravel; but these requirements can be quite variable (Donaldson, personal communication). Thus a total of about 1000 to 1100 TU are required for development from spawning to emergence from the gravel.

This technique was applied to the spawning and incubation of the rainbow trout in the major tributaries of Ross Lake. Weekly stream temperatures were taken by City Light personnel. In Ruby, Big Beaver and Lightning Creeks continuous recording thermometers and spot temperature measurements provided daily stream temperature data and their equivalents in temperature units are presented in Appendix 12.

FIGURE 3.3-1

SEXUAL CONDITION OF ROSS LAKE RAINBOW TROUT

BOTH SEXES

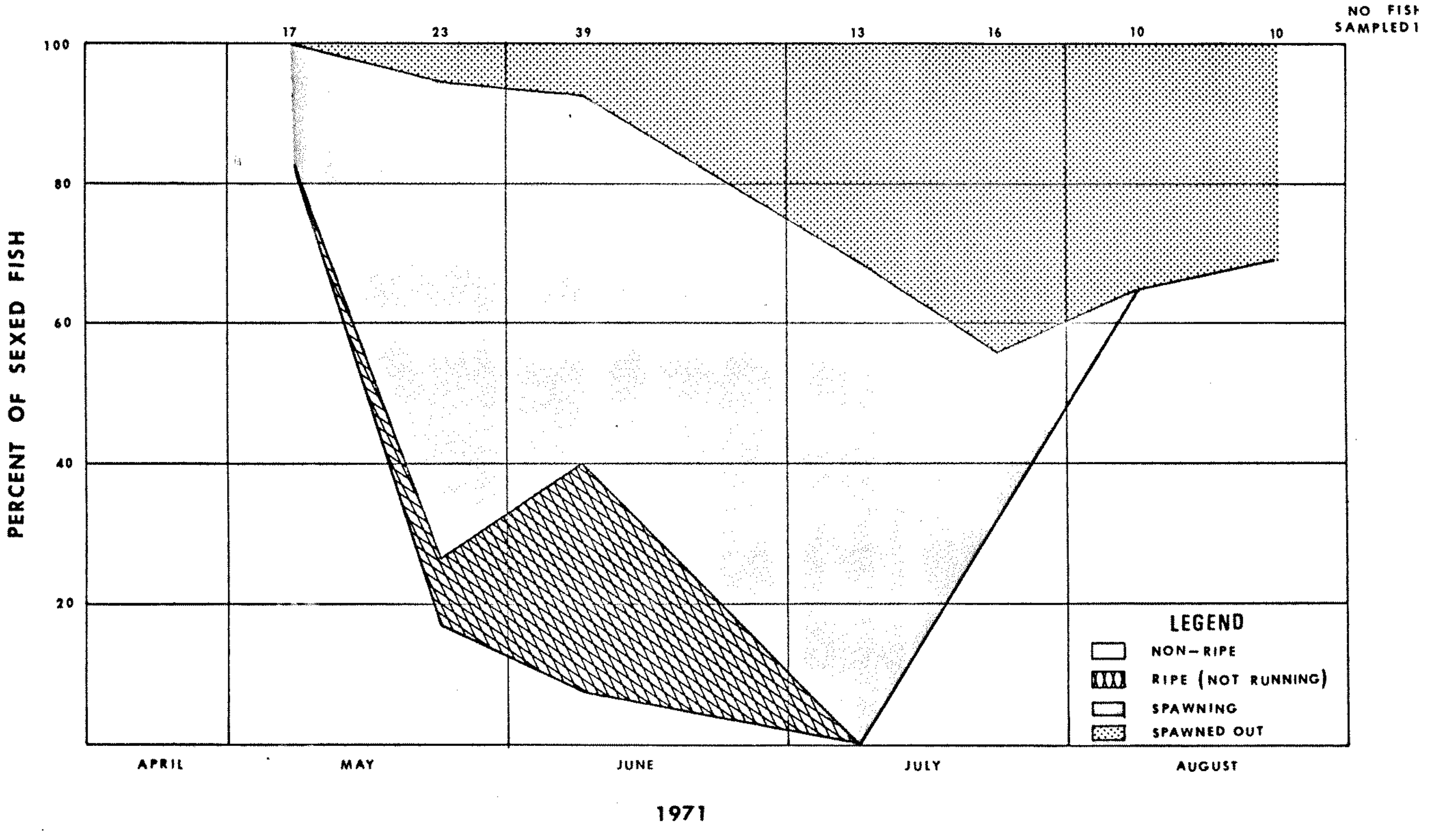


FIGURE 3.3-2

SEXUAL CONDITION OF ROSS LAKE RAINBOW TROUT

BOTH SEXES

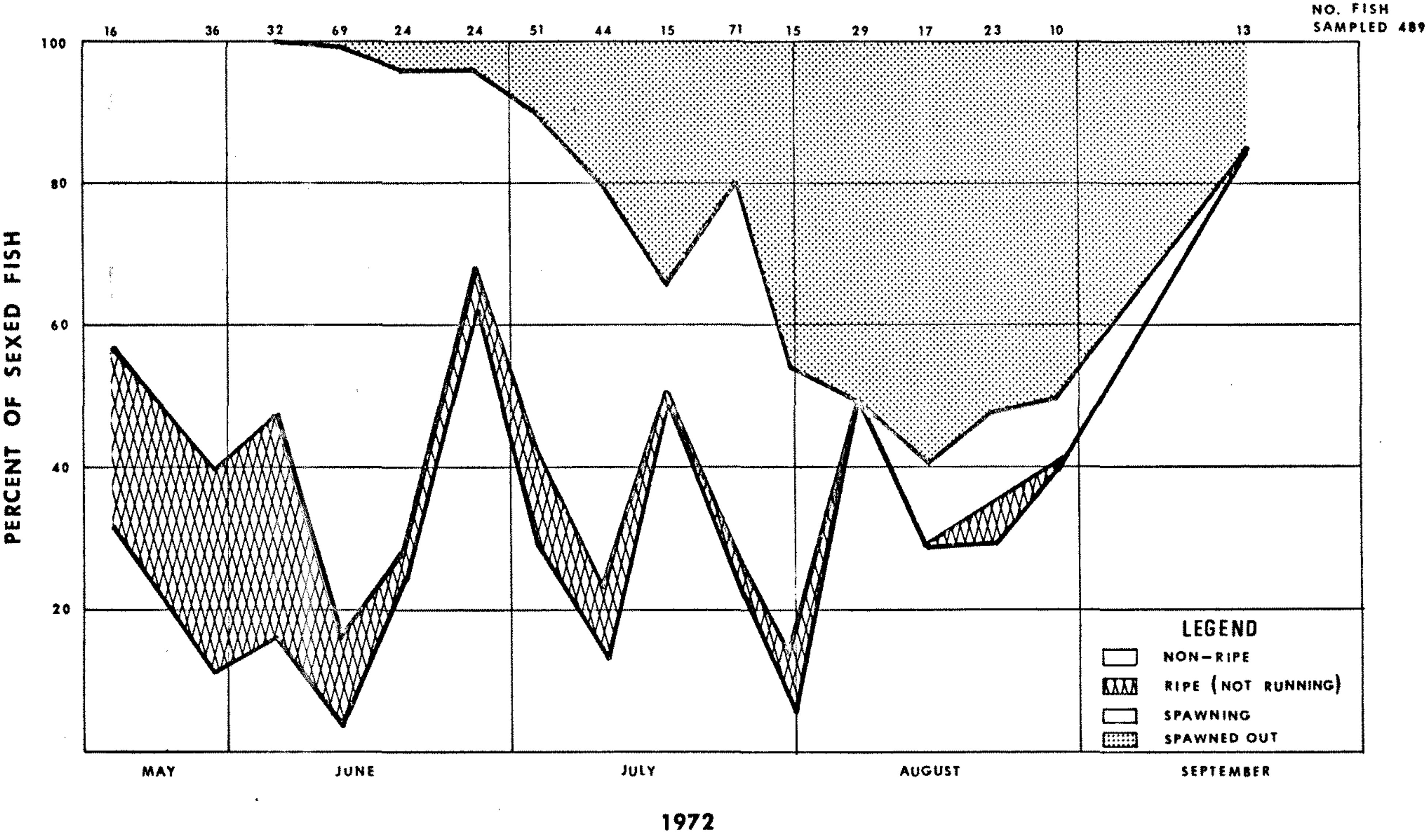


FIGURE 3.3-3

APPROXIMATE RAINBOW SPAWNING AND HATCHING TIMES

Ross Lake American Tributaries

1971

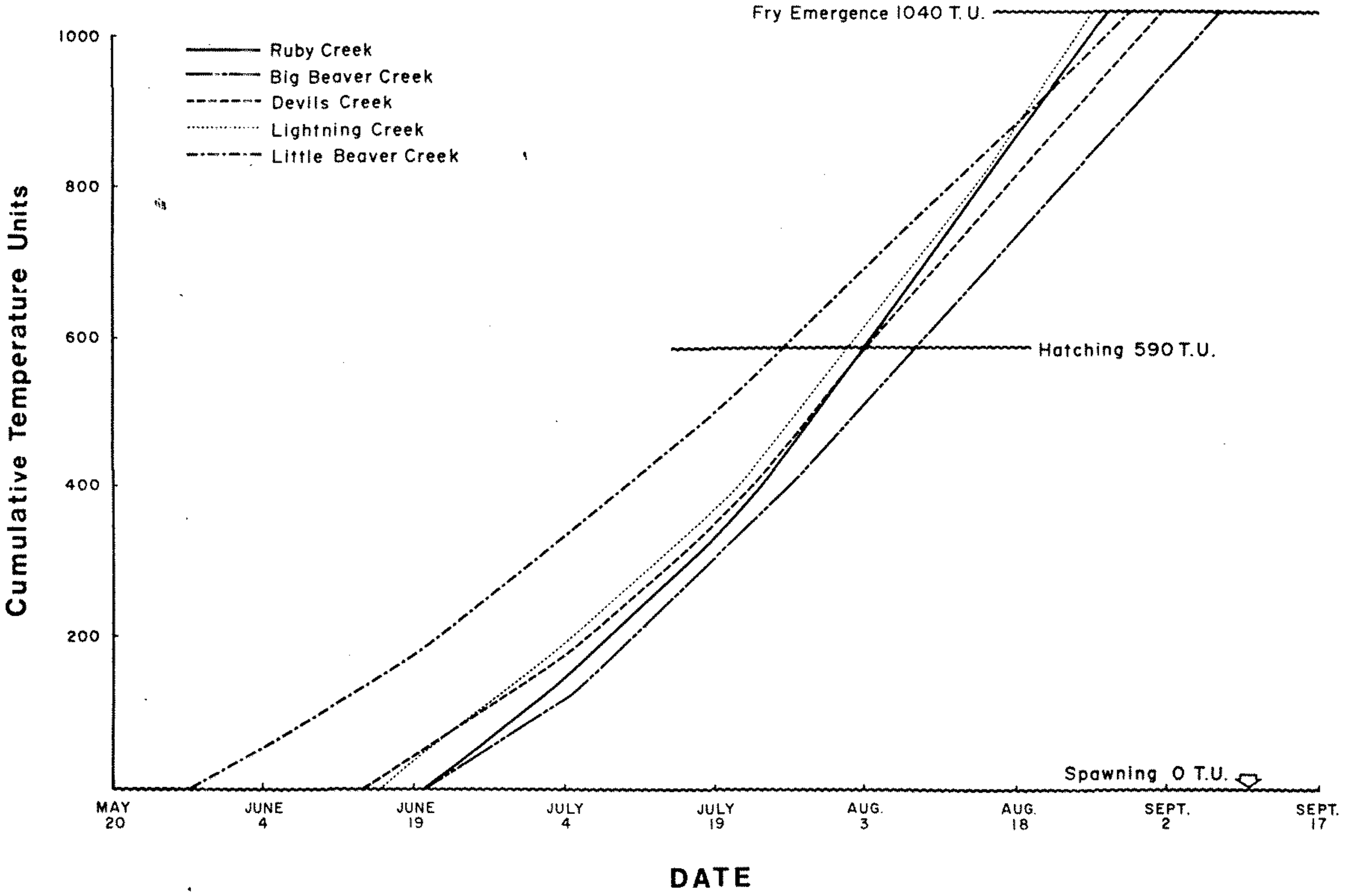
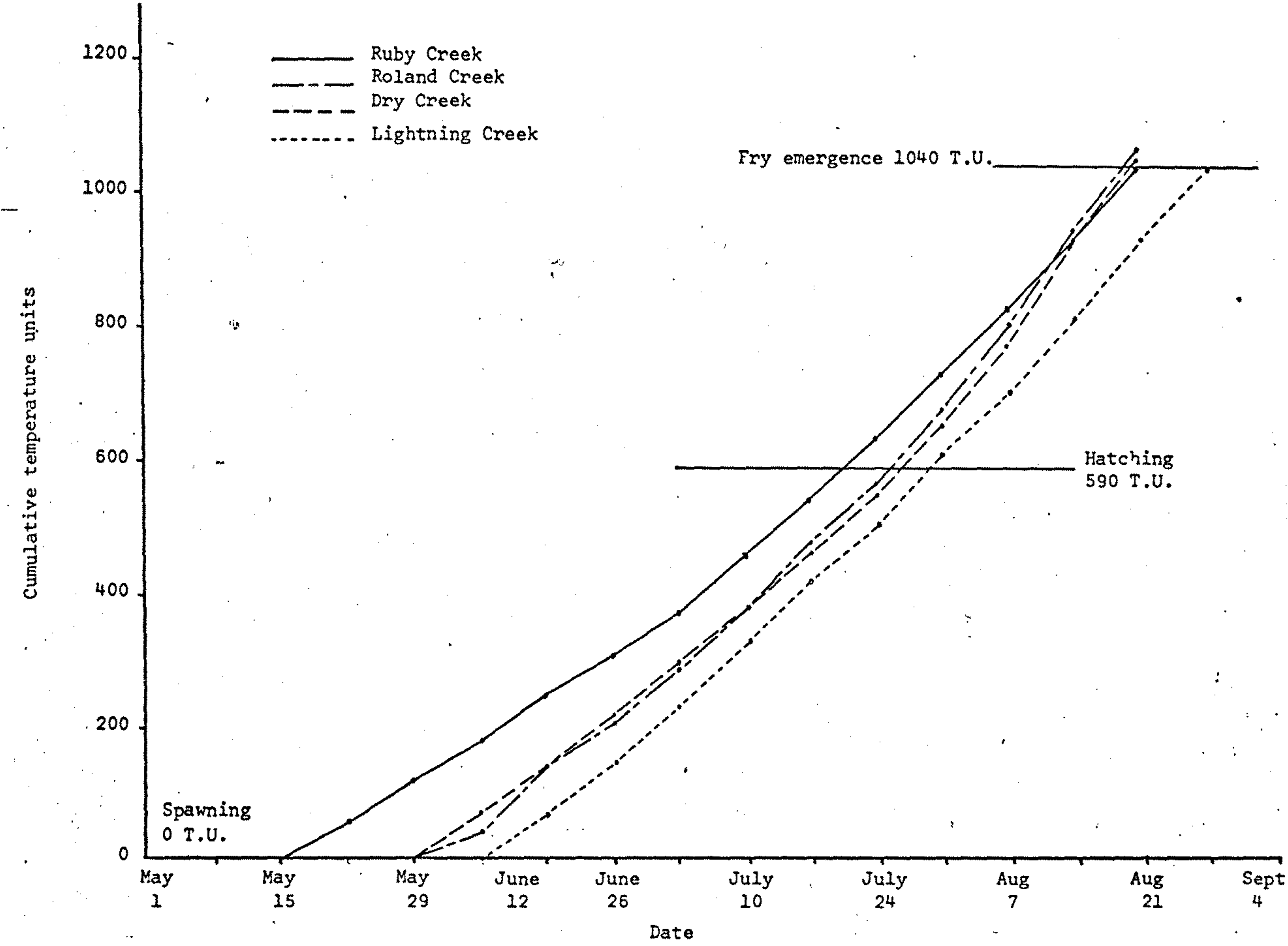


FIGURE 3.3-4

Beginning of rainbow spawning and hatching, Ross Lake American tributaries, 1972.



The locations of the observations were marked on a map of Ross Lake and on stream gradient profiles (Figure 3.3-5 and Appendix 11). The gradient profiles were constructed from measurements made with a surveyor's range height finder on foot surveys on Ruby, Panther, Big Beaver, Roland, Devils, Dry, Lightning, Silver, Little Beaver, Hozomeen, and International Creeks. Supplemental aerial surveys, U.S. Geological Survey topographic maps and aerial photographs were used on Big Beaver and Little Beaver Creeks to gather information on sections of these streams not accessible by foot and to verify measurements made on foot surveys. In addition, float surveys of Big Beaver Creek were conducted. Two persons equipped with wetsuits and snorkel floated the entire length of Big Beaver Creek from the 1722 foot elevation to the lake (approximately seven miles) on June 16-17, 1971, and the upper 4-1/2 miles of this stream section on June 20-21, 1972. The lower 2-1/2 miles were floated on April 26, 1972.

Notes were made on the location of suitable spawning habitat during the foot surveys. The criteria used in determining a suitable spawning area were the presence of gravel (.125 - 3 inches) and gentle-to-moderate stream gradient (pools and riffles). Rainbow trout prefer riffles of moderate gradient and the lower ends of pools for spawning (McAfee, 1966). The fish spawn in crude gravel nests or redds. Sites on streams meeting these criteria are noted on the stream gradient profiles of Ruby and Lightning Creeks as possible spawning locations. No such sites were seen in Devils or Little Beaver Creek in the distance included in the profiles. Details of gravel location could not be recorded during the drift surveys of Big Beaver Creek.

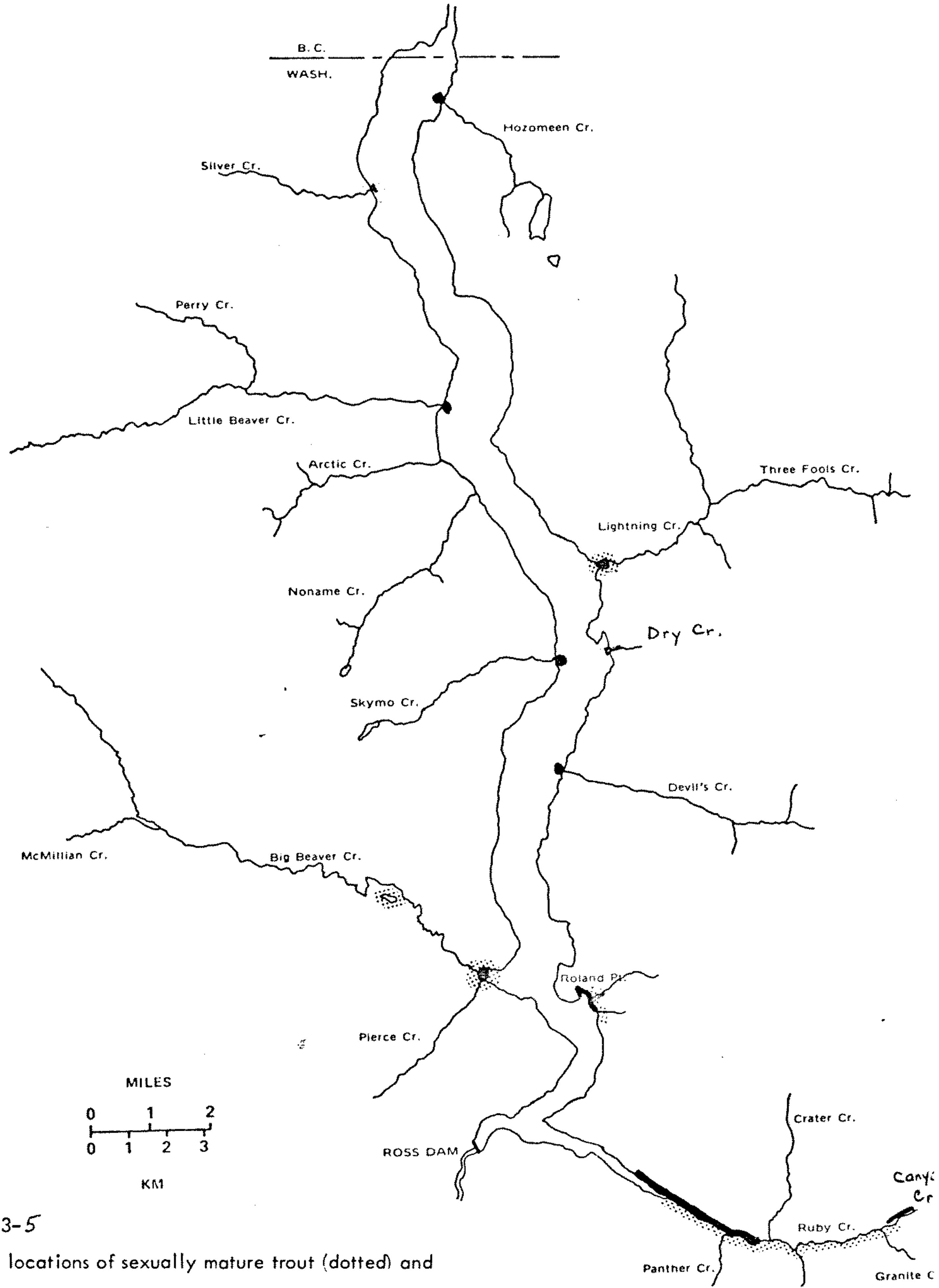


Figure 3.3-5

Observed locations of sexually mature trout (dotted) and emergent fry (solid)

3.3.2.2 Time of Rainbow Spawning

The plots of the distribution of sexual maturity stages of the Ross Lake rainbow trout over time in 1971 and 1972 are shown in Figures 3.3-1 and 3.3-2. Included in this analysis are all sexed fish captured in lake sampling including those captured in stream mouths. Fish captured in stream spawning surveys were not included in the graph because these samples were selective only for spawning fish. Stream mouth sampling possibly was also selective for spawning fish. The percentage of sexually mature fish from May through August tends to place the peak spawning period between mid-May and mid-July in both years.

In 1971, fry were first observed on August 24 in Lightning Creek and in Lightning Arm of Ross Lake, on August 25 in Ruby Creek and Ruby Arm, on August 30 in Devils Arm of Ross Lake and on September 8 in Big Beaver Bay (Appendix 13). Some fry captured by dip net in Devils Arm on September 2 1971 were examined for evidence of recent emergence; several showed the remains of a yolk sac. This, and their small size (21-24 mm) indicate that the fry probably had emerged from the gravel within approximately one week before capture.

Twenty-six fry were observed in Ruby Creek on August 28, 1970 at eight locations from the confluence of Granite and Canyon Creeks to Ross Lake. In the lower mile of Canyon Creek one fry was observed on August 28, 1970, and in Granite Creek on this date six fry were observed in the lower four miles of the stream (Eggers and Gores, 1971). In 1971, no fry were observed in Big Beaver or Little Beaver Creeks on foot surveys; however, on September 23, 1971, one fry was captured in a 24-hour set of a small fyke net in Big Beaver

Creek just upstream from the stream mouth (Appendix 14). First observations of fry in Lightning and Ruby Creeks preceded the dates of capture of fry in fyke nets which were fished in the latter half of September 1971 (Appendix 14).

In 1972, fry (3) were first captured on August 10 in the Dry Creek fyke nets (Appendix 15). The presence of large yolk sacs on these fish indicated that they were pre-emergent alevins; they may have been dislodged from the stream gravel before normal emergence could occur. This conclusion was further substantiated when six alevins with similarly developed yolk sacs were dug from the stream gravels. The next fry catches occured on August 15 in Ruby, Roland, and Dry Creeks. These fry, with very little yolk sacs remaining, appeared to be emergent fry. Results of fry observations in 1972 (Appendix 21) compared with the fyke net fry catches (Appendix 15) show that the catches preceeded first direct observations of fry in each stream. Indications are that emergence had occurred less than 5 days prior to capture. Emergent fry were not captured or observed in Lightning Creek until August 27, or in Silver Creek until September 9. No fry were captured or observed in Big Beaver Creek in 1972. The fry catches are used only to determine timing of emergence and are not intended to be compared quantitatively by stream because the streams vary in size; thus, the fry nets were more effective in some streams than in others. For example, the fry traps strained about one-half of the stream flow in Dry Creek but only about 1/120 of the stream in Ruby Creek.

Based on back calculation from time of fry observation by numbers of temperature units required for incubation and emergence, the beginning of spawning in streams in 1971 appears to have occurred by the last week of May to the first week in June (Fig. 3.3-3). This estimate of spawning time also applies to lake spawning in the proximity of the respective stream mouths since the cold stream water stays on the lake bottom for some distance after flowing into the lake. The water temperature in spawning gravels in stream mouths would thus be similar to the temperature of the inflowing stream. Hatching appears to have occurred during the last week of July.

In 1972, beginning of trout spawning is calculated to have occurred in mid-May in Ruby Creek and late May to early June in Roland, Dry, and Lightning Creeks (Fig. 3.3-4). Hatching and fry emergence began in mid-July and mid-August, respectively. Generally, beginning spawning, hatching, and fry emergence was calculated to have occurred 1-2 weeks earlier in 1972 than in 1971. In Ruby Creek spawning may have begun about 4 weeks earlier in 1972 than in 1971.

The time of spawning of rainbow trout coincides very closely with the period of maximum vernal stream discharge (See Figure 2.1-2).

3.3.2.3 Location of Rainbow Spawning

Information on location of spawning in areas accessible to Ross Lake trout was also provided by the sampling of ripe fish and fry observations in the lake near stream inlets and in streams (Figure 3.3-5, Appendices 11, 29, and 30). Other fish sampling and visual observations made in stream sections inaccessible to fish from Ross Lake (Appendix 30) in Granite, Lightning, and Little Beaver Creeks show that resident fish populations exist in these streams.

Stream sections and areas where both fry and ripe fish were found are considered as spawning areas. The results of these observations indicate that the mouth of Silver Creek, the lower 1/4 mile and mouth of Lightning Creek, the lower 1/4 mile and mouth of Dry Creek, the mouth of Pierce Creek, the lake shore in the vicinity of Roland Creek and the lower 1/3 mile of Roland Creek, and Ruby Creek are important spawning grounds for Ross Lake trout on the American side of the U.S./Canadian border. The 1970 fry observations (Appendix 21) further suggest that Ruby Creek and at least the lower 1/3 mile of Canyon Creek may be utilized for spawning by Ross Lake trout. General observations showed that Crater and Panther Creeks are extremely precipitous streams characterized by falls and rapids. Little gravel suitable for spawning is present in either stream. Therefore, they appear to offer little potential for spawning utilization.

The observations and sampling conducted in Big Beaver Creek in 1970-1972 provided no evidence that Ross Lake rainbow trout utilize Big Beaver Creek to any significant extent for spawning. Spawning sites were not determined for the population of rainbow trout residing in the ponds adjacent to the creek 2-1/2 miles upstream from Ross Lake. They may use Big Beaver Creek or small tributaries for spawning. Very few large fish (>250 mm) were observed during the 1971 and 1972 June float surveys of Big Beaver Creek (Table 3.3-I), nor were fry observed in Big Beaver Creek on foot surveys (See Appendix 13). The one fry captured by fyke net just above the stream mouth on September 23, 1971, could have been a progeny of trout resident in the ponds adjacent to Big Beaver Creek.

TABLE 3.3-1

SUMMARY OF OBSERVATIONS MADE ON FLOAT SURVEY OF BIG BEAVER CREEK

JUNE 16-17, 1971 AND APRIL 26 AND JUNE 21-22, 1972

		Fish Observed									
		Large Fish (> 250mm)				Small Fish (< 250 mm)					
Date	Creek Section	RB	CT	DV	undetermined	RB	CT	DV	undetermined	(Total)	Remarks
6/16/71	Lower 4 miles (between 1625 and 1602.5 ft. elevation)	3	1	-	-	-	-	-	6	10	1 CT - possible spawner. 3 possible redds approximately 2 miles upstream from lake. Extensive gravel bottom in upper 2 miles of this stream section. 5 log jams in this section. Visibility > 25 ft.
6/17/71	Upper 3 miles (between 1725 and 1625 ft. elevation)	3	2	1	6	-	-	1	25*	38	1 CT - possible spawner. Bottom of this stream section is mostly gravel. Visibility > 25 ft.
	Totals (6/16-17/71)	6	3	1	6	-	-	1	31*	48	Most of the stream above lower 2 miles appeared to be good spawning habitat but little evidence of spawning observed. Stream visibility excellent (725 ft.)
/26/72	Lower 2 miles (between 1615 and 1602.5 ft. elevation)	-	-	-	-	-	-	-	-	0	No fish observed. Visibility > 25 ft.

---

* Includes one possible whitefish.

TABLE 3.3-1 (Page 2)

		Fish Observed									
		Large Fish (> 250 mm)				Small Fish (< 250 mm)					
Date	Creek Section	RB	CT	DV	undetermined	RB	CT	DV	undetermined	(Total)	Remarks
6/21/72	Stream reach between 1625 and 1615 ft. elevation (2 mi.)	-	-	-	-	-	-	-	-	0	No fish observed Visibility reduced to 15 ft.
6/22/72	Stream reach between 1722 and 1625 (3 mi.)	-	-	-	3	-	-	-	-	3	Visibility reduced to 15 ft.
	Totals (4/26, 6/21, 6/22/72)									3	Visibility fair (15 ft.)

The stream gradient profile of Big Beaver Creek (Appendix II) shows that a nine foot fall forming a fish migration block exists at the 1578 foot elevation with the top of the falls at the 1587 foot elevation. Fish would thus be prevented from entering Big Beaver Creek until the lake rose sufficiently to eliminate the barrier, usually in mid-May (See Figure 2.1-3). Some Ross Lake rainbow trout do enter the stream. A rainbow trout (373 mm in length) which had been tagged at the mouth of Lightning Creek on April 19, 1971, was recaptured and released in the mouth of Lightning Creek on July 6. The fish was again recaptured and released in Big Beaver Creek just below Thirty-nine Mile Creek 6-3/4 mile upstream from the lake on October 7. Since it entered Big Beaver Creek after July 6, it probably did not spawn there.

It is apparent that Devils and Little Beaver Creeks are not utilized for spawning by fish from Ross Lake. Presently, migration blocks formed by falls exist 359 and 200 feet respectively from the mouths of both streams at full reservoir (see Appendix II). It is doubtful that significant numbers of Ross Lake trout could successfully spawn in Devils Creek in the absence of these blocks due to very limited gravel areas. Both streams are characterized by falls and steep rapids flowing over bedrock, boulders and rubble in the stream sections for which the gradient profiles were constructed. Other falls forming fish barriers also exist in both streams.

Newly emerged fry were observed at the shoreline of Ross Lake in the immediate vicinity of other stream inlets including Pierce, Devils, Skymo, Dry, Roland, Little Beaver and Hozomeen Creeks. These inlet areas also may support spawning by Ross Lake trout. It is doubtful that the fry could have moved into these areas from other spawning sites as newly emergent fry. It is possible that downstream recruitment of fry from spawning of resident fish in Little Beaver and Hozomeen Creeks could occur.

In summary, evidence to date indicates that Ruby Creek and its tributary, Canyon Creek are probably the most important American spawning areas for Ross Lake trout at present. Lightning Creek is utilized for spawning in its lower 1/4 mile below the migration block. The lower 1/4 mile of Dry Creek and the lower 1/3 mile of Roland Creek also support spawning by rainbow trout from Ross Lake. The lake shore in the immediate vicinity of the mouths of Ruby, Lightning, Pierce, and Roland Creeks appears to support spawning by Ross Lake rainbow trout. Shoreline trout spawning may also occur near inlets of Dry, Devils, Skymo, Little Beaver, International, Silver, and Hozomeen Creeks.

3.3.2.4 Spawning of Other Species

Ripe cutthroat trout were captured off the mouth of Big Beaver Creek on June 1, 1971, (see Appendix 29) at a time when a falls at approximately 1596 foot elevation may have blocked migration into Big Beaver Creek. The fish may have spawned at the creek mouth. Because newly emerged cutthroat and rainbow fry are indistinguishable visually, fry observed around Big Beaver Creek mouth later in the year may have been either rainbow or cutthroat.

Several spawned out cutthroat trout were captured on July 20, 1971, and on September 7, 1972, in the larger beaver pond along Big Beaver Creek (see Appendix 30). A mark and recapture experiment (simple Peterson method) was conducted in the summer of 1972 in the pond to estimate the size of the trout population. On July 27 and August 24, 44 fish were released after removal of the adipose fin. On September 7, 86 fish were captured, three of which were previously fin-clipped fish, giving a rough population estimate of approximately 1200 – 1300 fish. Basic assumptions using this type of estimate will be discussed in Section 3.7.3.2. The pond did not appear to have favorable spawning area and the spawning location of these fish remains unknown, although they may utilize Big Beaver Creek (The pond is closed to sport fishing).

Dolly Varden char were observed in Ruby Creek about 1/4 mile upstream from Ross Lake and in Lightning Creek approximately 600 feet upstream on September 23, 1971. A spawning male Dolly Varden (235 mm in length) was captured by angling at the 1722 foot elevation about seven miles upstream from Ross Lake in Big Beaver Creek on October 7, 1971. No other observations of char spawning were made at expected spawning time in fall. Eggers and Gores (1971) reported large Dolly Varden char in Ruby and Canyon Creeks between September 7 and 9, 1970, and in Lightning Creek about 1/4 mile upstream from Ross Lake on September 26, 1970. Probably the Dolly Varden enter these streams to spawn.

3.3.3 Skagit River and Tributaries

(by F.F. Slaney and Company)

3.3.3.1 Physical Characteristics

Size Composition of Substrate

Size composition of bottom materials in the Skagit River was examined to determine the relative amounts of fine particles present. Large amounts of fines can increase egg and larval mortality in the gravel by reducing its permeability.

Methods used were the "wet" techniques discussed by McNeil and Ahnell (1964). A gravel sampler with tube six inches in diameter was worked down into the substrate. The contents of the tube were brought up into the sampler and the sampler removed from the stream bed. The contents of the sampler were then washed through a series of nine Tyler sieves with mesh sizes between 0.105 and 26.9 mm. in diameter. (The sieve sizes are given in Appendix 17. Volumes of material retained were measured by displacement of water.

The gravels were sampled in 1971 before and after the spring freshets in sections of the river selected at random. No samples were taken from the U Area because of the inaccessibility, high water levels, or predominance of boulders in randomly chosen sections. A total of 18 samples were taken along the Skagit River. Samples were also taken in the drawdown river, Nepopekum Creek, and Klesilkwa River. The date, location and percent composition by volume of each of the samples are given in Appendix 18.

Statistical tests (t Test) were made comparing the mean percentages of particles less than 0.83 mm. in size in the 18 samples from the Skagit River. Means tested were those from samples taken before and after the spring freshets from all locations in the river, and those determined from samples taken after the spring freshets in areas F, M, A. For the latter, comparisons were made between the means of F and M, F and A, and M and A.

The 0.83 mm. particle size threshold was used for testing the means because it is a standard found in the literature (Hall and Lantz, 1969) and because the percentage of a sample less than 0.83 mm. shows a good inverse relationship to the coefficient of permeability of the substrate (McNeil and Ahnell, 1964).

There were no significant differences at the .05 level between the mean percentages of particles less than 0.83 mm. in size in samples taken before and after the spring freshets ($T = 1.72$; $0.1 < p < 0.5$; d.f. = 18). No significant differences were found between the means of samples taken after the freshets from Areas F and M ($T = .28$; $p > 0.5$; d.f. = 10), Areas F and A ($T = .31$; $p > 0.5$; d.f. = 9), or Areas M and A ($T = 1.65$; $0.1 < p < 0.5$; d.f. = 9).

As a result, in the subsequent analysis all 18 Skagit River samples are considered together.

A summary diagram of the combined sample results is presented in Figure 3.3-6 as percentage smaller than a given particle diameter. The mean percentages less than 0.210, 3.36 and 26.9 mm. in diameter with the 99 percent confidence limits about the mean values are shown. The mean percentage less than 0.83 mm. in these 18 samples was 7.2 percent, while a mean of 8.2 percent was less than 1.0 mm. in diameter.

Also shown in the Figure are the curves for single samples taken in the draw-down river before the spring freshets, in Nepopekum Creek, and in the Klesilkwa River. The Klesilkwa sample is notable for its high percentages of fines (27.1 percent and 29.9 percent less than 0.83 and 1.0 mm. in diameter respectively) and for the small percentage of the total substrate larger than 26.9 mm. Subsequent surveys have indicated that this single sample may not be typical of the whole stream.

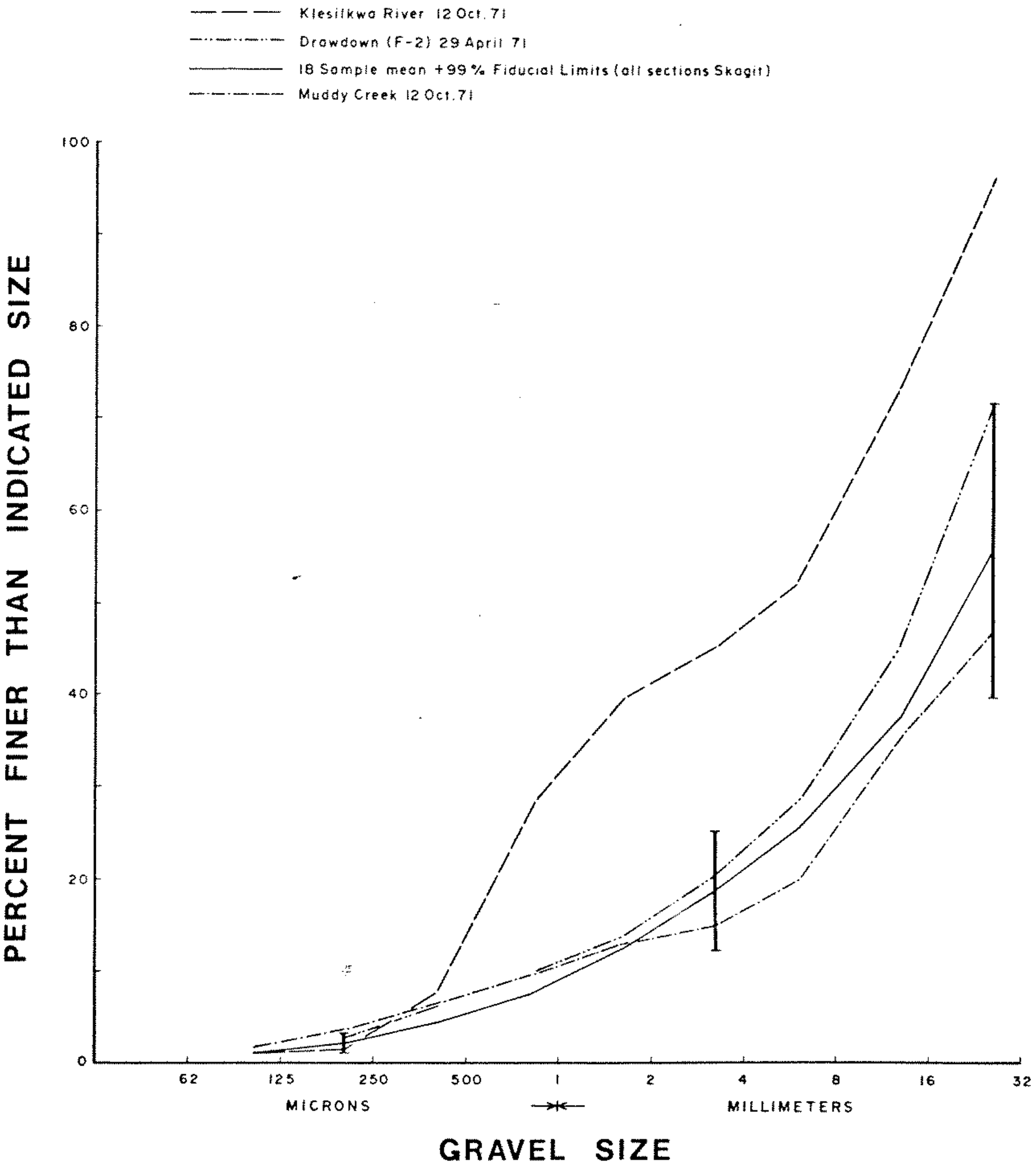
Gradients

The gradients of various portions of the Skagit River are shown in Figure 2.3-2 (see also Section 2.3.3.2).

FIGURE 3.3-6

PERCENT SIZE COMPOSITION OF SUBSTRATE

Skagit River System 1971



S14-C66

The mean gradient of the Skagit River from elevations 1602.5 to 2011.8 feet is 0.38 percent. The maximum gradient on the river is 2.78 percent in Section M-9. Nowhere along its length are there waterfalls or other barriers that block fish migration.

The gradients along Nepopekum Creek are shown in Figure 2.3.11. The mean gradient of this creek is 2.07 percent. Again, there are no blocks to fish movements.

Gradients along the Klesilkwa River are shown in Figure 2.3-10. The mean gradient of this tributary is 0.6% for the lower 1.5 miles. There are no blocks to fish movement.

Shawatum Creek descends from a small drainage on the east side of the Skagit valley with an average gradient of approximately 11%. At the base of the hillside, the stream disappears into porous fluvial gravels. Shawatum Creek reappears in an old Skagit channel which is of interest, since it has a gradient approximately the same as the Skagit, is fed by clear spring water year round, and has Skagit gravels beneath a thin organic layer resulting from impoundment by beaver dams.

This is the only location within the proposed area of inundation where spawning by rainbow trout was observed. Spawning habitat was poor, and redd building was attempted in tiny patches of clean gravel spilled from a culvert and strewn with debris.

3.3.3.2 Methods

Sightings

Visual sightings of fish engaged in redd building, courtship or spawning behaviour provide direct information on the spawning times and locations of fish. Sightings of redds built in the gravels also provide good evidence of fish spawning. These kinds of data from observers on the river bank as well as wet-suited divers were used to determine times and locations of char (Eastern brook trout and Dolly Varden char) spawning in the Skagit River system. Char spawn in autumn when water levels and river flow are low and visibility through the water is good.

Rainbow trout spawning occurs in spring, however, when water levels and flows are high and turbidity is increased to the point where visibility is reduced to a few inches. Visual sightings of fish behaviour or redds were not possible at that time except in a few clear tributaries. In the Skagit River itself and other turbid streams, indirect methods were necessary to indicate times and locations of rainbow spawning.

Sightings and records of the locations of char spawning and char redds were made at regular intervals throughout the autumn of 1971. The F and M sections of the river, the lower Klesilkwa River and some tributary streams were examined regularly, at least every few days and often daily, for redds or spawning fish.

Sightings of recently emerged rainbow trout fry were made along the Skagit River throughout the late summer and autumn. Records of the numbers of fry observed per length of shoreline traversed provided comparative data on fry density. In some cases, these observations were made during the course of other work on the river. In other cases, randomly chosen sections of the river were surveyed specifically for the determination of rainbow trout fry densities.

Gill Net Sets

Gill net sets were the primary means used to capture adult fish in the river throughout the study. Data from the fish taken provided indirect evidence on the times and locations of rainbow trout spawning. Monofilament nylon gill nets used had mesh sizes of one inch, two inches, 2½ inches, 2-1/6 inches, three inches and four inches (stretch dimensions). A nylon gill net with 2½ inch mesh was also used. Sets were made for varying lengths of time at locations in the F, M, U and A sampling sections of the Skagit system. Occasional sets were also made in other parts of the system.

Gill net sets were made in locations along the river that were accessible by boat or land and in which nets could be set during the high water levels and high flows of the spring freshets. Thus, the locations could not be chosen at random. These locations were mainly sloughs and back eddies where the nets could be set away from the main river current. The primary areas used are shown in Appendix 9.

Tracking with Sonic Tags

A program was attempted in 1972 to track large female rainbow trout using Smith-Root ultrasonic transmitters ("sonic tags"). These were inserted into the stomachs of anaesthetized and measured fish, using glycerin as a lubricant.

The fish were held overnight in holding pens to determine early mortality and tag retention; upon release the fish were tracked for some distance to determine range of detection. Unfortunately, the range was only 20 to 30 feet in quiet stretches of the river and backwaters, and a matter of inches in most areas, due to high background noise levels.

Fry Net Sets

Fry nets were used to sample rainbow trout fry from the river.

Each fry net consisted of a 2 ft. x 2 ft. frame of strap iron, with a pyramid-shaped net about 27 inches long. The net was made of "Nitex" nylon monofilament screen cloth with 11 x 11 meshes/inch and a mesh opening of 0.0709 inches.

The nets were set in riffle areas to a depth of between 6 and 18 inches in most cases. In 1972, current velocity was measured for each set and flow through the net was calculated.

The numbers of fry taken were used as indications of fry abundance and times of movement. Fry were examined for stage of development and measured as an indication of length of time since hatching.

Other Methods

Seining and electrofishing were also used on occasion to capture fish. In general, however, they were less effective than the other techniques described above. Angling was useful in some areas but was not utilized extensively.

Fish Sampling

All fish other than fry taken by any of these methods had fork length (in cm.) and weight (in grams) measurements taken. Sex and maturity condition was also recorded. Examination of each fish for fin clips or tagging scars was also made. Stomachs were removed and preserved for later analysis. Scale samples were also taken by the method outlined in Section 3.3.1.

3.3.3.3 Time of Rainbow Spawning

Sexual Condition of Adults

A table giving complete data on the date, location and duration of gill net sets as well as mesh size of nets used, catch and catch per hour of set comprises Appendix 19. Appendix 20 shows the 1971 data in graphical form.

The sex and sexual condition of all fish sampled in gill nets or during the creel census were recorded after internal examination as outlined in Section 3.2.2.2.

The numbers of fish in each category of sexual condition (0–6) have been summed at twice monthly (approximately two-week) intervals for the 1971 sample. The results are shown graphically as percentages in Figures 3.3–7 and 3.3–8. The sample size is also indicated on each graph.

Figure 3.3–7 shows the sexual condition of the fish of both sexes in the gill net and creel census samples from 1971 while Figure 3.3–8 shows only the females. Both figures indicate that maximum numbers of spawning fish were taken in May and early June. In comparing the two figures, it can be seen that a greater proportion of ripe fish were males than females both early and late in the spawning season.

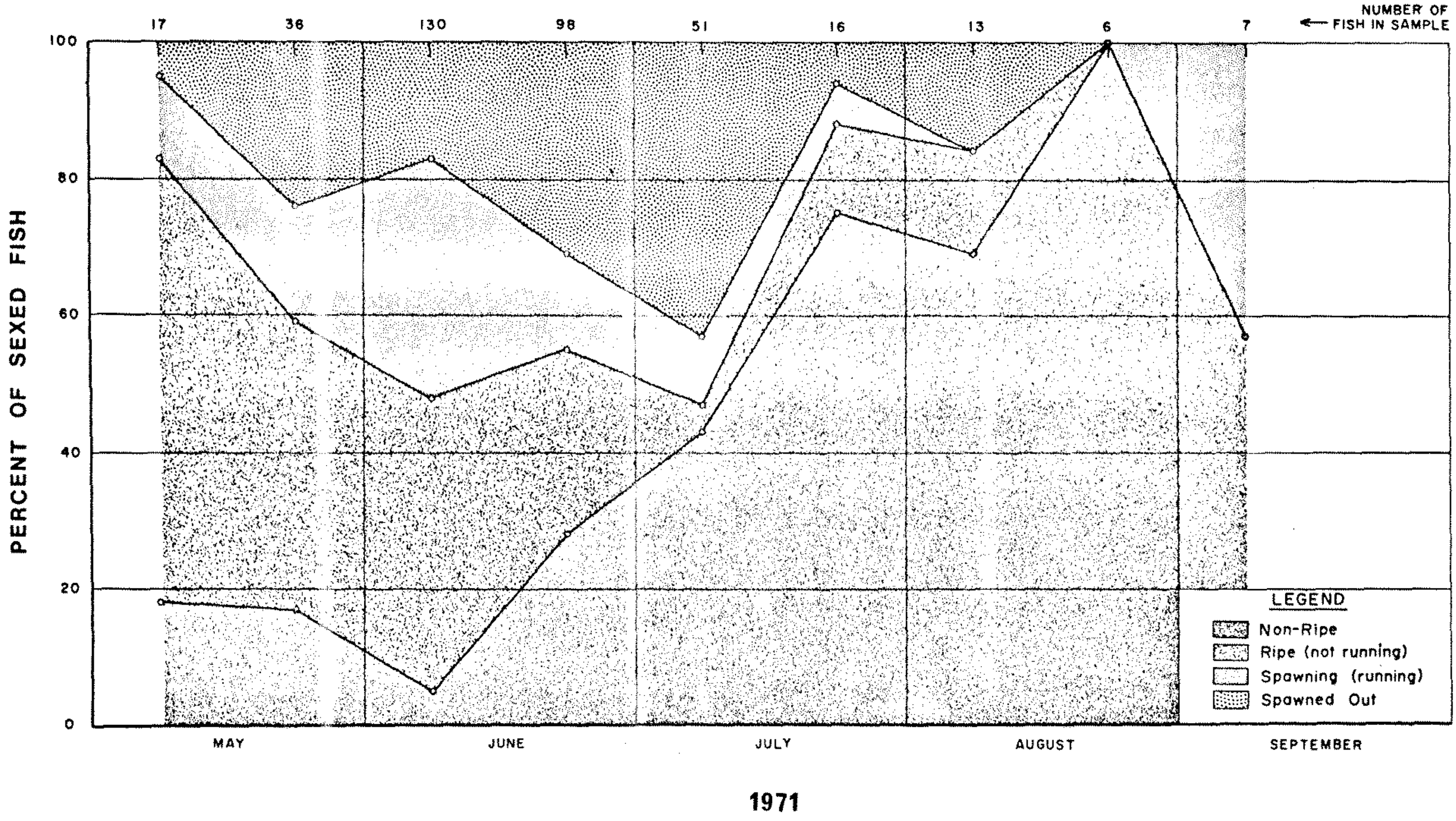
Emergence of Fry

Tables showing the times, duration and location of fry net sets as well as the catches of fry per set and catch per hour of set can be found in Appendix 21. The 1971 catches of fry per hour of set are plotted against date of capture in

FIGURE 3.3-7

SEXUAL CONDITION OF SKAGIT RIVER RAINBOW TROUT

Both Sexes

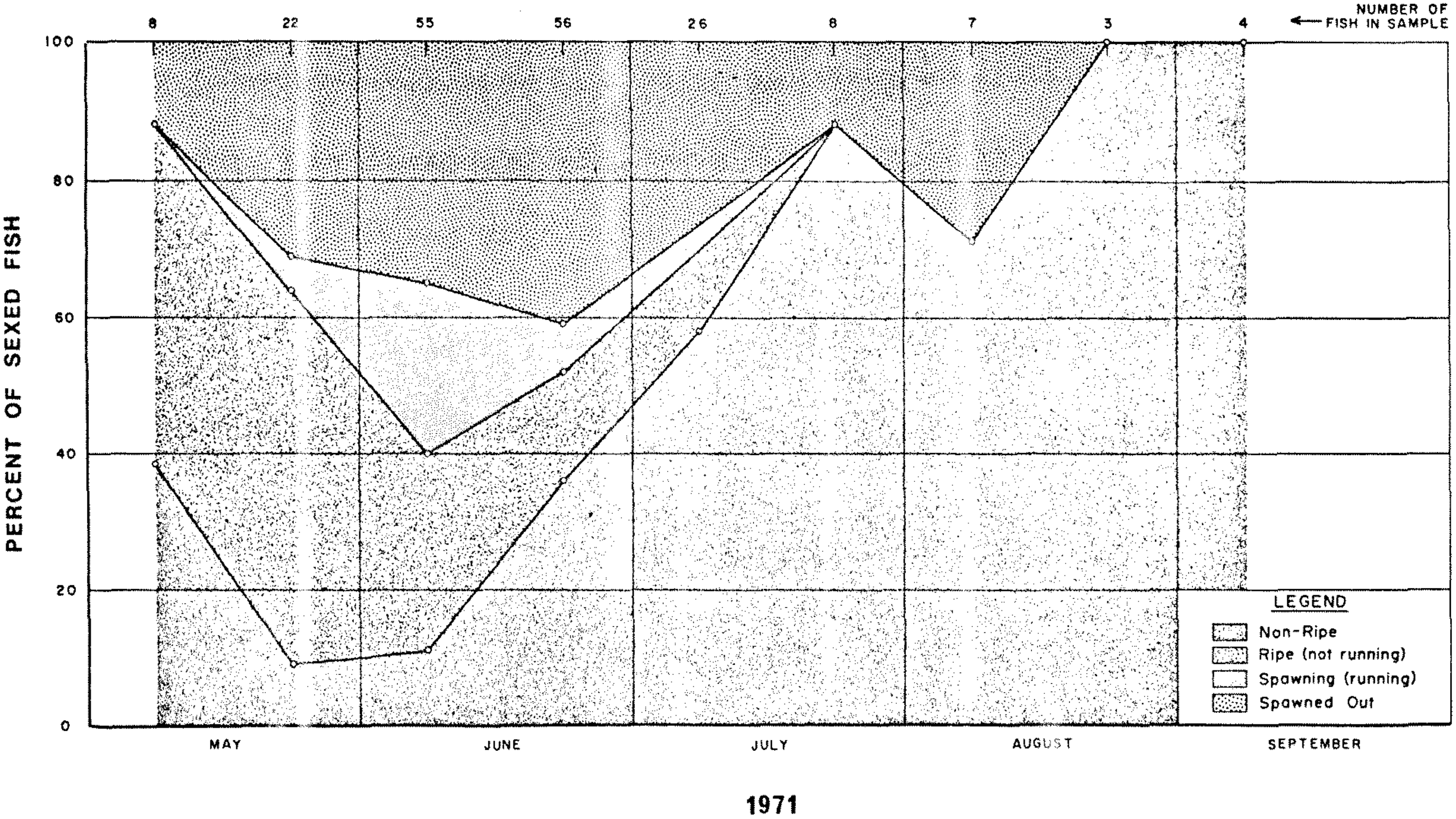


514-C09

FIGURE 3.3-8

SEXUAL CONDITION OF SKAGIT RIVER RAINBOW TROUT

Females Only



814-C810

Figure 3.3-9. Catches for 1972 are shown by date in Figure 3.3-10 as catch per hour of set per cubic foot per second of flow through the fry net. These units adjust the catch to a unit volume but do not take differences in stream size into account. The numbers of fry observed by date, adjusted to the numbers in a 50 foot length of stream, are shown for 1971 on Figure 3.3.11.

The size frequency distribution of rainbow trout fry sampled in fry net sets is shown in Figure 3.3-12. The 1971 curve has a mode at 23-24 mm in length and the 1972 sample has a mode at 23 mm. A few fry of about 22-23 mm length were noted to have recently absorbed yolk sacs, indicating recent emergence from the gravels. This suggests that fry moving downstream and captured in the fry nets were recently emerged.

The first emergent fry in the Skagit River was observed on August 8, 1971, in Section F-3. Back-calculation using temperature units (T U's) to time of spawning (see the methods outlined in Section 3.3.2) indicates that first 1971 spawning occurred in the Skagit River about mid-May.

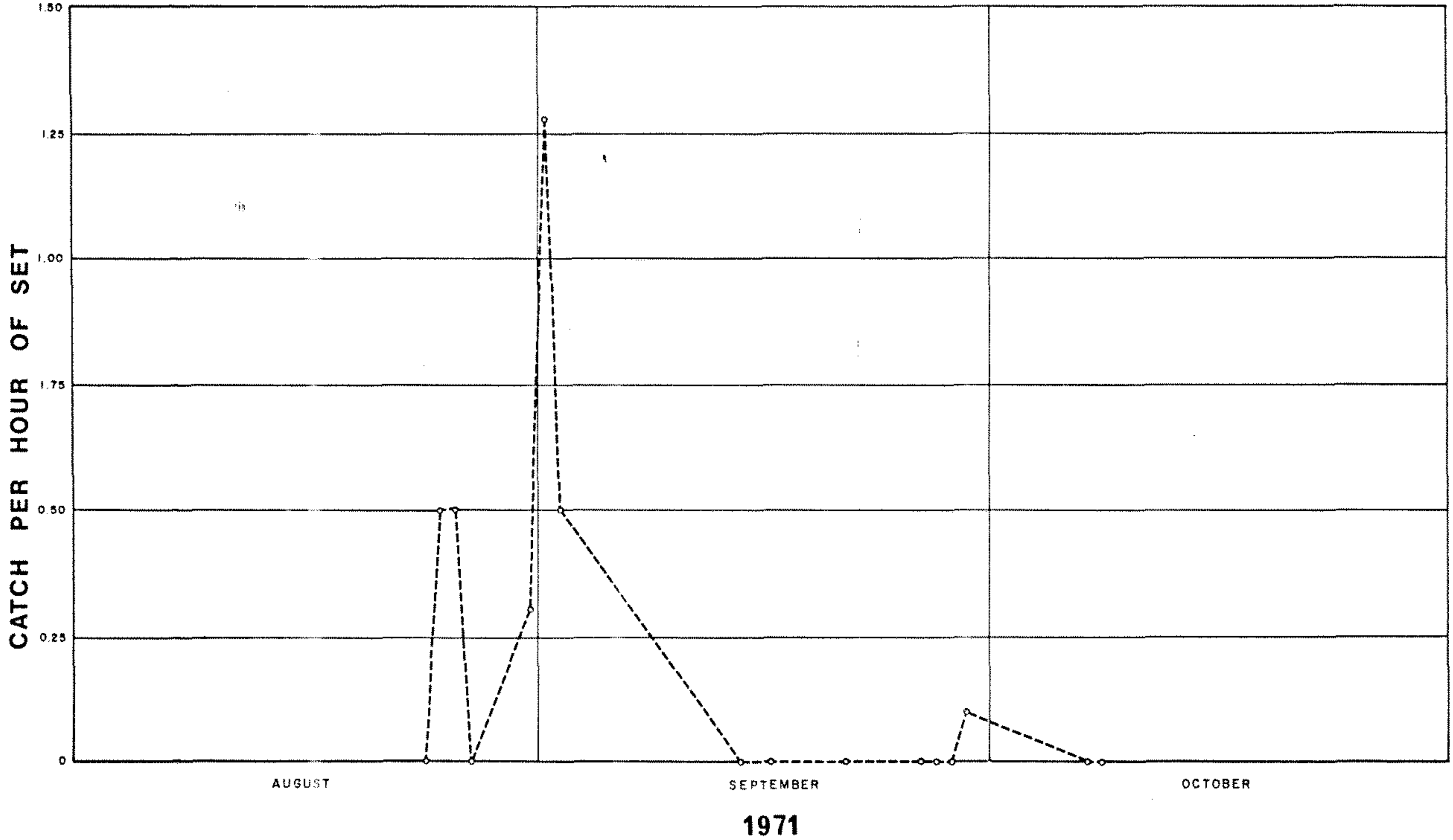
The greatest numbers of emergent fry were sampled and observed in late August 1971 (see Figures 3.3-9 and 3.3-11 and Appendix 21). Back-calculation in TU's indicates that the peak of spawning in the Skagit River system occurred around mid-June in 1971.

The first emergent fry in the Skagit River was observed on August 1st in 1972. Back-calculation by temperature units indicates that first spawning occurred in the Skagit River between late April-early May in 1972.

FIGURE 3.3-9

DAILY CATCHES OF RAINBOW TROUT FRY

Skagit River System



DAILY CATCHES OF RAINBOW TROUT FRY

Skagit River System

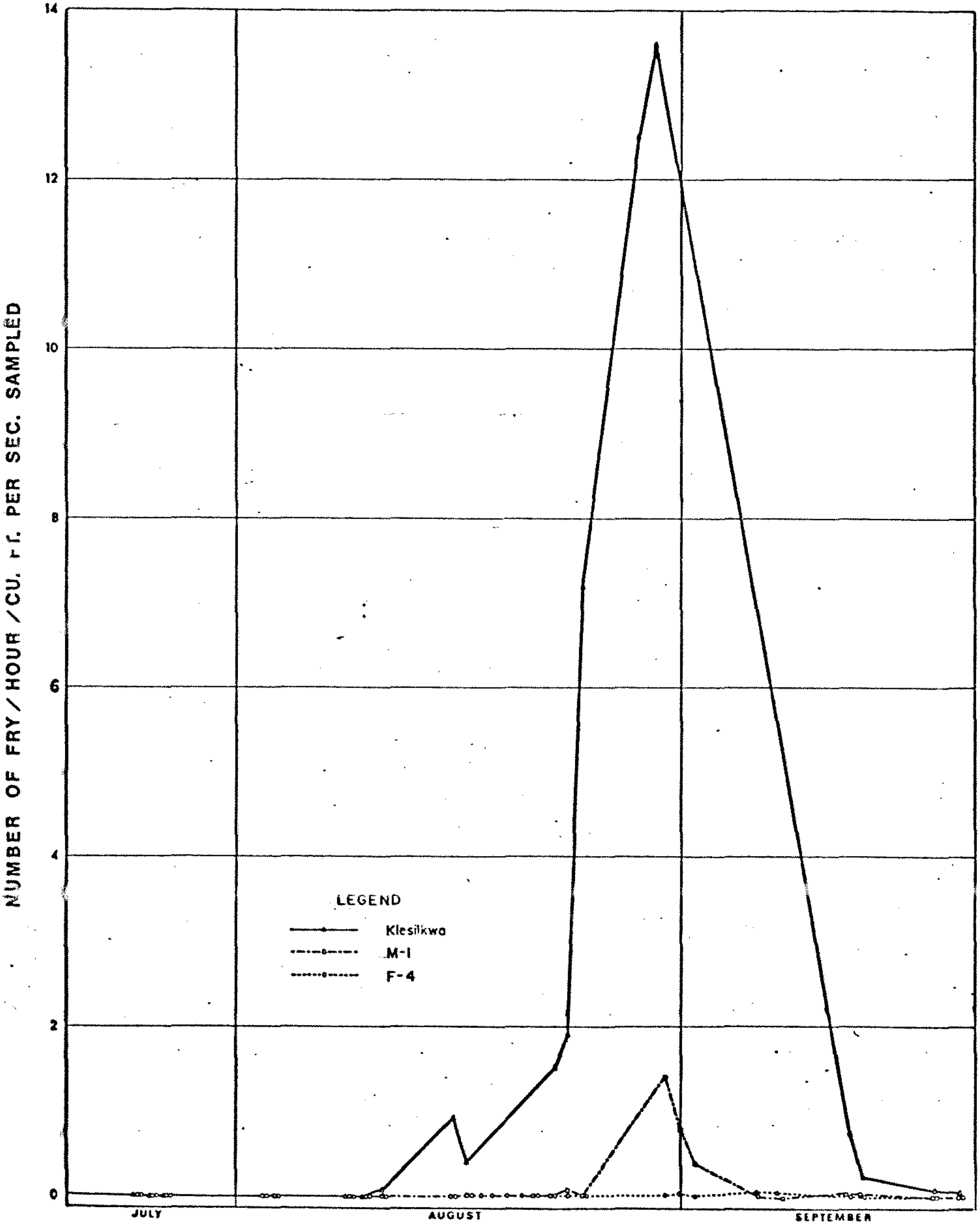


FIGURE 3.3-11

OBSERVATIONS OF RAINBOW TROUT FRY

Skagit River

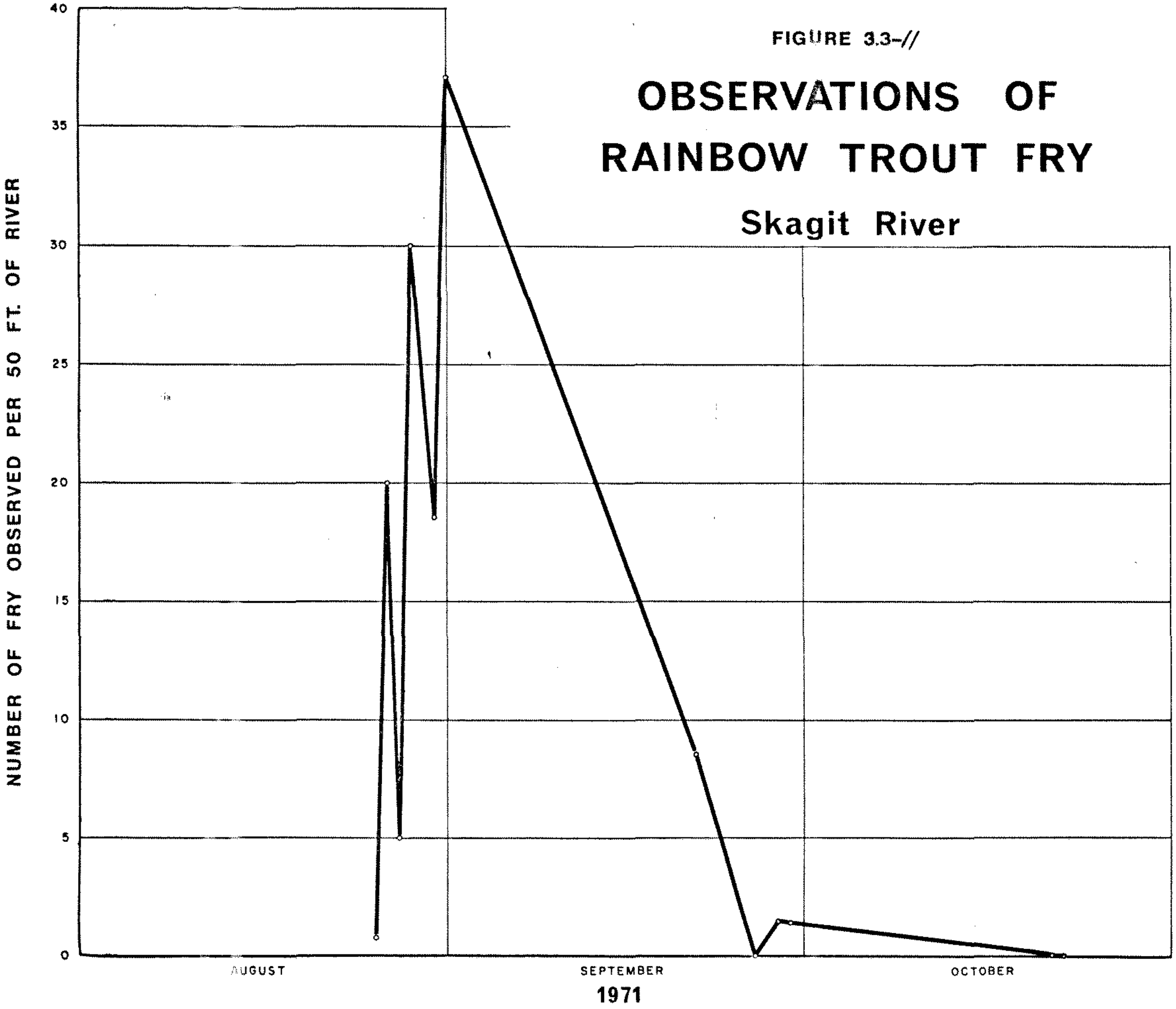


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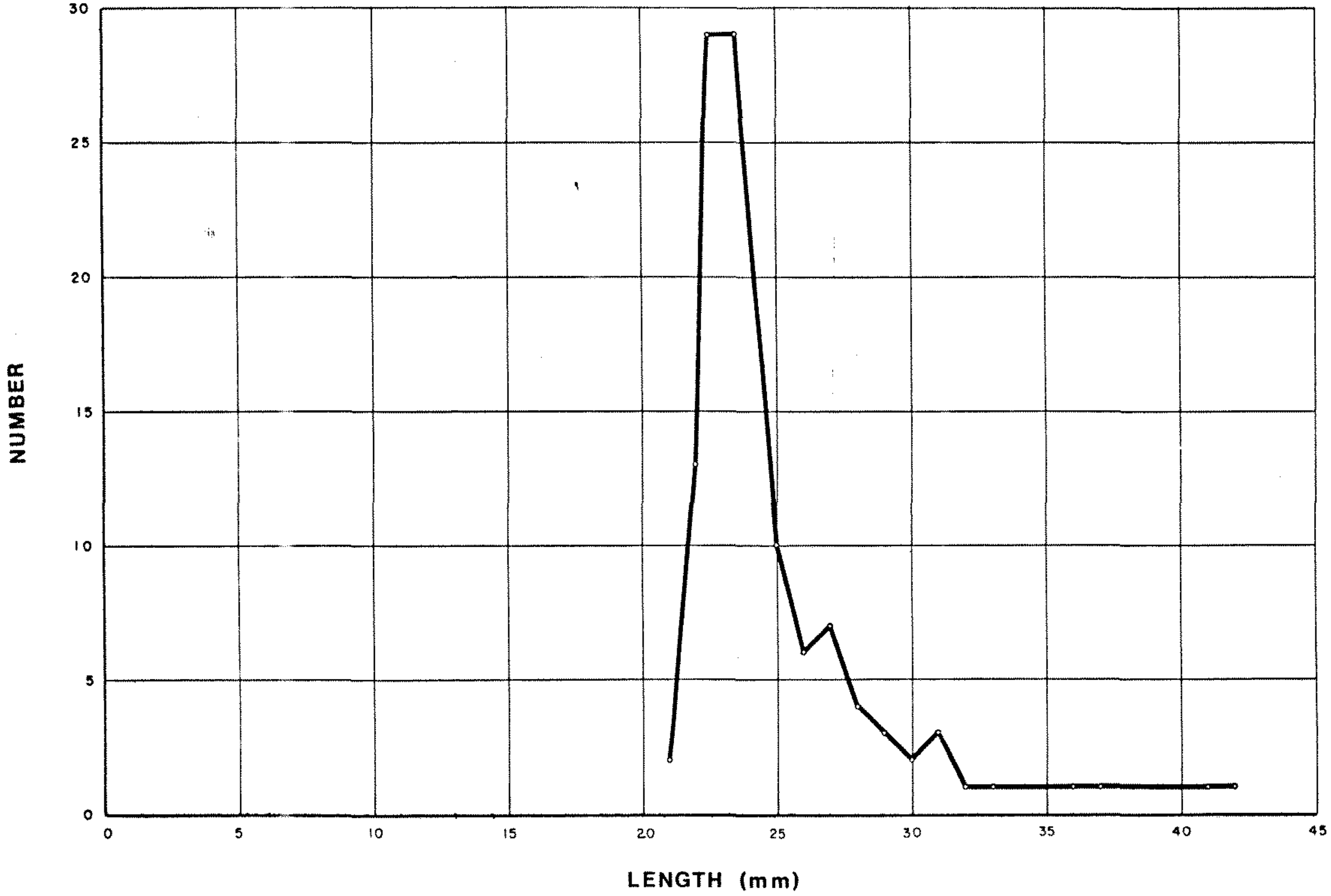
FIGURE 3.3-12

SIZE-FREQUENCY DISTRIBUTION OF RAINBOW TROUT FRY

Skagit River

1971



314-C6

The largest numbers of emergent fry were taken in late August 1972. Back-calculation in temperature units indicates that the peak of spawning in the Skagit system occurred in mid-June in 1972.

The details of the back-calculations are provided in tables in Appendix 22.

3.3.3.4 Location of Rainbow Spawning

Catches of Adults

Table 3.3-2 shows the data on catches of rainbow trout by gill net between May 11 and June 24, 1971. The data are broken down by sex of the fish and sexual condition as well as by location of the set on the river.

Detailed calculations to determine the proportion of mature females (maturity stages 4, 5 and 6 - see Section 3.2.2.2) taken below the 1725 foot elevation are shown on Table 3.3-3. These calculations used data on mature females only, because, as shown in Section 3.2.1.4, mature males were present both before and after the peak spawning period. Calculations were done both using absolute numbers of fish caught and the numbers of fish per hour of net set.

Results of the calculations are also shown on Table 3.3-3. The proportions of mature females taken in the Skagit River below elevation 1725 feet is 45 or 68 percent depending on the calculation used. If the validity of the (b) alternatives is accepted because of the small numbers of fish (8 mature females of 82 and 7.6 percent of all fish) taken upstream of M-13 the proportions are 50 or 55 percent.

TABLE 3.3-2

GILL NET CATCHES OF RAINBOW TROUT

SKAGIT RIVER SYSTEM

11 MAY - 24 JUNE, 1971

Location	Sections F-1 through M-2 (below 1725 feet)				Sections M-3 through M-13				Areas U, A				Sections M-3 through A (above 1725 feet)			
Total hours set	533.8				662.3				692.3				1354.6			
Fish	Ripe		Non-Ripe		Ripe		Non-Ripe		Ripe		Non-Ripe		Ripe		Non-Ripe	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	M	F	Male	Female	Male	Femal
Numbers	55	37	8	20	58	37	2	3	10	8	0	0	68	45	2	3
Catch/hour set	0.103	0.069	0.015	0.037	0.088	0.056	0.003	0.005	0.014	0.012	0	0	0.050	0.033	0.001	0.002

TABLE 3.3-3

CALCULATIONS OF PERCENTAGE OF RIPE FEMALE FISH TAKEN BELOW 1725 FEET ELEVATION

SKAGIT RIVER SYSTEM, 1971

a) = fish from F-1 through M-2 as percentage of all fish taken (F-1 through A)

b) = fish from F-1 through M-2 as percentage of fish taken between F-1 and M-13

I Numbers

- a) 37/82 = 45%
- b) 37/74 = 50%

II Catch/hour set

- a) .069/.102 = 68%
- b) .069/.125 = 55%

9.8% of all ripe females (8/82) were taken in Areas A and U (above M-13). 7.6% (18/238) of all fish were taken in Areas A and U (above M-13). In 692.3 hours of sets in Areas U and A, 18 fish were taken.

These data provide one estimate of the proportion of the population in the Skagit River that spawned below the 1725 foot elevation. The estimate is some amount too high, however. Most of the fish appeared to be moving upstream when caught and some proportion of these would have spawned above the 1725 foot elevation. If rainbows distribute along the river to spawn, a unit of effort that samples in proportion to abundance would provide highest catch per unit of effort at the lowest point in the river and declining catch per unit of effort upriver as the fish drop along the way to spawn in tributaries on the main river. Therefore, catches of mature fish below 1725 feet overestimate the proportion of the population that actually spawned below that elevation. Mature fish taken above the 1725 foot elevation are assumed to have spawned upstream of that level.

It should be noted that gill net sets were made only in the main Skagit River and the Sumallo River and only in 1971. This method provides no data on the tributaries to the system. The assumption is made that net efficiency averages out to be the same below and above elevation 1725 feet and thus, that CPUE truly represents the relative abundance of mature fish in the two sections. It could not be determined how closely this assumption was met.

Gill netting of adult rainbow trout was quite limited in 1972. As a result, time and locations of spawning could not be determined in 1972 by the methods described above and utilized in 1971.

As described in Section 3.3.3.2, attempts were made in 1972 to track large female rainbow trout using sonic tags. Unfortunately, background noise levels in the river made subsequent detection of tagged fish very difficult. As a result, no significant insight into spawning areas of rainbow trout was provided by the sonic tagging work in 1972.

Catches and Sightings of Fry

Tables in Appendices 21 and 23 give the locations of sightings and catches of rainbow trout fry in the Skagit River system. These data provide additional indirect information on the locations of rainbow spawning.

Most of the fry captured were recently emerged from the gravels (see Section 3.3.3.3) and were moving downstream when sampled. Spawning is assumed to have occurred upstream of the locations where the fry were captured or sighted.

Of 85 fry taken in 1971 fry net samples, 45 came from sets made in the Klesilkwa River. Another 26 were taken in Section M-1; 12 were captured from the F Sections. During the observations moderate to large numbers were seen throughout the F and M Sections. Fry were also sighted in lower numbers in the Klesilkwa River and Nepopekum Creek.

In 1972, a total of 907 fry were taken in fry net samples. 702 or 77.4% were taken at the Klesilkwa River mouth, and 171 or 18.9% came from Section M-1. At all other locations a total of 34 fry (3.75%) were collected (29 from F-4, and 5 from A-1). Since the M-1 location is slightly more than one mile downstream from the mouth of the Klesilkwa River, it is thought that most of the 171 fry taken there originated in the Klesilkwa River. However, no samples were taken between Sections M-1 and A-1 on the mainstream Skagit to confirm this.

After August 11, 1972, when the first fry of the season were captured, fry nets were set for a total of 251 hours in the Klesilkwa, 635 hours in Section M-1, and 2964 hours, the most intensive sampling, in Section F-4. Catch per hour of set for the 1972 season was 2.8 in the Klesilkwa, 0.27 in M-1, and 0.01 in F-4.

Fry were observed throughout the F Sections in moderate numbers during August and September 1972, and in the M and A Sections in low numbers, except for Section M-1 which had consistently high numbers. No fry were seen in Nepopekum Creek, 10-mile Creek or Silvertip Creek, in 1972, although fry were observed in 1971 or spawning observed in 1972 in these. Fry were observed in moderate to high densities in the Klesilkwa near the mouth throughout August.

3.3.5 Spawning of Other Species

Eastern brook trout and Dolly Varden char spawning behaviour and redds were observed in the Skagit River system during the autumn of 1971. Visual observations from the river bank and by Scuba divers during float downs (see Section 3.6.1.3) were the primary method used to locate spawning activities. In most cases, Dolly Varden and Eastern brook trout could not be distinguished from one another.

The peak of char spawning in 1972, as determined from shore observations, was in early November. In late August 1972, more than 3500 char were observed by divers, between Sections F-20 and F-3. In late September, approximately 40 chars and 9 redds were observed between Sections M-4 and F-4. No fish were seen from shore until late October when schools of up to 200 char were seen in the Hozomeen area. Dense spawning activity was also observed in a small unnamed creek there.

First evidence of spawning behaviour was observed on 26-28 September 1971 in a pool about 100 yards upstream in the Klesilkwa River from its confluence with the Skagit. About 26-30 Dolly Varden and Eastern brook trout were observed holding in this pool for three days. Four fish samples on the 28th were mature Eastern brook males. Female Eastern brook trout sampled on 28, 29 and 30 September had eggs still in the skein. On October 8, 15 fish were seen in the same pool and one pair appeared to be spawning.

During the float down on 16 and 17 October 1971 covering Sections M-4 to F-8, redds were seen in Sections F-20, F-16 and F-8. The numbers seen in each location were 8, 10-12, and 25-30 respectively.

Between 22 and 27 October 1971 counts and observations of redds were made in the F and M sections (up to M-9) of the river. The results are shown in detail on the table in Appendix 24. Complexes of many redds were found in Sections F-3, F-8, F-10, F-16, F-19, M-4 and M-5. Estimated numbers of redds in these complexes ranged from about eight in F-3 to as many as 50 in Section F-19.

Most of the redds observed between 22 and 27 October were not seen or were not seen in such large numbers on the float down of 16 and 17 October. It appears that the major spawning effort occurred between these dates.

Areas utilized for char spawning were characterized by slow flowing water over a gently sloping or level stream bed. Gravel sizes varied from about pea size to approximately one and one half inches in diameter.

3.4 FOOD AND FEEDING

3.4.1 Introduction

(by F. F. Slaney and Company)

The comparison of the diets of fish with the amounts of food available in an aquatic system provides the basis for estimating future requirements of fish populations in that system. The bottom fauna of the Skagit River system and the primary production, benthos and zooplankton of Ross Lake as well as the feeding habits of the fish in the Skagit-Ross system were studied for this purpose.

3.4.2 Primary Production

(by Fisheries Research Institute)

3.4.2.1 Introduction

In a relatively large lake such as Ross Lake, trout which feed directly on pelagic zooplankton thereby obtain their food energy indirectly from primary production. The primary production in Ross Lake is confined mostly to phytoplankton due to the high proportion of deep to shallow water.

Concentration of chlorophyll a per m^3 is commonly used as a measure of standing crop of primary producers (phytoplankton) in lakes. It is therefore useful to compare the standing crop of phytoplankton in Ross Lake with that of other lakes whose levels of productivity are known.

3.4.2.2 Methods

On September 18, 1972, replicate water samples were taken with a 2 liter Van Dorn water bottle at 6 depths, 1, 10, 20, 30, 40 and 50 m in mid-lake off Green Point near the south end of Ross Lake. The spectrophotometer method (Richards and Thompson, 1952 and Creitz and Richards, 1955) and computational formula (Parsons and Strickland, 1963) were used to determine chlorophyll a content per m^3 of lake water at each sample depth. The entire procedure is presented by Low (1972).

3.4.2.3 Results

Results (Fig. 3.4-1) show a maximum chlorophyll a concentration of 0.83 mg/m^3 at 10 m and a minimum concentration (0.14 mg/m^3) at 50 m. The mean concentration for the entire 0-50 m depth stratum was .47 mg/m^3. Mean concentrations for some Alaskan sockeye lakes were 0.97 mg/m^3 in September 1962-1972 in Lake Aleknagek from 0-45 m (Rogers, unpublished data and a September 1971 mean of 1.38 mg/m^3 in Knutson Bay in Iliamna Lake from 0-50 m (Low, 1972). Narver, 1966, and Burgner, et al. 1969 compare various indices of productivity including chlorophyll a of 10 Alaskan Lake systems. The range of values was 0.2-15.3 mg/m^3; the mean was 1.83 mg/m^3. July and August values in Lake Washington in 1970 were approximately 8-9 mg/m^3 in the upper 10 m (Edmondson, 1972); by comparison, chlorophyll a concentration in the upper 10 m of Ross Lake during the September 1972 sampling was 0.74 mg/m^3.

In summary, the standing crop of phytoplankton as measured by chlorophyll a concentration in Ross Lake is quite low compared to that of other cold, deep lakes in Alaska and Washington State. This could partially explain the low zooplankton abundance which will be discussed in a later section.

FIGURE 3.4-1

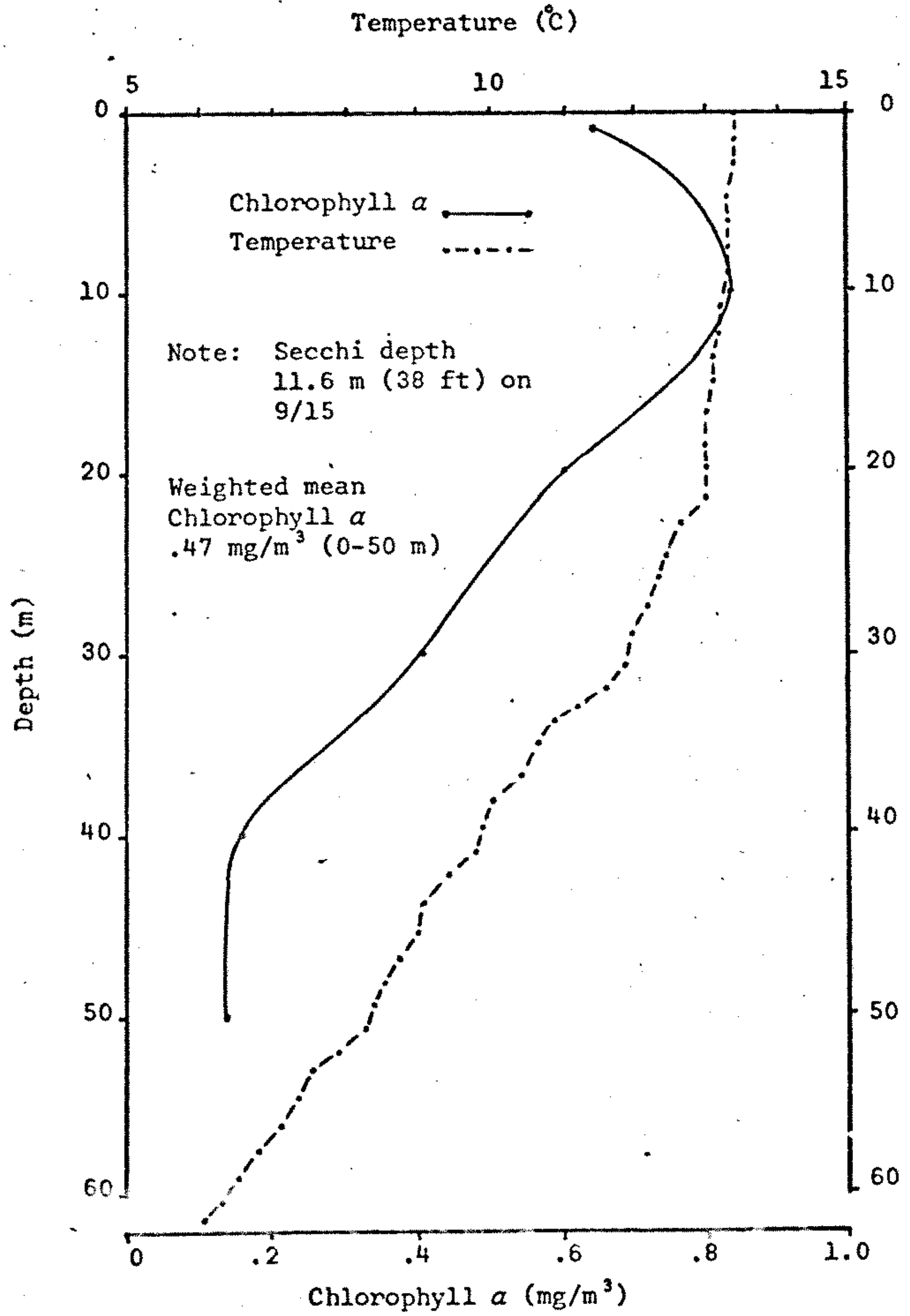


Fig. Chlorophyll a content, Ross Lake at Log Boom near Green Point, September 15, 1972. Temperature profile of Ross Lake at Ross Intake, one half mile from Log Boom near Green Point, September 18, 1972.

3.4.3 Ross Lake Zooplankton 1971

(by Fisheries Research Institute)

3.4.3.1 Methods

Six stations were established for plankton sampling sites in 1971 (Figure 3.4-2). Station depths are given at maximum lake level.

Station 1: the southermost station, mid-lake south of Green Point at a depth of 410 feet
Station 2: Ruby Arm off Lillian Creek, 145 feet
Station 3: mid-lake off Devils Creek, depth 235 feet
Station 4: under the Lightning Creek bridge, depth 70 feet
Station 5: mid-lake off Cat Island, depth 130 feet
Station 6: off Silver Creek, depth 55 feet

Plankton sampling was conducted at Stations 1 and 5 in May, June, and July, and September and at Stations 2, 3, 4, and 6 in July and September. Samples were collected by vertical hauls of a 0.5 meter conical nylon plankton net of 130 microns mesh size with open area of 43 percent. The towing cable was shackled to a bridle attached to the net ring.

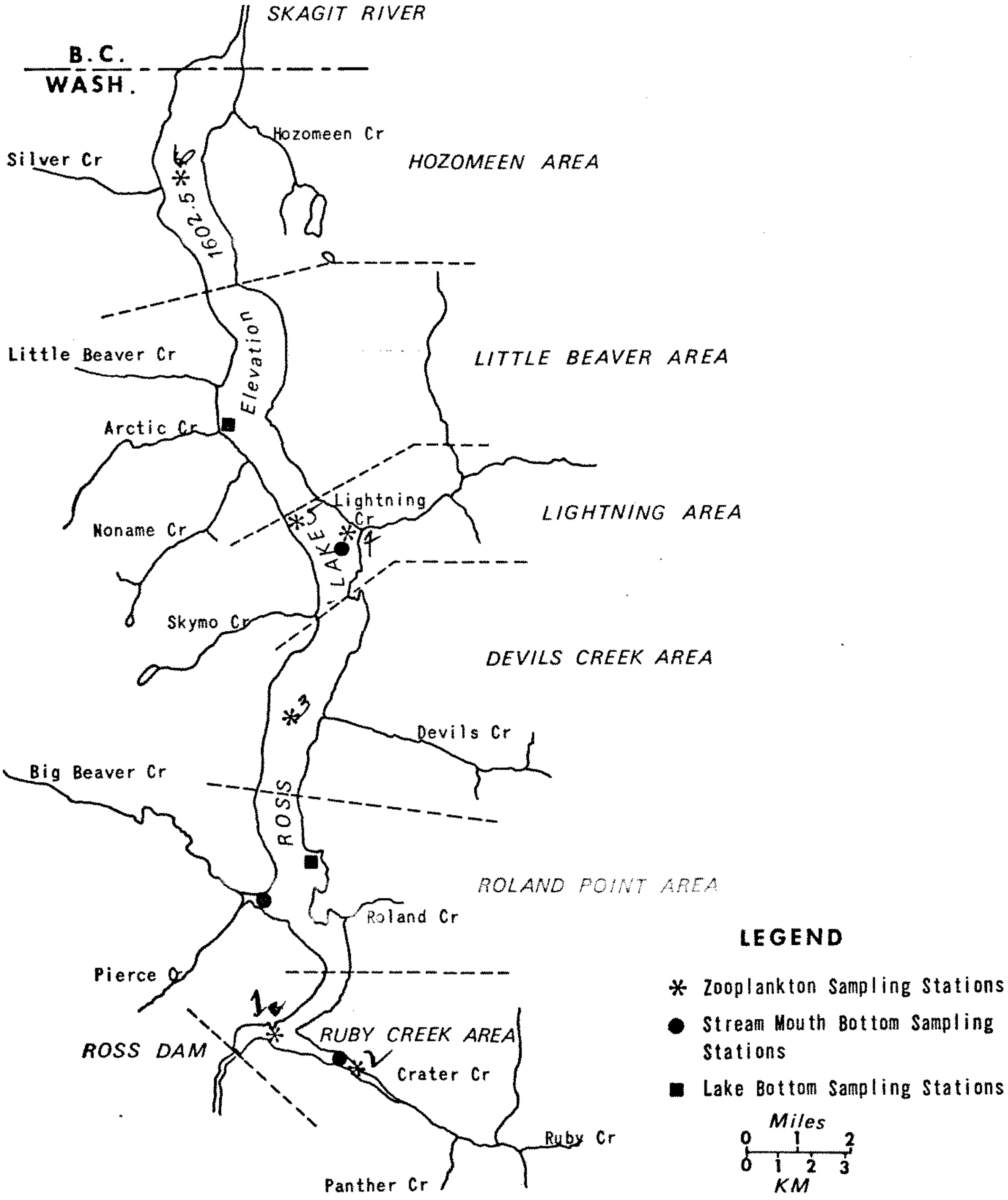
Station depth was determined using a Ross depth finder (Model 240-Sportsman). The total depth (from bottom to surface) at each station changed due to reservoir fluctuation over the course of the sampling period. Reservoir filling produced changes in total station depth until June 30 when lake level reached its maximum (1602.5 feet).

FIGURE 3.4-2

LOCATIONS OF SAMPLING STATIONS

ROSS LAKE

1971



Two vertical hauls were taken at each station and sampling date from as close to the bottom as possible to the surface. Retrieval rate was approximately 0.3 meters (m) per second. Plankton concentrates were placed in separate collection bottles, labeled, and preserved.

Before counting could begin, identification of the genera and species represented in the plankton concentrates was established. Identification to species was made whenever possible using Ward and Whipple (1966). Permanent mounts were made of individuals of each genus represented. This was done to verify taxonomic identification and to provide a permanent record of the plankton types found.

Analysis of the plankton followed the differential count procedure described by Welch (1948). Each sample was diluted to two hundred milliliters (ml) thoroughly agitated, and a one ml subsample was drawn with a Stempel pipette, transferred to a gridded counting cell under a binocular microscope, and counted by species. The subsample was then returned to the diluted sample and another fraction was drawn and counted in the same manner.

A true estimate of abundance (number of organisms per liter (1) of water strained) was not obtained because the amount of water actually strained by the net and the net selectivity was not determined. The data provide a relative estimate of zooplankton abundance, if it is assumed that the net efficiency did not change appreciably over the sampling season and that the total water column was adequately sampled on each date. Abundance is reported in average number of organisms per cubic meter in the water column and in average number per square meter of water surface, assuming 100 percent straining efficiency.

3.4.3.2 Results - 1971

Plankton sampling over a period of five months indicated that eight genera and nine species comprise the Ross Lake limnetic net plankton community. The genera represented included the cladocerans Bosmina, Daphina, Holopedium, Leptodora and Polyphemus, the copepods Cyclops and Diaptomus and the rotifer Asplanchna. Each genus was represented by one species except Diaptomus where two species were recognized but not identified. Copepod nauplii and an unidentified juvenile stage were also present.

Comparisons between stations indicated that for most species there was less variability between stations in number per m^2 than per m^3. This is an indication that the plankton in the water column tended to be concentrated in and above the metalimnion, and therefore that plankton production in the reservoir is more a function of lake area than lake volume. Results are presented in Table 3.4-1 by species, station and number per m^2. Tables giving the number of organisms per sub-sample and per m^3 are presented in Appendices 30 and 3 .

Total abundance of copepods and cladocerans increased from early May to late June and remained fairly constant until September 20. However, the seasonal pattern varied among species. Of the cladocerans, Daphnia pulex and Bosmina coregoni were most abundant. D. pulex abundance was highest

TABLE 3.4-

AVERAGE NUMBER OF PLANKTONIC ORGANISMS IN LAKE WATER COLUMN PER m^2 SURFACE AREA, 1971

		Date				
Species	Station	7 May	20 May	28 June	9 July	20 Sept.
Daphnia pulex	1	13,260	18,564	13,176	21,228	47,975
	5	244	7,683	54,298	31,403	52,080
	2				39,266	299,742
	3				45,660	54,275
	4				55,417	53,283
	6				16,551	46,702
Bosmina coregoni	1	3,006	3,890	5,673	27,084	2,570
	5	13,512	14,025	160,146	67,607	2,306
	2				14,255	9,170
	3				40,282	4,796
	4				14,548	2,295
	6				1,280	5,612
Leptodora kindtii	1	0	0	0	549	0
	5	0	0	1,050	1,524	0
	2				512	788
	3				220	0
	4				6,382	522
	6				2,286	0
Holopedium gibberum	1	0	0	183	1,098	685
	5	0	0	1,778	229	0
	2				1,963	4,083
	3				220	0
	4				238	765
	6				1,006	512
Polyphemus pediculus	1	0	0	0	0	514
	5	0	0	0	0	0
	2				0	501
	3				0	757
	4				0	0
	6				0	244

TABLE 3.4 - Page 2

Species	Station	Date 7 May	20 May	28 June	9 July	20 Sept.
Diaptomus spp.	1	1,591	1,768	4,575	5,307	54,143
	5	2,293	5,854	12,766	12,500	22,469
	2				31,839	235,982
	3				6,366	24,234
	4				15,816	9,704
	6				38,984	13,005
Cyclops sp.	1	0	0	183	5,307	685
	5	488	1,768	1,535	2,287	744
	2				4,609	2,292
	3				4,281	0
	4				2,101	522
	6				5,090	0
Total crustacea (excluding nauplii)	1	17,857	24,222	23,790	60,573	106,572
	5	16,537	29,330	231,573	115,550	77,599
	2				92,444	552,558
	3				97,029	84,062
	4				94,502	67,091
	6				65,197	66,075
Nauplii	1	0	2,122	4,758	8,052	7,710
	5	1,024	6,891	7,918	4,878	2,827
	2				12,206	8,454
	3				6,586	6,690
	4				753	1,009
	6				6,096	512
Asplanchna priodonta	1	7,602	63,825	201,300	910,974	46,949
	5	106,877	82,750	48,722	45,656	64,058
	2				2,686,791	56,094
	3				200,751	3,925
	4				77,139	59,126
	6				0	37,527

in the September sampling, while B. coregoni was at a maximum in late June - early July samples and showed a sharp drop in September. By far the largest plankter, Leptodora kindtii was found in relatively low abundance; it was not taken in May samples, had highest abundance in July, and decreased by September. Holopedium gibberum was absent in May samples and present in low numbers thereafter. Polyphemus pediculus was found in low numbers and only in September samples. Of the copepods, Diaptomus spp. rivalled the cladocerans Bosmina and Daphnia in abundance, increasing steadily in abundance during the season. Cyclops sp. was less abundant, reaching a definite maximum in July samples. The large rotifer, Asplanchna priodonta also was at a maximum in July samples.

With two exceptions the total number of crustaceans per haul was quite similar among stations on a given date in spite of differences in station depth and location. The two exceptions were caused by high abundance of Bosmina at station 5 on June 28 and of Daphnia and Diaptomus at station 2 on September 20.

3.4.4 Ross Lake Zooplankton - 1972

(by Fisheries Research Institute)

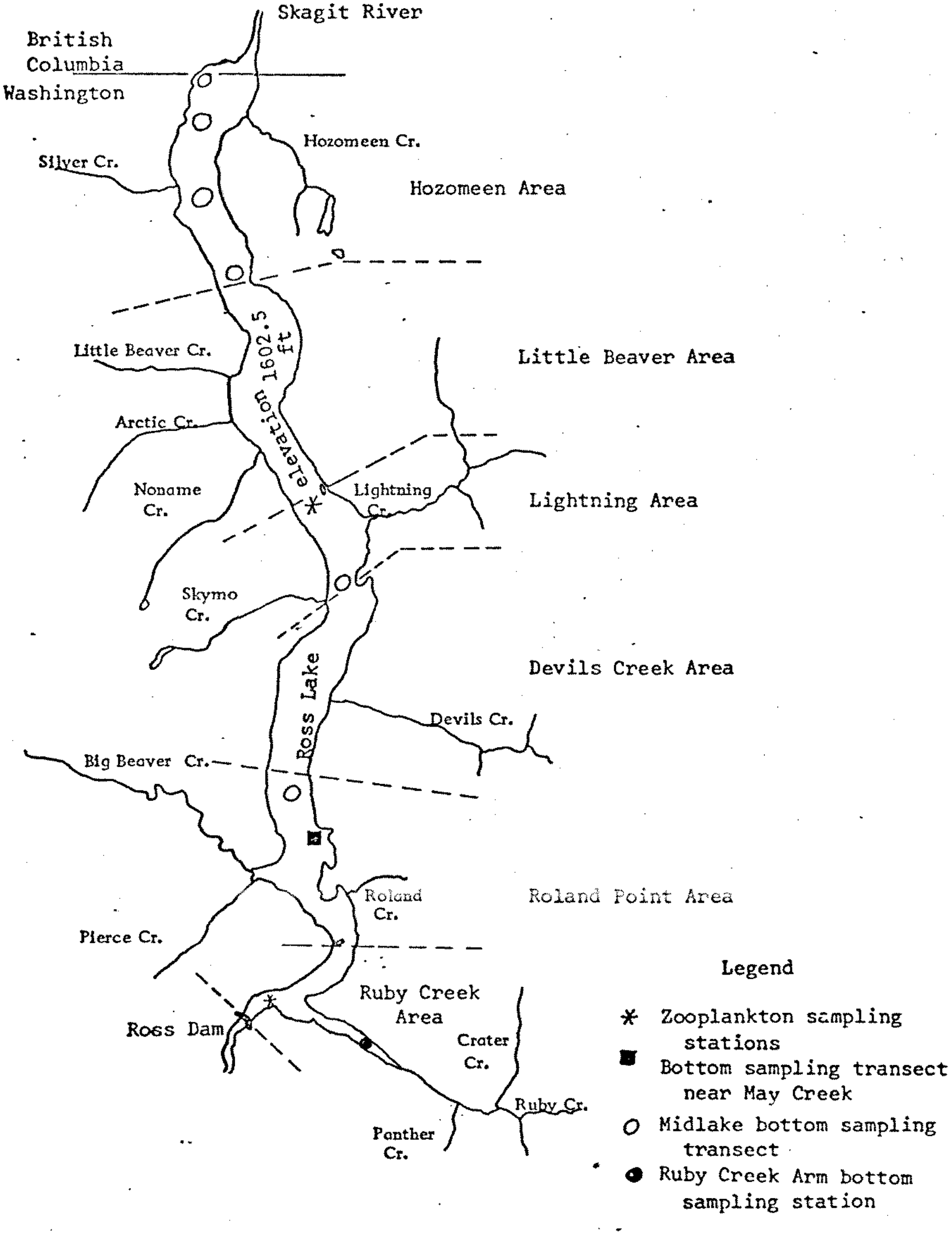
3.4.4.1 Methods

Two stations were repeated from 1971 for plankton sampling in 1972 (Fig. 3.4-3). Station depths from maximum lake level were:

Station 1:	the south station, midlake south of Green Point at a depth of 410 feet
Station 5:	midlake off Cat Island, depth 130 feet

FIGURE 3.4-3

Locations of sampling stations, Ross Lake, 1972.



Plankton sampling was conducted in April, June, July, and September. The equipment and procedures used for the vertical hauls were identical with those used in 1971. In addition, horizontal tows with a Miller plankton sampler were made at 9, 37, 72, and 108 ft. in June, July and September at station 1. Because of equipment breakdown, tows at 72 and 108 ft. only were made in April. As with the vertical hauls, horizontal tows were replicated except at 108 ft. in April. Towing speed was approximately 3 ft./sec. The Miller plankton sampler used consisted of a tube with an open end of 10 cm and a 160 micron mesh net with a detachable bucket at the trailing end. The water was thus strained through the net after passing through the tube as it was towed through the water. The wire angle was noted in order to calculate the actual depth of the sampler during the tows. The plankton concentrates were placed in separate collection bottles, labelled, and preserved.

Identification of the genera and species (whenever possible) was made using Ward and Whipple (1966). Permanent mounts of each identified taxon were available from 1971 studies for further positive identification.

The data provide a relative estimate of zooplankton abundance since it is assumed that the net efficiency did not change appreciably over the sampling season or between 1971 and 1972, and that the total water column was adequately sampled on each date. Abundance is reported in average numbers of organisms per cubic meter in the water column and in average number per square meter of water surface, assuming 100 per cent straining efficiency.

3.4.4.2 Results (1972) And Between Year Comparison (1971 and 1972)

Analysis of samples from mid-April to mid-September indicated a plankton species composition similar to that found in 1971. No new genera or species were identified. Plankters found included the cladocerans, *Daphnia*, *Bosmina*, *Leptodora*, *Holopedium*, and *Polyphemus*, the calanoid copepod, *Diaptomus*, the cyclopoid copepod, *Cyclops* and the rotifer, *Asplanchna*. Copepod nauplii were also present. The abundance data by species, station location, and sample date are presented in numbers per m^2 of lake surface in Table 3.4-2. Abundance data are also tabulated in numbers per subsample and numbers per m^3 in Appendix Tables 32 and 33 , respectively.

Due to lower abundance of cladocera (mainly *Daphnia* and *Bosmina*), total abundance of crustacea, excepting nauplii, in 1972 was generally lower than in 1971 at the Log Boom and Cat Island stations. Over the 1972 sampling period, total abundance in numbers per m^3 at the Log Boom and Cat Island stations respectively, ranged from 129 to 1064 and 251 to 2032. In 1971 total abundance ranges for these stations were 202 to 1244 and 678 to 5732, respectively.

Total abundance generally increased from the mid-April to mid-September sampling and was at a high level in the late December samples. As in 1971, the seasonal pattern varied among species; the pattern was quite similar in the April-September period in 1971 and 1972. *Daphnia* and *Bosmina* were the most abundant cladocerans. *Daphnia* was most abundant in September. It was relatively abundant in December at the Cat Island station but not at the Log Boom station. *Bosmina* was most abundant at station 1 in July and at station 2 in December. It was the most abundant crustacean at both stations in December. The largest plankter, the predaceous cladoceran *Leptodora*, was relatively scarce or absent in all samples. Its peak of

TABLE 3.4-2

AVERAGE NUMBER OF PLANKTONIC ORGANISMS PER M^2, ROSS LAKE, 1972

Species	Station	Date				
		April 18	June 14	July 19	September 15	December 28
Daphnia pulex	1	15,410	9,297	17,448	23,051	1,146
	5	2,802	5,222	16,556	26,995	19,995
Bosmina coregoni	1	3,184	1,274	17,702	10,698	10,061
	5	1,274	23,943	18,721	4,457	32,476
Leptodora kindtii	1	127	0	764	127	0
	5	0	255	1,401	382	0
Holopedium gibberum	1	0	637	2,165	127	0
	5	509	1,656	127	0	0
Polyphemus pediculus	1	0	0	0	1,274	0
	5	0	0	0	0	0
Diaptomus spp.	1	127	509	24,325	49,159	509
	5	891	3,566	12,608	44,320	7,005
Cyclops sp.	1	127	0	1,274	0	127
	5	255	127	637	1,274	382
Total crustacea	1	18,975	11,717	63,678	84,437	11,844
(excluding Nauplii)	5	5,731	34,768	50,051	77,433	60,112
Nauplii	1	0	891	16,429	19,103	509
	5	255	4,840	1,999	9,424	1,910
Asplanchna priodonta	1	1,656	62,150	186,195	7,005	9,170
	5	73,484	75,904	35,787	13,372	145,950

abundance was in July. In 1971, it did not appear in the September samples at the Log Boom or Cat Island stations; however, in 1972, it was present in the September samples at both locations. It was absent in the December samples. Holopedium was also in relatively low abundance. It was found in greatest numbers in June and July and was absent in the December samples. Polyphemus, in few numbers, was found only in September at the Log Boom station and in December at the Cat Island station.

Diaptomus, a calanoid copepod, increased steadily in abundance from April until September, when it was the most abundant zooplankter at either station. Cyclops, found in small numbers throughout the sampling, was more abundant in July, September, and December than in April and June. Asplanchna, the rotifer, was most abundant in the December samples at both stations.

As in 1971, the numbers of organisms per m^2 varied less than numbers per m^3, thus indicating that the zooplankton were concentrated above the metalimnion. The results from the horizontal plankton tows show this to be the case, particularly during the summer when thermal stratification was at its maximum (see Fig. 2.1-4). The relative abundance at each sample depth of Daphnia, Bosmina, Leptodora, Diaptomus, and total crustaceans are presented in Figs. 3.4-4 to 3.4-8. Daphnia and Diaptomus showed a strong tendency to concentrate above the thermocline while Bosmina and Leptodora showed a weaker but still definite tendency to concentrate in the epilimnion. The total zooplankton community was concentrated mainly in the epilimnion (Figs. 2.1-4 and 3.4-8).

FIGURE 3.4-4

NUMBERS OF ORGANISMS PER 2-MIN HORIZONTAL TOW

APRIL 18, 1972

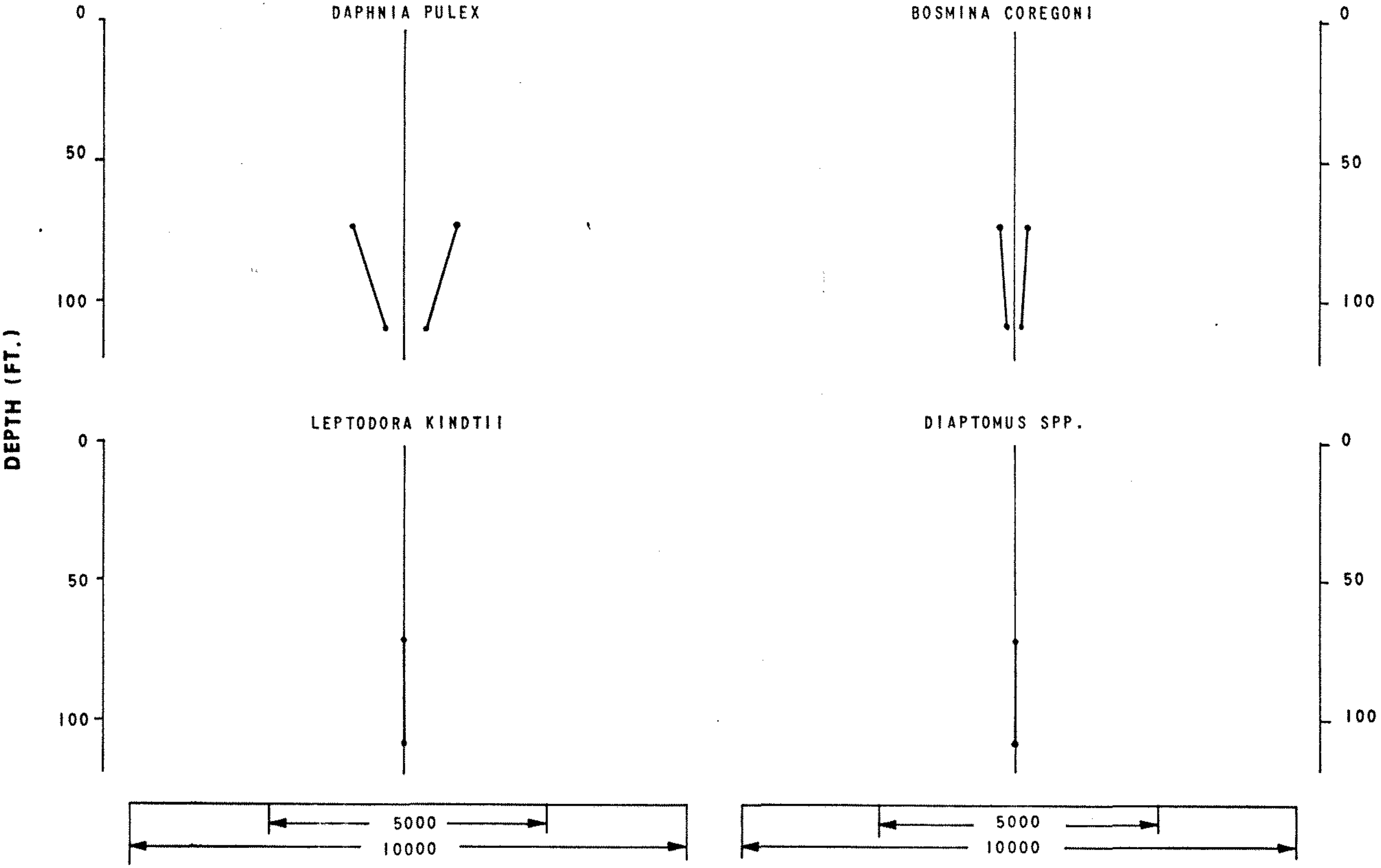
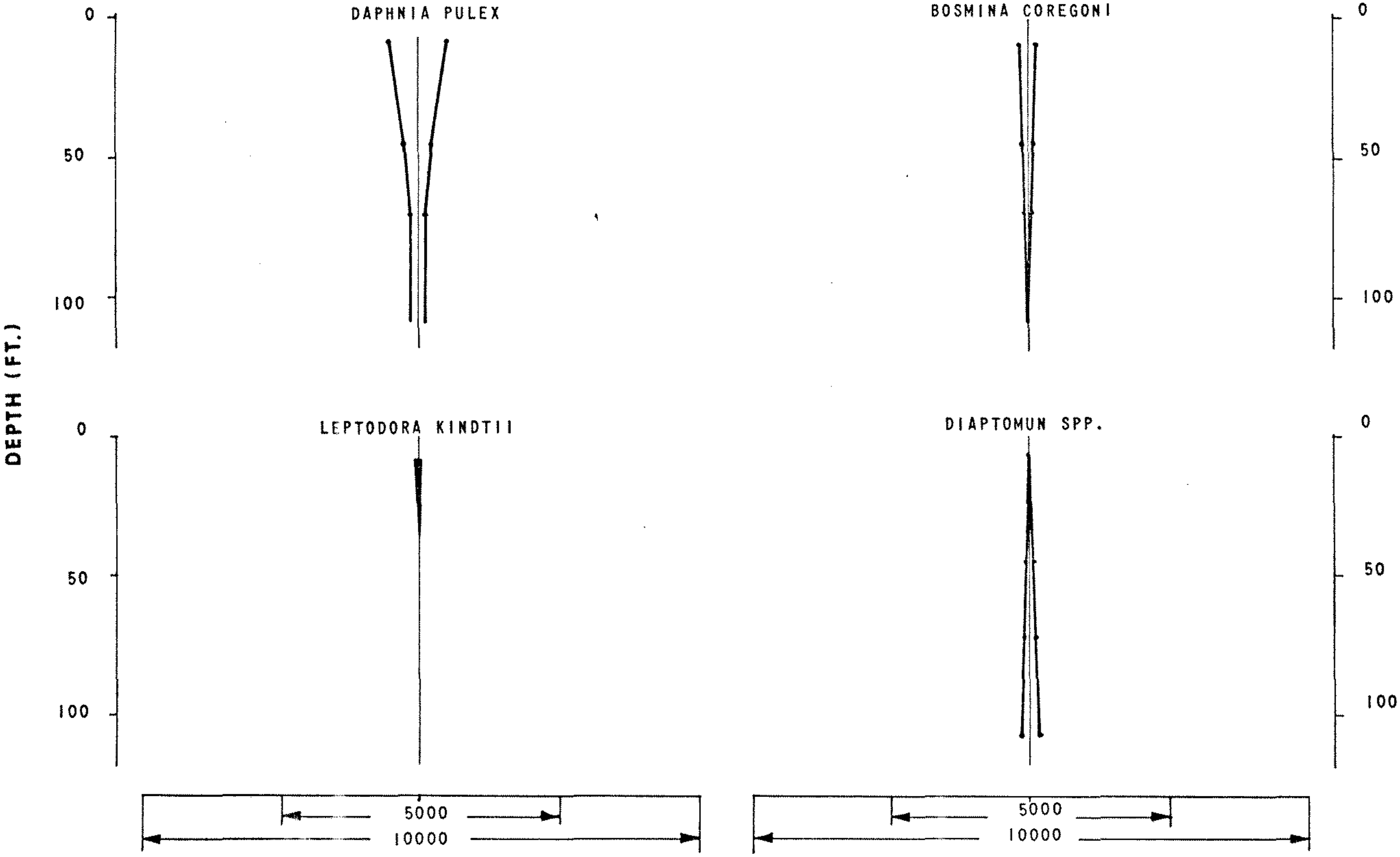


FIGURE 3.4-5

NUMBERS OF ORGANISMS PER 2-MIN HORIZONTAL TOW

JUNE 14, 1972



FIGL E 3.4-6

NUMBERS OF ORGANISMS PER 2-MIN HORIZONTAL TOW

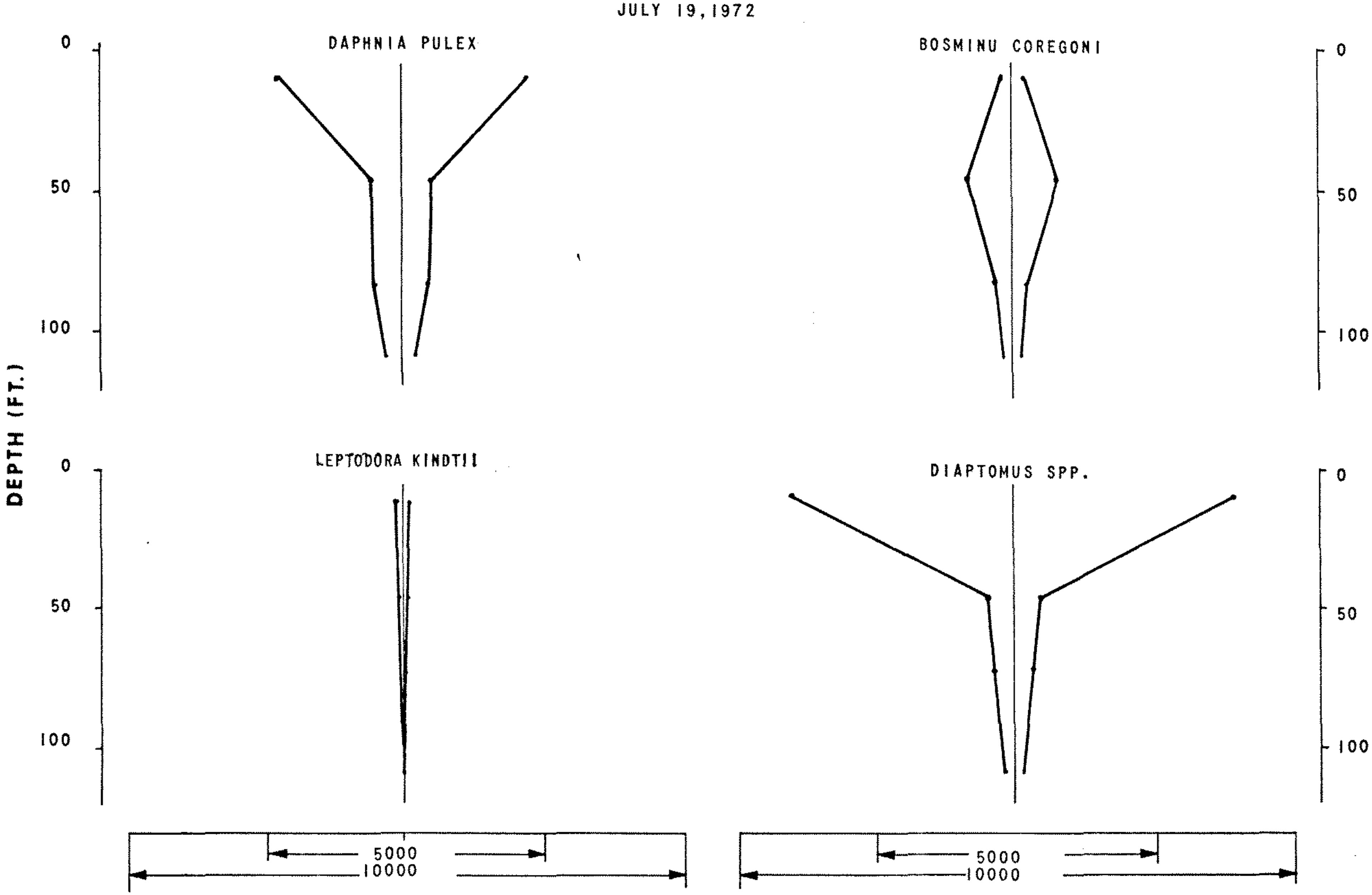


FIG E 3.4-7

NUMBERS OF ORGANISMS PER 2-MIN HORIZINTAL TOW

SEPTEMBER 15, 1972

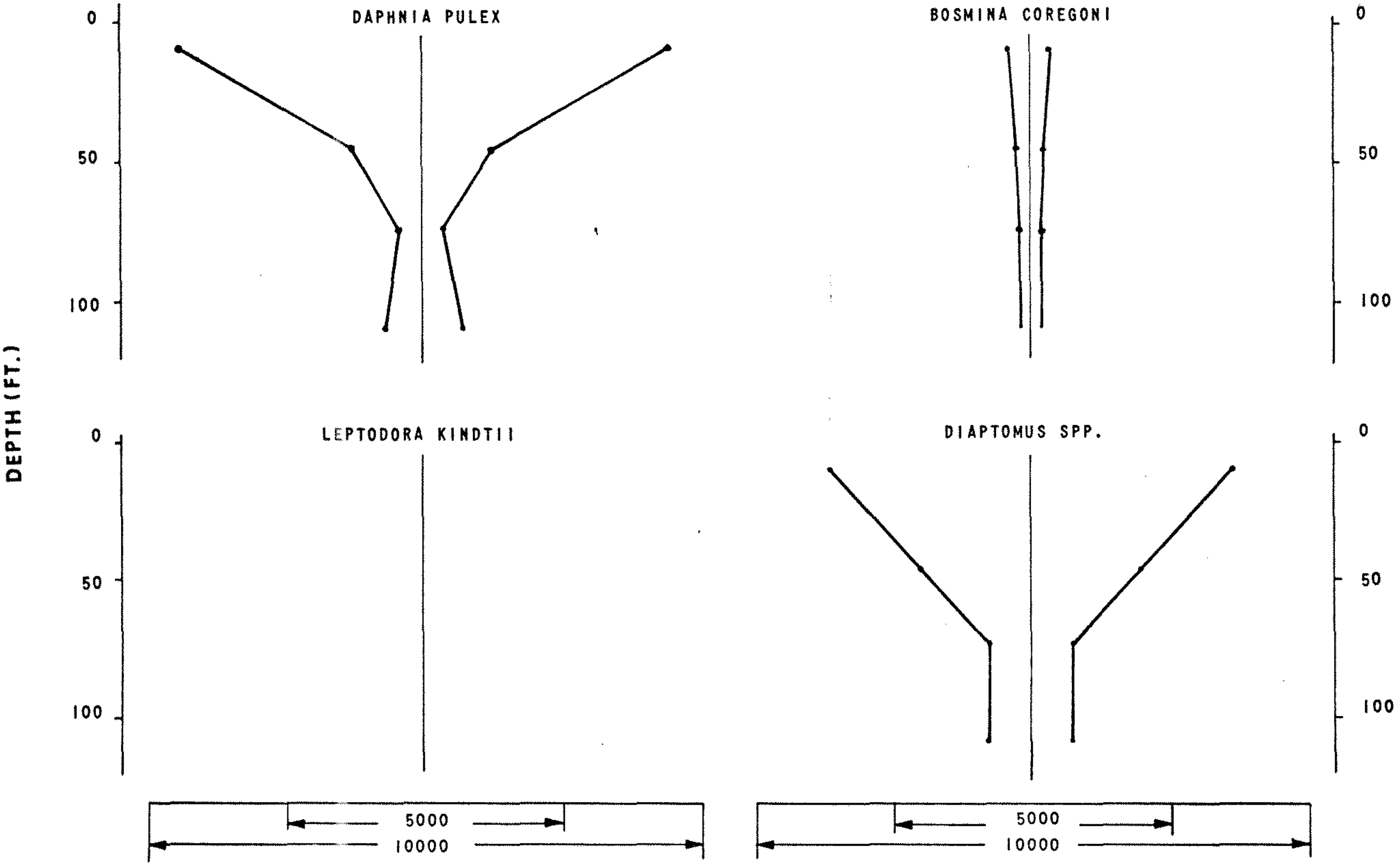
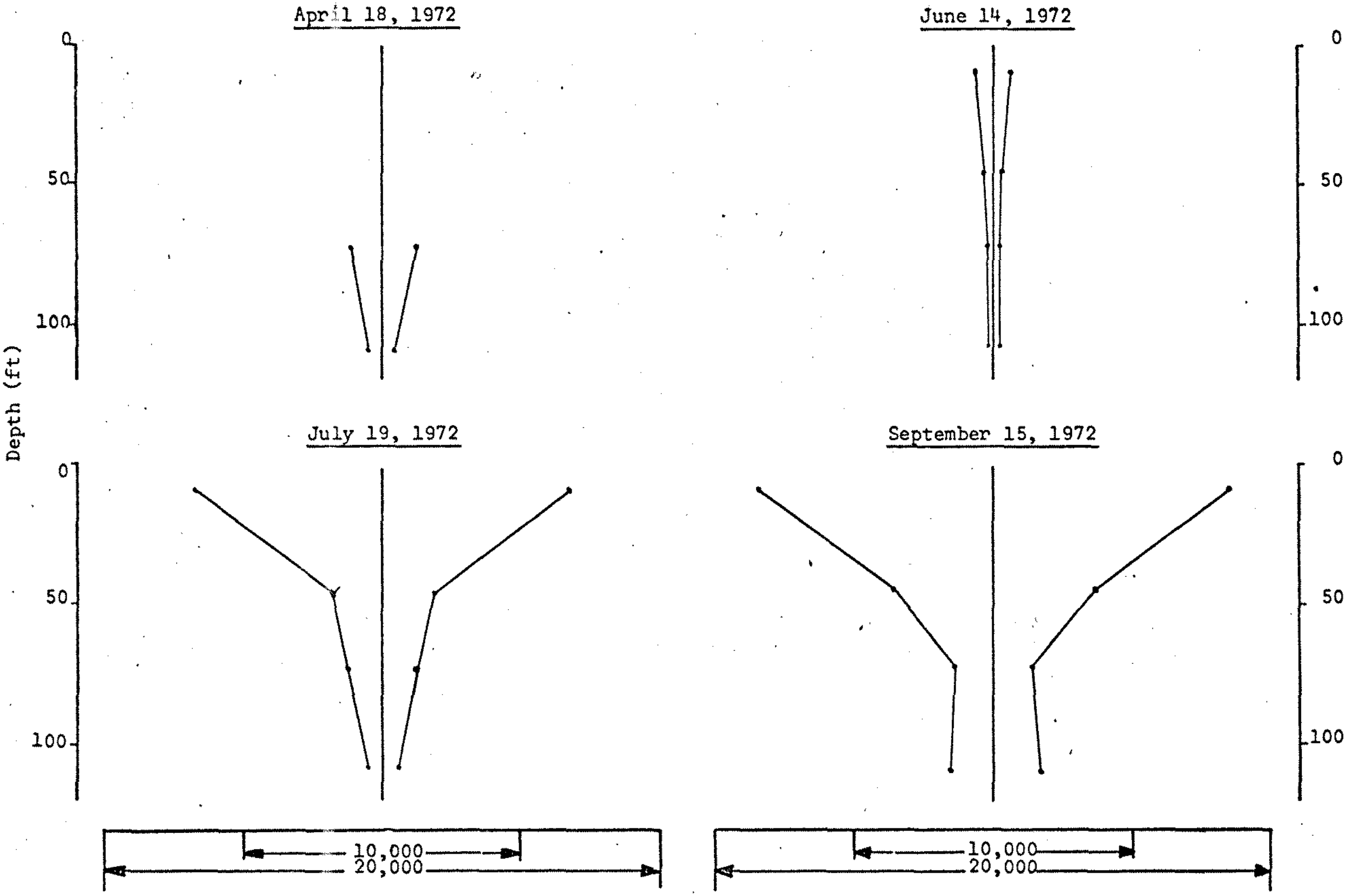


FIGURE 3.4-8

Total crustacea (excluding nauplii).



Numbers of organisms per 2-min horizontal tow

Zooplankton biomass is relatively low and fairly characteristic of that to be expected in an oligotrophic lake of relatively low nutrient status. In highly oligotrophic Lake Iliamna, Alaska (Baxter, 1968) summer standing crop of zooplankton, disregarding rotifers, ranged from approximately 3000 to 14,500 organisms per m^3 (Hoag, 1968). Zooplankton concentration disregarding rotifers in Ross Lake during the summer ranged from 300 (Station 1) to about 15,000 (Station 2) organisms per m^3 in 1971 and from 130 to about 2,000 in 1972 (Stations 1 and 5). The 1/2 m net used in Lake Iliamna was utilized with a no.6 mesh (243 micron) cloth (Hoag, op cit.); the cloth in the 1/2 m net used at Ross Lake was no.10 (160 micron). Such a difference in aperture could have resulted in a relative upward bias in estimate of Ross Lake plankton abundance compared to that of Lake Iliamna because of the ability of the smaller mesh net to capture smaller organisms. Any correction for bias due to different mesh size would reduce the abundance of the Ross Lake zooplankton relative to that in Lake Iliamna.

3.4.5 Ross Lake Benthos

3.4.5.1 Methods

1971

Benthic fauna from the unexposed lake bottom and bottom area exposed by drawdown were collected along two transects on Ross Lake reservoir. In addition to the lake shore transects, sampling stations were set at the mouths of three of the large tributaries (Big Beaver, Ruby and Lightning Creeks). The lake transects were located near May Creek at the southern end of the lake and near Arctic Creek toward the northern end (See Figure 3.4-2).

A 34 pound Van veen dredge with a sampling area of 0.03 square meter was used for all sampling. Sample sites along the lake transects were centered around the 1971 maximum drawdown level of 1530.8 feet. The locations of sampling stations in relation to water level at the maximum drawdown are shown in Figure 3.4-9 for the transect near May Creek. Two dredge hauls were taken at each station if bottom composition permitted successful sampling at the station.

Samples were collected in April, May, June and September along the lake transect near May Creek and in May, June, August and September along the transect near Arctic Creek. Creek mouth stations were sampled in April, May, June and September.

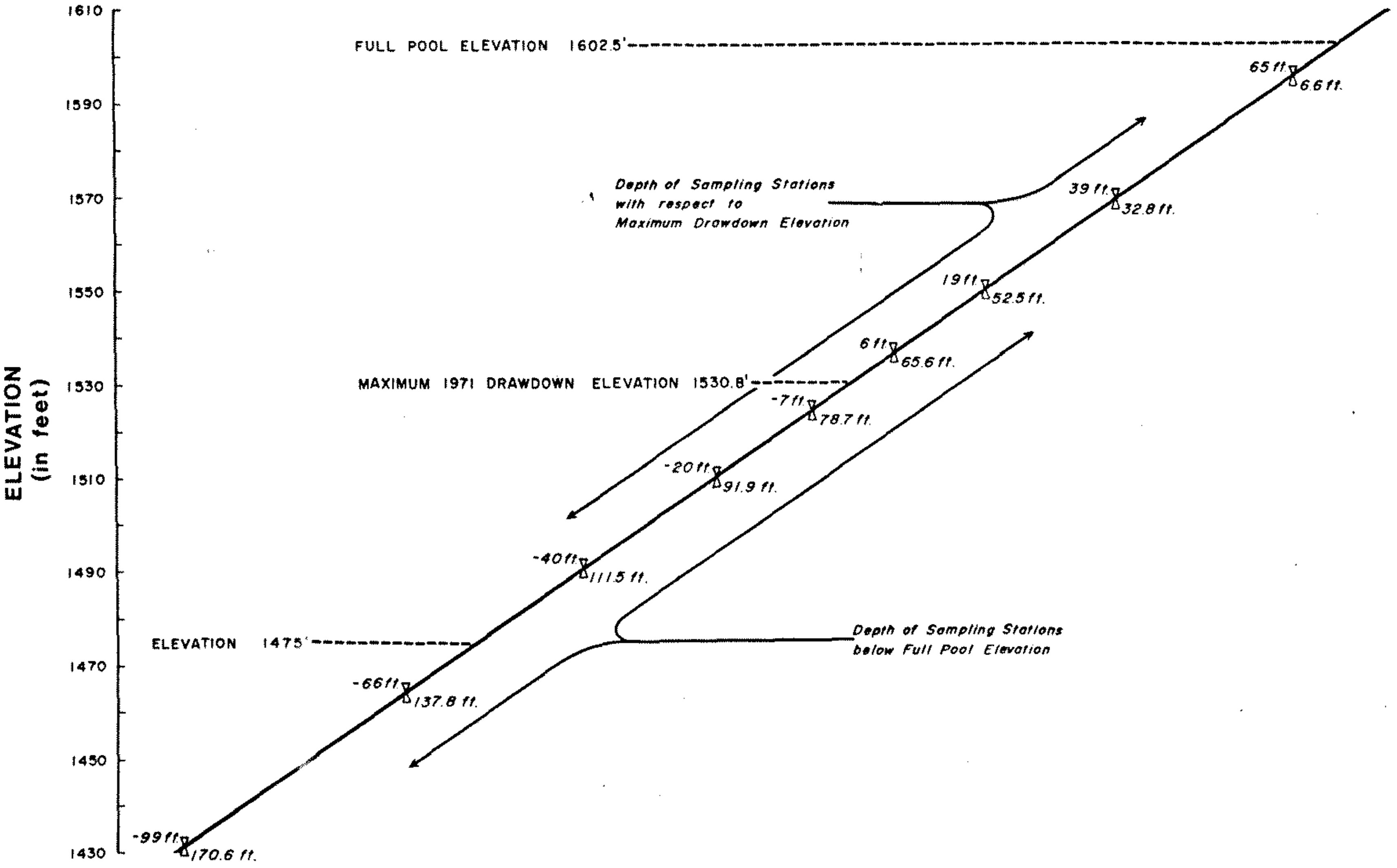
Dredge sampling was conducted from aboard a 21 foot work boat. Sample sites were located with the aid of shore markers and an echo sounder. The contents of each successful dredge haul were sifted through a wire screen of 30 meshes to the inch (open diameter = 0.020 inches) to concentrate the organisms. The resulting material was preserved for further processing.

In the laboratory the samples were washed out and a sugar solution was added to float the organisms free from the substrate. After all visible insects were picked from the sample the sugar water was rinsed out, replaced with fresh water and the sample again examined. Upon completion of this step the organisms were counted by taxonomic groups and preserved. The composition of the substrate was noted and samples of the substrate were periodically preserved.

Samples were selected from the May and September invertebrate groups for dry weight computations. Samples were dried at 68° C for 24 hours and then weighed.

URE 3.4-7

SAMPLING STATION LOCATIONS FOR LAKE TRANSECTS NEAR MAY AND ARCTIC CREEKS IN RELATION TO MAXIMUM 1971 DRAWDOWN AND FULL POOL



314-C869

1972

Bottom fauna were sampled above and below maximum 1972 drawdown along two transects on Ross Lake (See Fig. 3.4-3). A sampling station was also established near the mouth of Ruby Creek. The 1971 transect near May Creek was repeated in 1972 in order to have comparable results between the two years (Fig. 3.4-10). Because the lake transects in 1971 were established on a greater slope than exists in the drawdown area at the upper end of the lake a mid-lake transect was established to sample this flatter area. The mid-lake transect was set along the main axis of the lake beginning at the north end of the lake (Fig. 3.4-11).

A 34 lb. Van veen dredge with a sampling area of 0.03 m^2 was used on the transect near May Creek and near the mouth of Ruby Creek in April. For the remainder of the sampling in 1972, a 75 lb. Van veen dredge with a sampling area of 0.1 m^2 was used. Two hauls were made at each station.

Samples were collected in April, July, and August along the transect near May Creek and in May, July, and August along the mid-lake transect. The station off Ruby Creek was sampled in April, July, and September.

The processing of the samples following collection was as described for 1971 samples.

3.4.5.2 Results

Lake Transects - 1971

The results of sampling along the transects near May Creek and Arctic Creek are presented in Tables 3.4-3 and 3.4-4 respectively. The mean numbers

FIGURE 3.4-10

SAMPLING STATION LOCATION FOR BENTHIC SAMPLING LAKE TRANSECT NEAR MAY CREEK IN RELATION TO MAXIMUM 1972 DRAWDOWN AND FULL POOL ELEVATIONS

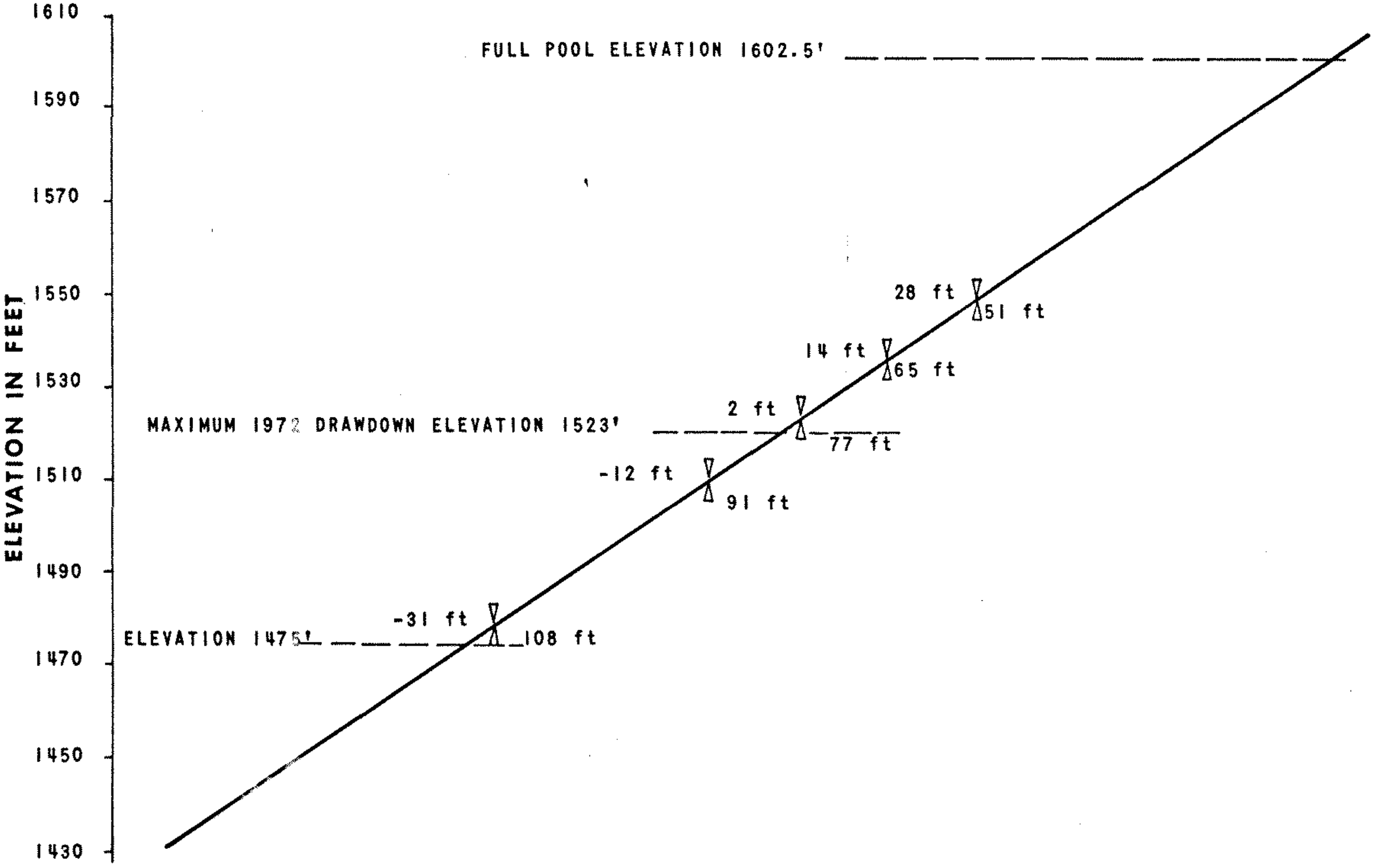


FIG E 3.4-11

SAMPLING STATION LOCATIONS FOR BENTHIC SAMPLING, MID-LAKE TRANSECT IN RELATION TO MAXIMUM 1972 DRAWDOWN AND FULL POOL ELEVATIONS

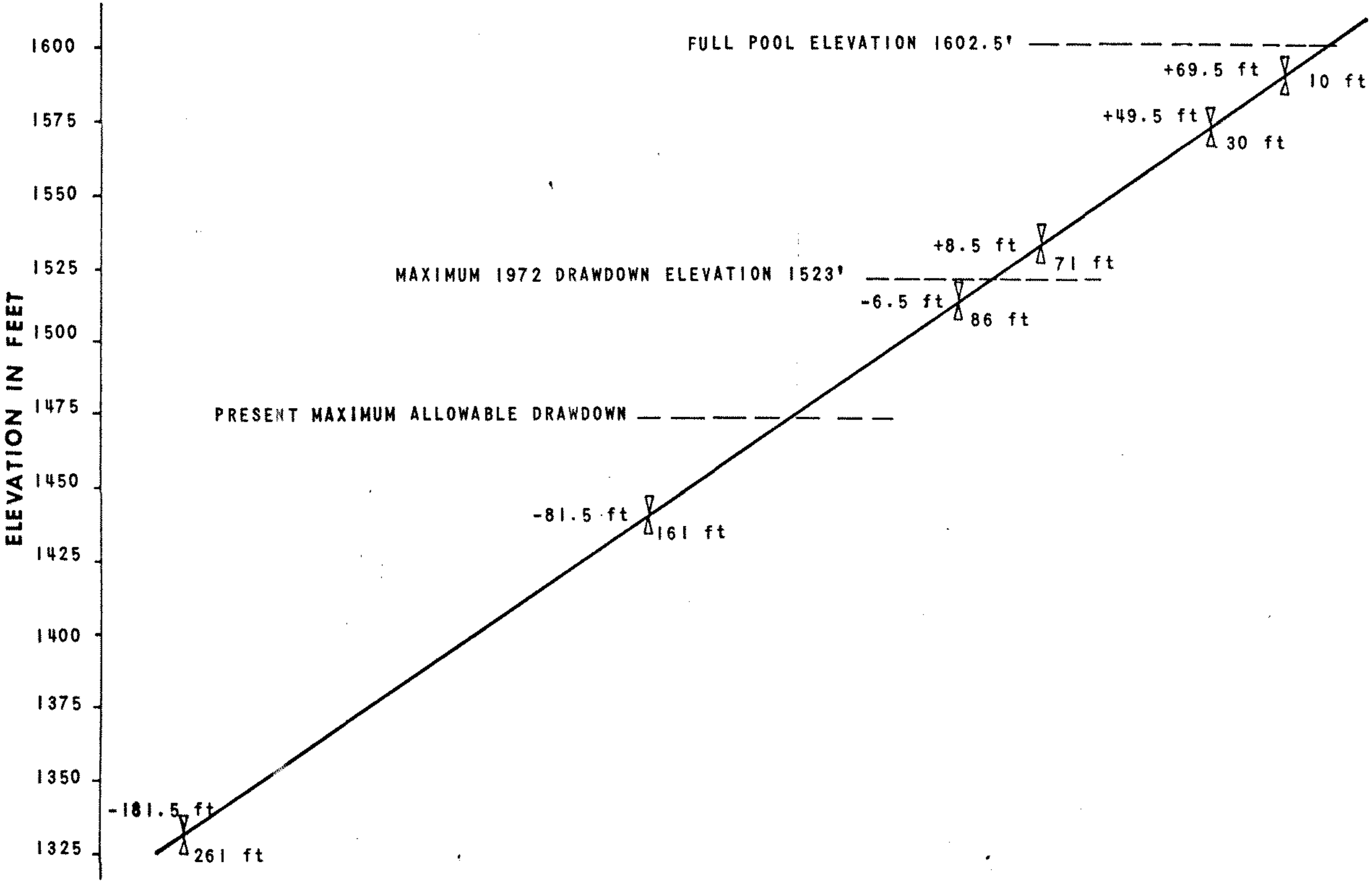


TABLE 3.4-3

MEAN NUMBERS OF INVERTEBRATES PER M^2 NEAR MAY CREEK, 1971

Sample locations are designated by depth of water at full pool elevation (1,602 ft) and by feet above (+) and below (-) maximum 1971 drawdown elevation (1,531 ft)

Transect near May Creek

Depth of Sta. at max. pool (1,602 ft)	7	33	53	66	(ft)	79	92	112	138	171	
Feet above (+) and below (-) max. drawdown	+66	+39	+23	+7	(ft)	-7	-23	-39	-66	-98	Total per-centages
	21 April				1971 Maximum drawdown 1,531 ft elevation		Water level = maximum drawdown				
Tendipedidae	No sampling			0		532	1273	1425	608	874	90.0
Oligochaetes				0		57	266	38	95	38	9.6
Amphipods				0		19	0	0	0	0	0.4
Others				0		0	0	0	0	0	0
	18 May						Water level = +43 ft				
Tendipedidae	0	19	76	19		456	1653	1558	361	665	92.0
Oligochaetes	0	0	0	0		95	95	19	76	133	8.0
Amphipods	0	0	0	0		0	0	0	0	0	0
Others	0	0	0	0		0	0	0	0	0	0
	22 June						Water level = +66 ft				
Tendipedidae	19	95	57	285		475	589	608	836	456	81.2
Oligochaetes	0	0	0	95		95	304	76	76	114	18.0
Amphipods	19	0	0	0		0	0	0	0	0	0.4
Others	19	0	0	0		0	0	0	0	0	0.4
	15 September						Water level = +71 ft				
Tendipedidae	931	532	304	1178		1805	3249	817	798	437	87.5
Oligochaetes	76	57	19	95		76	38	152	304	114	8.1
Amphipods	95	57	19	38		0	0	0	0	0	1.8
Others	19	5	266	0		38	0	0	0	0	2.6

TABLE 3.4-4

MEAN NUMBER OF INVERTEBRATES PER M^2 NEAR ARCTIC CREEK, 1971
Sample locations are designated by depth of water at full pool elevation (1,602 ft) and by feet above (+) and below (-) maximum 1971 drawdown elevation (1,531 ft)

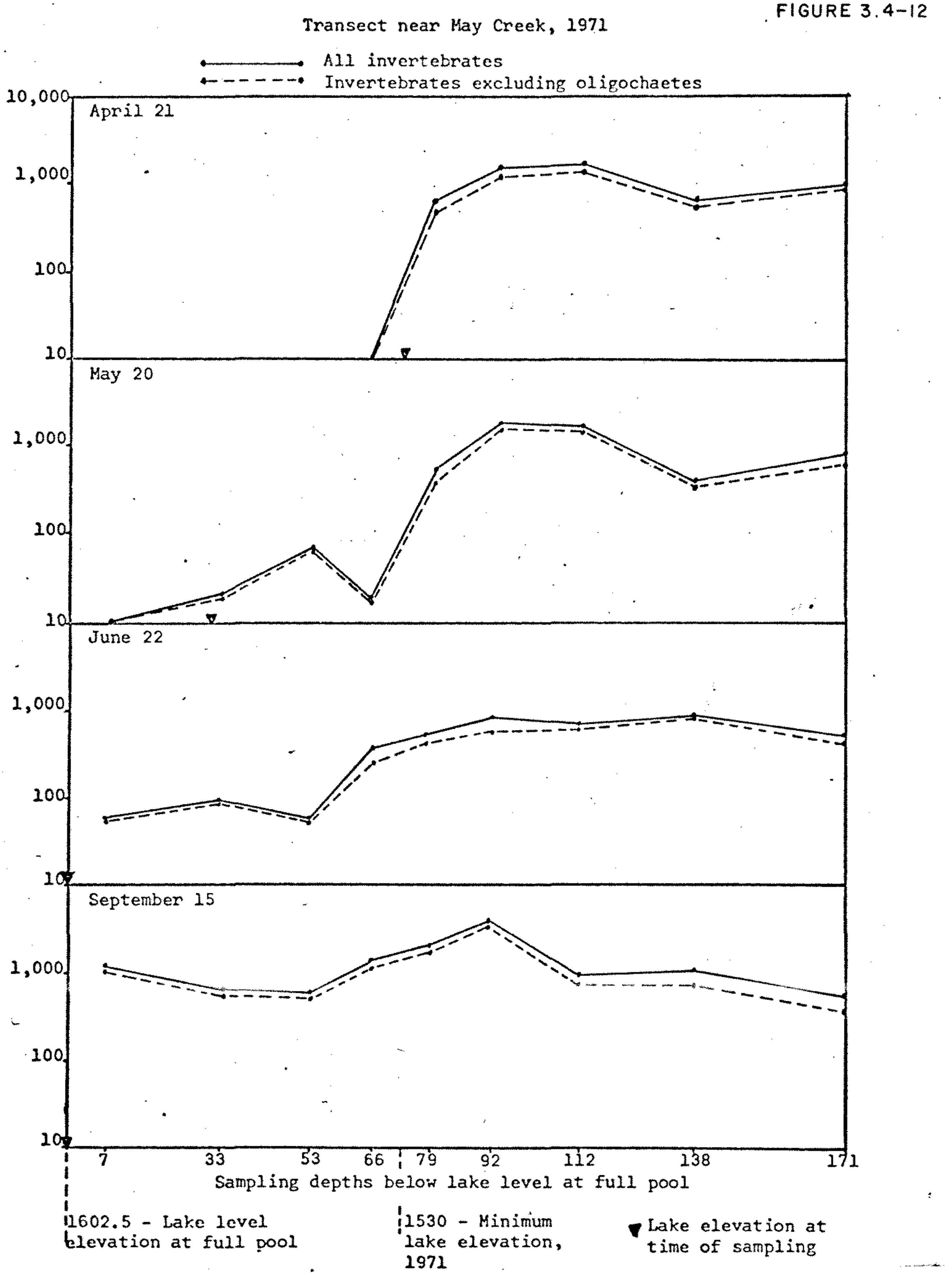
Transect near Arctic Creek

Depth of sta. at max. pool (1,602 ft)	7	33	53	66	(ft)	79	92	112	
Feet above (+) and below (-) max drawdown	+66	+39	+23	+7	(ft)	-7	-23	-39	Total per-centages
			20 May		Maximum drawdown 1,531 ft elevation		Water level +43 ft		
Tendipedidae			76	608		817	1463	228	72.7
Oligochaetes			57	437		190	399	38	25.6
Amphipods			0	0		0	0	19	0.4
Others			0	57		0	0	0	1.3
			22 June				Water level +66 ft		
Tendipedidae			266	190		171	1007	1159	57.0
Oligochaetes			342	228		361	209	874	41.1
Amphipods			0	19		0	0	0	0.4
Others			38	0		0	38	0	1.5
			10 August				Water level +71 ft*		
Tendipedidae						1539	2774	494	86.1
Oligochaetes						38	342	380	13.6
Amphipods						0	19	0	0.3
Others						0	0	0	0.0
			16 September				Water level +71 ft		
Tendipedidae			1387	6194		7087	8531	399	92.3
Oligochaetes			95	1007		323	475	38	7.6
Amphipods			0	0		0	0	0	0.0
Others			38	0		0	0	0	0.1

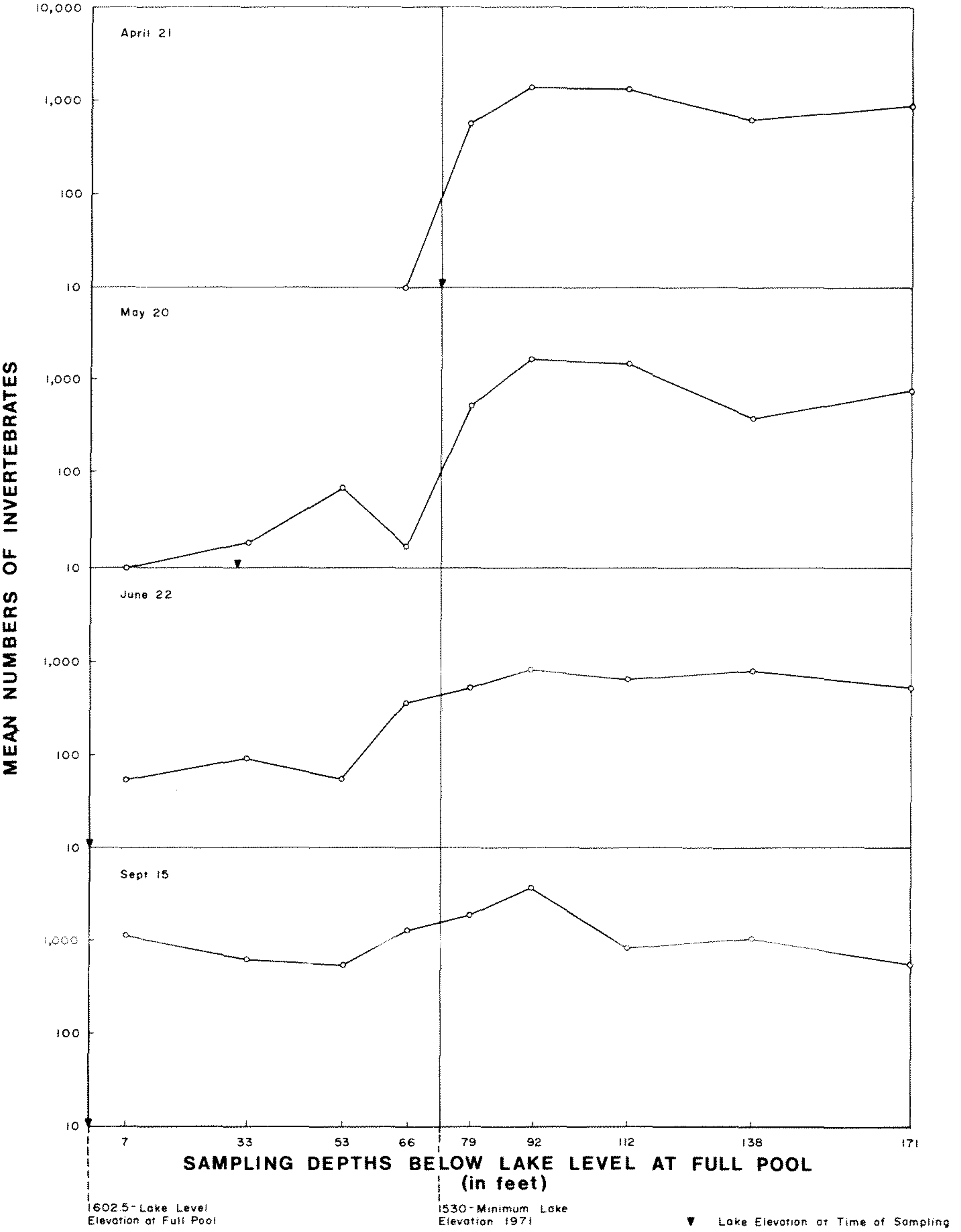
*Winch burned out and sampling was halted shown are the average of two samples taken at each sampling station. The data are shown graphically in Figures 3.4-12 and 3.4-13. The graphs indicate the depth distribution of the total mean numbers of invertebrates. Stations +39 and +66 along the transects near Arctic Creek could not be sampled due to hard substrate composition. Stations +23 and +7 were not sampled due to hard substrate composition. Although the transect near Arctic Creek is incomplete the invertebrate abundance appears to follow a depth distribution pattern similar to that near May Creek. Figure 3.4-12 indicates that there is a gradual increase in invertebrate numbers in the bottom areas exposed by drawdown with respect to time. Examination of exposed lake bottom material before inundation revealed no living invertebrates after the material was passed through a seive of 30 mesh/inch. The peak invertebrate abundance along transects remained below the maximum 1971 drawdown level for all sampling periods.

As Tables 3.4-3 and 3.4-4 indicate, Tendipedidae midges accounted for 80 to 92 percent of the invertebrate numbers in the transect near May Creek, and 57 to 92 percent in the samples near Arctic Creek. These midges ranged in size from approximately 3 mm to 20 mm total length. Extensive taxonomic analysis of this group was not attempted, but preserved samples are available if such a study appears to be warranted.

Oligochaetes were second in abundance. These specimens were generally less than 25 mm in length. It was evident during sample processing that obligochaetes did not float as consistently as midges. In an evaluation of the sugar floatation sorting methods, Fast (1971) found the sorting efficiency for obligochaetes to be 24 percent. However, he notes that all specimens above 15 mm were sorted using this method. Most oligochaetes sorted from Ross Lake samples were in the range of 15 mm or above. This could indicate some smaller specimens were missed in the processing.


Transect near May Creek, 1971
All invertebrates
Invertebrates excluding oligochaetes
10,000
1,000
100
10
April 21
May 20
June 22
September 15
7
33
53
66
79
92
112
138
171
Sampling depths below lake level at full pool
1602.5 - Lake level elevation at full pool
1530 - Minimum lake elevation, 1971
Lake elevation at time of sampling

MEAN NUMBERS OF INVERTEBRATES per m^2
ROSS LAKE
May Creek Transect 1971



Amphipods accounted for usually less than one percent of invertebrate numbers. The group entitled "Others" includes leeches, Hydracarina sp., Hydra sp., miscellaneous diptera, mayflies and terrestrial insects.

A table of factors for converting numbers of the two major invertebrate groups to dry weight was assembled (Table 3.4-5). Invertebrates used for dry weight determination were taken from similar depths of the May and September transect samples. The average dry weight of individual tendipedids was about 38 percent that of oligochaetes. However, because of the much greater numbers of tendipedids, their total biomass in samples considerably exceeded that of oligochaetes.

The composition of substrate along the transects near May and Arctic Creeks is readily divided into three basic types: 1) from maximum pool level (1602) to about the area of maximum drawdown there is an area composed of angular rock, gravel and sand with very little organic material except stumps; 2) in the area of maximum drawdown, there is a narrow transition zone where there is a gradual increase in organic material; 3) from the transition zone down to as far as samples were taken the substrate is composed of silt, wood bits, needles, cones, leaves and twigs.

Lake Transects - 1972

Results of the sampling along the transect near May Creek are shown in Table 3.4-6 and Fig. 3.4-14. The mean numbers shown are the average of two samples taken at each sampling station. As in 1971 the results

TABLE 3.4-5

DRY WEIGHTS OF TENDIPEDIDS AND OLIGOCHAETES FROM POOLED SAMPLES BELOW THE MAXIMUM DRAWDOWN ELEVATION (1,531 FT)

May Creek Transect

Tendipedidae	Replicates	N	Dry weight per 100
20 May 1971	1	71	0.0251g
	2	120	0.0189g
15 Sept. 1971	1	191	0.0236g
	2	147	0.0245g
Oligochaetes		60	0.0600g

TABLE 3.4-6

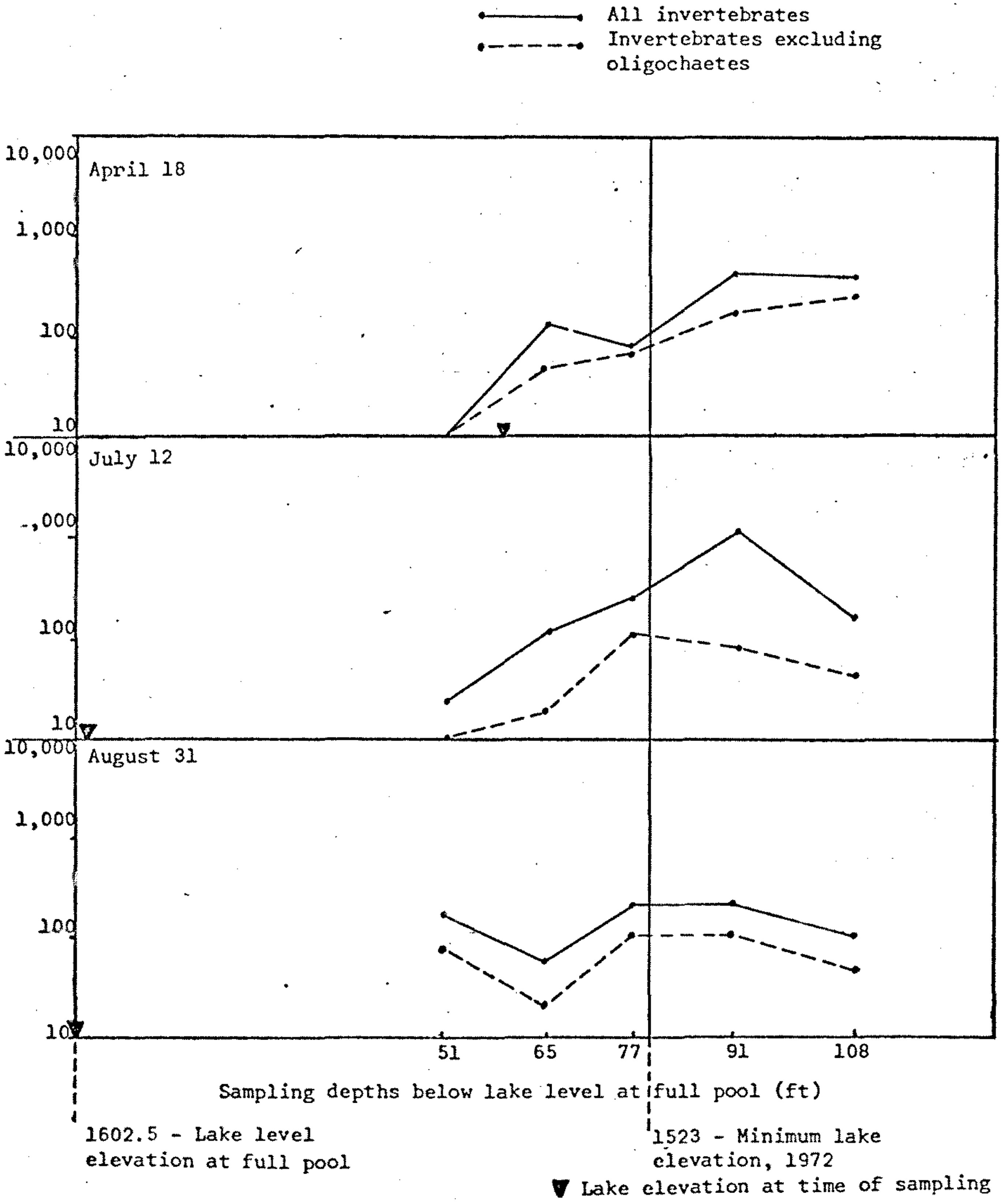
MEAN NUMBERS OF INVERTEBRATES PER M^2. SAMPLE LOCATIONS ARE DESIGNATED BY DEPTH OF WATER AT FULL POOL ELEVATION (1602.5 FT.) AND BY FEET ABOVE (+) AND BELOW (-) 1972 MAXIMUM DRAWDOWN ELEVATION (1523 FT.)

Transect near May Creek

Depth of sta. at max. pool. (1602.5 ft.)	51	65	77		91	108
Feet above (+) and below (-) max. drawdown	+28	+14	+2		-12	-31
18 April (Lake elev. 1541 ft.)				1972 maximum drawdown 1523 ft. elevation		
Tendipedidae	0	50	33		133	200
Oligochaetes	0	83	17		233	133
Amphipods	0	0	17		0	17
Others	0	0	17		50	33
TOTAL	0	133	84		416	383
12 July (Lake elev. 1601 ft.)						
Tendipedidae	0	20	110		80	40
Oligochaetes	25	115	160		1005	125
Amphipods	0	0	0		0	0
Others	0	0	5		5	5
TOTAL	25	135	275		1090	170
31 August (Lake elev. 1602.5 ft.)						
Tendipedidae	50	20	90		75	40
Oligochaetes	75	40	115		125	60
Amphipods	35	0	0		0	0
Others	0	0	25		40	10
TOTAL	160	60	230		240	110

FIGURE 3.4-14

Mean numbers of invertebrates per m^2, Ross Lake transect near May Creek, 1972.



indicate that recolonization of the drawdown area by benthic invertebrates from bottom not exposed by drawdown occurs. Maximum drawdown in 1972 (1,523 ft.) was reached on February 26. Results of sampling on April 18 show that benthic invertebrates were present in the recently inundated drawdown area but not in the exposed drawdown area just above the lake surface. The peak of invertebrate abundance remained below the maximum 1972 drawdown in all sampling periods along this transect.

A comparison of the data collected along the transect near May Creek in 1971 and 1972 show that overall invertebrate abundance at given depths was substantially lower in 1972. Tendipedid larvae comprised 88 percent of the samples in 1971. Oligochaeta, the other major constituent of Ross Lake benthos, were found in approximately the same numbers as in 1971. Thus, their relative abundance was much higher in 1972 than in 1971.

The mid-lake transect results are presented in Table 3.4-7 and Fig. 3.4-15. The means are the average of two samples taken at each sampling station.

A general increase in abundance of invertebrates in the exposed drawdown area occurred following inundation and continued through the summer until the abundance above the maximum 1972 drawdown ($405/m^2$) approximated the abundance immediately below it ($470/m^2$). This was probably due to recolonization from areas below the exposed drawdown. The invertebrates were most uniformly distributed over depth during August, but showed a tendency to remain concentrated around the maximum 1972 drawdown depth. Abundance dropped sharply between 161 and 261 ft. below full pool. Oligochaeta (77 percent of invertebrates) generally outnumbered the Tendipedidae (21 percent of invertebrates) in the samples.

TABLE 3.4-7

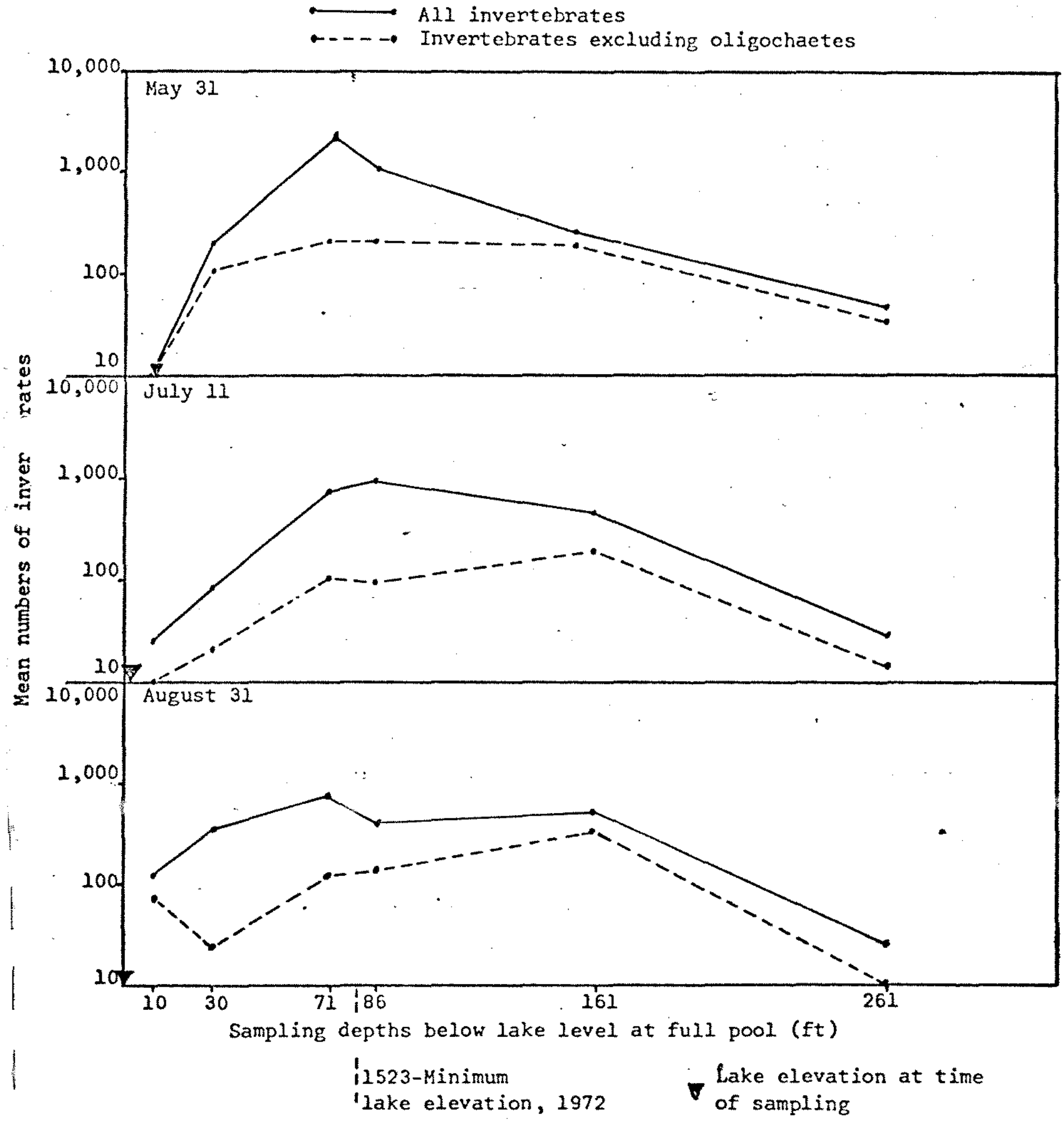
MEAN NUMBERS OF INVERTEBRARES PER M^2. SAMPLE LOCATIONS ARE DESIGNATED BY DEPTH OF WATER AT FULL POOL ELEVATION (1602.5 FT.) AND BY FEET ABOVE (+) AND BELOW (-) 1972 MAXIMUM DRAWDOWN ELEVATION (1523 FT.)

Mid-lake Transect

Depth of sta. at max. pool (1602.5 ft.)	10	30	71		86	161	261
Feet above (+) and below (-) max. drawdown	+69.5	+49.5	+8.5		-6.5	-81.5	-181.5
31 May (Lake elev. 1591ft.)							
Tendipedidae	0	40	185	1972 maximum drawdown 1523 ft. elevation	210	215	30
Oligochaetes	0	105	2015		890	70	10
Amphipods	0	0	5		5	0	0
Others	0	70	45		10	0	5
TOTAL	0	215	2250		1115	285	45
11 July (Lake elev. 1601 ft.)							
Tendipedidae	0	20	95		75	190	15
Oligochaetes	15	55	640		880	255	15
Amphipods	0	0	0		0	0	0
Others	10	10	15		20	5	0
TOTAL	25	85	750		975	450	30
31 August (Lake elev. 1602.5ft)							
Tendipedidae	40	20	130		150	335	0
Oligochaetes	45	310	635		320	205	25
Amphipods	25	0	0		0	0	0
Others	5	5	0		0	10	0
TOTAL	115	335	765		470	550	25

FIGURE 3.4-15

Mean numbers of invertebrates per m^2, midlake transect, Ross Lake, 1972.



The presence of abundance peaks above the drawdown level (Fig. 3.4-15) indicates relatively high productivity in the flat drawdown area along the main axis of the reservoir and that the benthic invertebrates are able to recolonize this area and flourish in a short period of time following inundation. Import of silt and organic detritus from the Skagit River undoubtedly contributes to the productivity of the drawdown bottom.

Comparison of Transect Locations

A comparison of invertebrate abundance between the mid-lake transect and the transect near May Creek is shown in Table 3.4-8. In the exposed bottom above the 1972 maximum drawdown level, abundance in samples taken along the mid-lake transect in 1972 was 3-6 times that of the samples taken along the transect near May Creek. Abundance of benthic invertebrates in the unexposed bottom below the maximum 1972 drawdown level along the mid-lake transect was also greater (approximately $1\frac{1}{2}$-2x) than the abundance along the transect near May Creek. The larger standing crop along the mid-lake transect is probably due to the flatter slope of the bottom and greater deposition of silt and organic detritus. It was observed that samples taken along the mid-lake transect contained more silt and detritus and fewer rocks than the samples along the transect near May Creek.

Creek Mouth Sampling

A single sampling station was established at the mouths of three of the larger tributaries: Big Beaver, Ruby, and Lightning Creeks in 1971. The stations were set up in 10 to 15 feet of water at the time of maximum 1971

TABLE 3.4-8

A COMPARISON OF THE VERTICAL DISTRIBUTION OF MEAN NUMBERS OF INVERTEBRATES (PER M^2) FROM BENTHIC STUDIES IN ROSS, BARRIER AND BLÅSJÖN RESERVOIRS AND LAKE ANKARVATTNET

DEPTH		ROSS RESERVOIR						
Feet	Meters	Transect near Arctic Creek	Transect near May Creek		Mid-lake transect	Barrier[1] Reservoir	Blåsjön Reservoir[2]	Ankarvattnet Lake[2]
		1971	1971	1972	1972			
								0 drawdown level
0 - 16.4	0 - 5		288		47	1177	1398 ←6m	8113
16.4 - 32.8	5 - 10		243		651	831←10m	4067	4783
32.8 - 49.2	10 - 15		190	160		4098	2855	3657
49.2 - 65.6	15 - 20	1839	308 ← 22m	86		2065	1474	2717
65.6 - 80.0	20 - 25	2751	646	153	1255 ←24m	1798	750	1599
80.0 - 98.4	25 - 30	3207	1391	582	853	2504		
98.4 - 114.8	30 - 35	2360	1520	221	641	25 18		
114.8 - 131.2	35 - 40	980	1909				733	1421
131.2 - 164.1	40 - 50		749		428			
164.1 - 229.7	50 - 70							
229.7 - 292.3	70 - 90				33			
Percent chironomid		77	88	27	21	68	54	32
Max. drawdown during year of sampling		71 ft	71 ft	80 ft	80 ft	33 ft	20 ft	unregulated
Time of sampling		May, June August, Sept.	April to June & Sept	April, July August	May, July August			
Location		north-central Washington				south-west Alberta, Canada	northern Sweden	northern Sweden

1 Taken from Fillion, 1967

2 Taken from Grimås, 1961

drawdown. Two dredge hauls were taken at each station during each sampling round. Table 3.4-9 gives the number of invertebrates per sample for the four sampling periods. The numbers of invertebrates in these samples were considerably higher than in the lake shore transects (Table 3.4-10). The bottom material at the creek mouths was very silty and contained a high percentage of detritus. Benthic organisms were most abundant in the April and September samples. This could possibly be due to emergence of midges in the spring and the appearance of young larvae in the September samples. Furthermore, increased flow in the creeks during May and June could have displaced soft bottom material and organisms.

During the September 1971 sampling period, samples were collected from four locations in Ruby Creek Arm. The samples were spaced to form a transect down the center of the arm. A description of station locations, depth and substrate composition is given with invertebrate abundances in Table 3.4-11. Station 3 in Table 3.4-11 was sampled in the regular monthly sampling round. The results indicafe that invertebrate production off the creek mouth was considerably higher in the area continuously inundated by the lake (Stations 3 and 4).

Results of the 1972 Ruby Creek Arm sampling are presented in Table 3.4-12. The samples were taken from a single location at depths varying from 67 to 71 ft. below full pool elevation, or 9-13 ft. above the maximum drawdown level. It is not known whether the samples were removed from the stream channel; however, the substrate composition was fine sand, silt, and organic detritus.

TABLE 3.4-9

NUMBERS OF INVERTEBRATES PER M^2 AT THE CREEK MOUTH SAMPLING STATIONS, 1971

Depths are distances below lake surface at date of sampling.

Big Beaver Creek

Date	21 April			18 May		22 June		15 September	
Depth	15 ft			58 ft		84 ft		86 ft	
Sample No.	1	2	3	1	2	1	2	1	2
	Number of organisms								
Tendipedidae	1938	8550	7676	2432	4826	3496	6498	10,450	2470
Oligochaetes	114	950	304	190	266	1558	2432	646	2242
Amphipods	0	38	38	0	0	0	0	0	0
Others	0	38	76	38	152	0	114	38	0

Ruby Creek

Date	21 April			18 May		22 June		15 September	
Depth	10 ft			53 ft		79 ft		81 ft	
Sample No.	1	2	3	1	2	1	2	1	2
	Number of organisms								
Tendipedidae	10,868	16,150	16,796	3002	3154	4750	5990	10,260	9424
Oligochaetes	190	0	0	114	114	418	114	380	2736
Amphipods	0	0	0	0	0	0	0	0	0
Others	0	0	0	380	0	38	0	0	0

Lightning Creek

Date	21 April			18 May		22 June		15 September	
Depth	10 ft			53 ft		81 ft		81 ft	
Sample No.	1	2	3	1	2	1	2	1	2
	Number of organisms								
Tendipedidae	14,288	9272		2888	1596	456	76	1710	2888
Oligochaetes	2736	418		1406	494	114	570	4522	1292
Amphipods	0	0		0	0	0	0	0	0
Others	0	152		0	38	0	0	0	0

TABLE 3.4-10

MEAN NUMBER OF INVERTEBRATES PER M^2 FROM LAKE TRANSECTS AND CREEK MOUTH STATIONS, Ross Lake, 1971

	Lake Transect						
	Near May Creek		Near Arctic Creek		Creek mouth stations		
	Total	Below 1,531 ft elev.	Total	Below 1,531 ft elev.	Big Beaver	Ruby	Lightning
April	870	1,045			6,563	14,668	13,433
May	581	1,022	878	1,053	3,952	3,382	3,211
June	467	726	980	1,273	7,045	5,605	608
September	1,281	1,566	5,115	5,616	7,923	11,400	5,206

TABLE 3.4-11

AVERAGE INVERTEBRATE NUMBERS, DESCRIPTION OF BOTTOM TYPE AND SAMPLING STATION LOCATION IN RUBY CREEK ARM, 15 SEPTEMBER, 1971

	Station 1	Station 2	Station 3	Station 4
Distance from mouth ft,	200	3,500	7,100	9,700
miles	1/26	5/8	1 1/4	1 5/8
Depth (ft) at:				
1,602 level	16	50	80	92
1,531 level	+55	+ 5	-25	-37
Substrate composition	coarse sand	fine sand, some silt	silt	silt
	Mean number of organisms per m^2			
Tendipedidae	3,591	3,211	9,842	7,334
Oligochaetes	0	152	558	1,083
Amphipods	0	0	0	0
Others	0	19	0	0

TABLE 3.4-12

Numbers of invertebrates per m^2 at the Ruby Creek Arm Sampling Station
(Depths are distances below lake surface at date of sampling.)

Ruby Creek Arm

Date	19 April		12 July		1 September	
Depth	10 ft.		66ft.	68ft.	68ft.	66ft.
Sample No.	1	2	1	2	1	2
			Number of organisms			
Tendipedidae	231	264	970	560	700	1010
Oligochaetes	33	132	20	70	0	0
Amphipods	0	0	0	0	0	0
Other	99	66	10	160	0	10
Total	363	462	1000	790	700	1020

As shown in Table 3.4-12, Tendipedidae larvae represented 60 percent of the invertebrate numbers in April and slightly less than 100 percent of the total abundance in September. In September 1972 the invertebrate abundance at a similar distance above maximum drawdown was about 1/3 that of September 1971.

The samples taken near the mouth of Ruby Creek contained fine silt, sand, and organic detritus and no rocks (The bottom composition was similar to that of the mid-lake transect). The abundance of benthic invertebrates in the July and August samples was nearly the same as that of the mid-lake transect at a similar depth. Tendipedid larvae were predominant in the Ruby Creek mouth samples, while Oligochaetes were found in greater numbers in the mid-lake samples.

Summary and Discussion

Results of the benthic macrofauna sampling conducted in 1971 indicate the following:

1. Tendipedidae predominated in lake bottom fauna both in total numbers and biomass. Oligochaetes were second in biomass and numbers.
2. Bottom fauna abundance was considerably greater off stream mouths than away from stream mouths.
3. As the reservoir filled in late spring, bottom fauna abundance per unit area was very low at depths above minimum reservoir drawdown elevation.

4. Some replenishment of fauna in the inundated area above minimum drawdown occurred during summer, but by later summer organism biomass per unit area was still much greater at depths below minimum drawdown.

Results of the benthic macrofauna sampling in 1972 indicate the following:

1. Oligochaetes were most abundant in the samples taken along the lake transects. Tendipedidae were second in number.

2. Tendipedidae predominated in abundance in the Ruby Creek mouth samples in 1972.

3. Total bottom fauna abundance in 1972 in the Ruby Creek mouth samples was approximately equal to total abundance along the mid-lake transect. The samples from the transect near May Creek contained the lowest invertebrate abundance.

4. When the lake bottom is exposed by drawdown, invertebrate abundance in the exposed area is apparently non-existent. However, rapid replenishment from areas below the drawdown level occurs when the reservoir is filled in the spring. Abundance in very deep water is low, and because of length of time of exposure by drawdown abundance in shallow bottom areas is also low. The greatest abundance of benthos is in the intermediate depths.

5. A shift in apparent relative abundance of Tendipedidae and Oligochaetes occurred from 1971 to 1972. Absolute abundance of Tendipedidae decreased while Oligochaete abundance was approximately the same in 1972 as in 1971. Oligochaetes were second in abundance to

Tendipedidae in 1971 lake transect samples, but in 1972 Oligochaetes were more abundant.

6. The indications are that abundance of benthos in Ross Lake was less in summer of 1972 than in summer of 1971.

The conclusion with respect to the area exposed by drawdown is that its macro-invertebrate production is severely restricted. This phenomenon has been found to occur in other reservoirs in Sweden (Grimås, 1961; Fillion, 1966). The low standing crop of invertebrates in the drawdown zone is generally attributed to absence of littoral vegetation and lengthly intervals of exposure (Fillion, 1967).

With the drawdown to 1531 feet elevation in 1971, the area exposed exceeded 30 percent of the total lake area. In 1972, with a drawdown to 1523 ft. the exposed area was 36 percent of the total lake area. Since 1953, the exposed area has averaged 38 percent and has ranged from 15 to 54 percent.

A comparison of the vertical distribution of invertebrate numbers from Ross Lake transects with three other benthic studies is presented in Table 3.4-8. Barrier Reservoir and Ross Lake were both unmodified river valleys before impoundment. Blasjon was a natural lake before regulation and Ankarvattnet remains unregulated(Grimås, 1961).

The comparison is complicated by the varying drawdown levels of the four lakes and time of sampling. Sampling in Ross Lake and Barrier occurred at similar times of year, but Blasjon and Ankarvattnet were sampled the year round. All three reservoirs show peaks of abundance just below the drawdown level. Invertebrate numbers from the transect near Arctic Creek in 1971 were quite similar to those of Barrier Reservoir in the drawdown area. The lower standing crop of the transect near May Creek is believed due to less silting and the steep sloping lake bottom in this area. Such conditions result in less detrital food for the invertebrates than in more heavily silted flatter areas. The depth distribution of organisms in the reservoirs listed indicates that greater drawdown results in fewer organisms available to fish feeding in the shallower waters when the reservoirs are full.

3.4.6 Skagit River System Fauna

(by F.F. Slaney and Company)

3.4.6.1 Methods

An estimate of the food available to fish in the Skagit River system was made from samples of bottom fauna collected in the river. The samples were taken with a modified Surber sampler which collects fauna from one square-foot of stream bottom. (See Photo Appendix 31). In practice the samples were usually taken from riffle areas of 6 to 18 inch depths with substrate typical for the sampling section. Pools and boulder areas were not sampled.

On February 11, 1971, 18 one square-foot samples were taken at the Chittenden's Bridge location (in Section F-4). A statistical analysis was done on the numbers of 11 types of Ephemeroptera (5) and Plecoptera (6) in the samples to determine the number of one square-foot samples required to ensure that at least one representative of each type would be sampled (Needham and Usinger, 1956. See calculation in Appendix 37). It was found that 13 one square foot samples at any given location would ensure a 95 percent probability of at least one individual being sampled from eight of the 11 types. Therefore, at least 13 square-foot samples were taken at each location during subsequent sampling. The 13 one square-foot samples taken at a given location at one time will henceforth be referred to as "a sample". Each of the 13 individual sampling efforts is a "subsample".

Commencing on March 5, 1971, bottom fauna samples were taken when water levels permitted at the rate of one per week. The sampling areas of the river were sampled generally in the order F, M, U, A with one area sampled each week; the section to be sampled within the area was chosen randomly by blind draw or from a random number table.

The first two samples taken (March 5, and March 12, 1971) were collected with a cotton net of 24 x 31 meshes per square inch on the Surber sampler. The remainder of the samples were taken with a "Nitex" nylon monofilament net of 39 x 39 meshes per square inch. Samples were preserved in 5-10 percent formaldehyde.

In the lab, each subsample was washed in water and placed in a Petri dish for microscopic analysis. Types of organisms below Order were distinguished by general anatomical features (head shape and size relative to eyes, for example) and classified by number. Thus two distinct Ephemeropterans might be "E-1" and "E-2". The ephemeropterans, plecopterans and trichopterans were keyed to type in this manner while the dipterans were keyed to Family. Other organisms were keyed to Order.

As each new type was noted a representative individual was preserved in 70 percent ethanol and included in a master collection of types. The master collection was sent to Dr. G. G. E. Scudder, Entomologist, University of British Columbia, who keyed the representative types as far as possible.

Statistical analyses (t tests) were done on the data to compare the numbers of bottom fauna collected between areas at various sample times.

3.4.6.2 Results

Twenty-two samples were collected during the sampling period (March 5 - October 21, 1971). These included six from area F, six from area M, four from area U, and six from area A (Appendices 33 and 34).

Area F averaged 72.7 organisms per square foot; area M had an average of 87.9 per square foot; U had 98.9 organisms per square foot on average, and A averaged 119.4 organism per square foot. The average numbers of organisms per square foot are given by sample in Appendix 34.

The results of the t tests indicated no significant differences in numbers of organisms per square foot among the four sampling areas (see Appendix 35). There were also no significant differences in total numbers of aquatic fauna by month (Appendix 36).

The percentage composition by numbers of the bottom fauna is summarized for the whole system (areas, F, M, U, A) in Figure 3.4-16. Figure 3.4-17 illustrates percentage composition by numbers of the bottom fauna by area.

FIGURE 3.4-16

COMPOSITION OF BOTTOM FAUNA

Skagit River System

1971

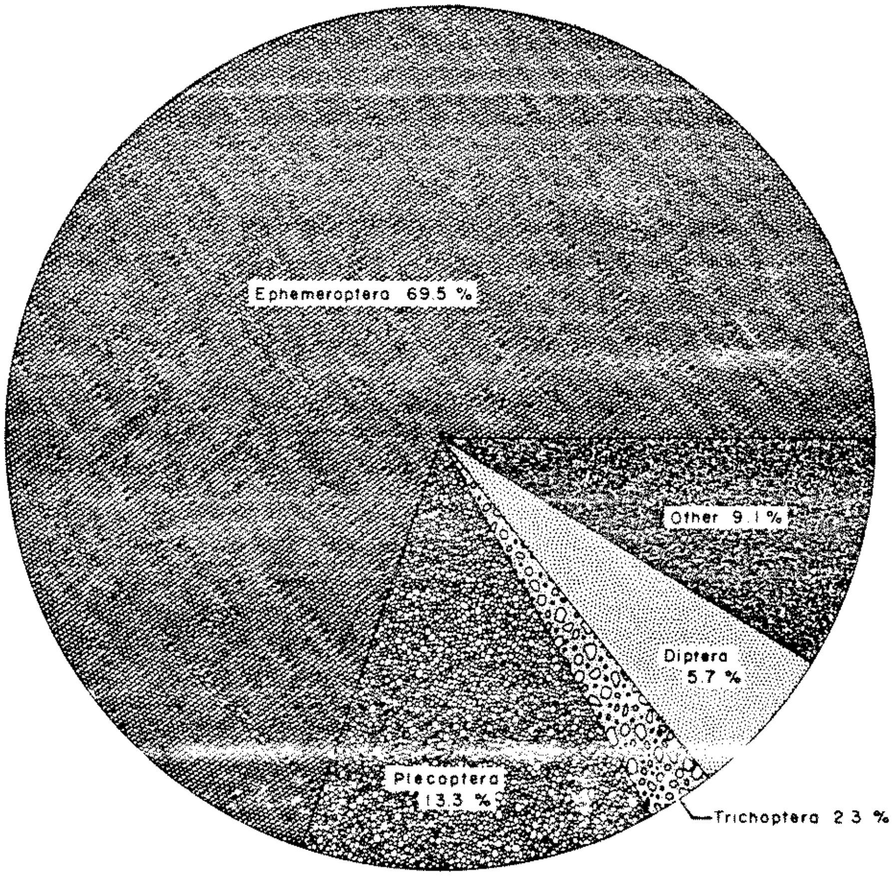
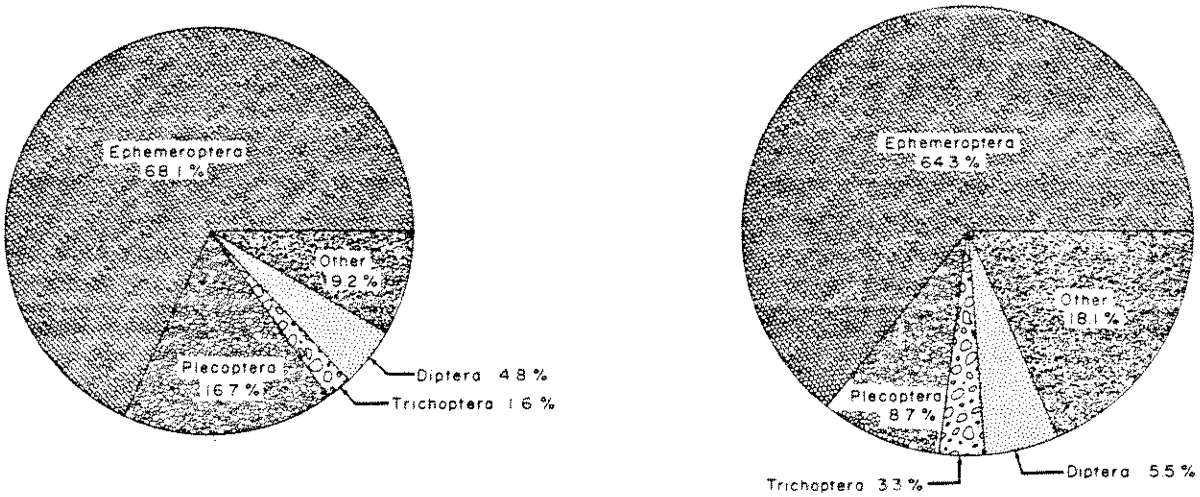


FIGURE 3.4-17

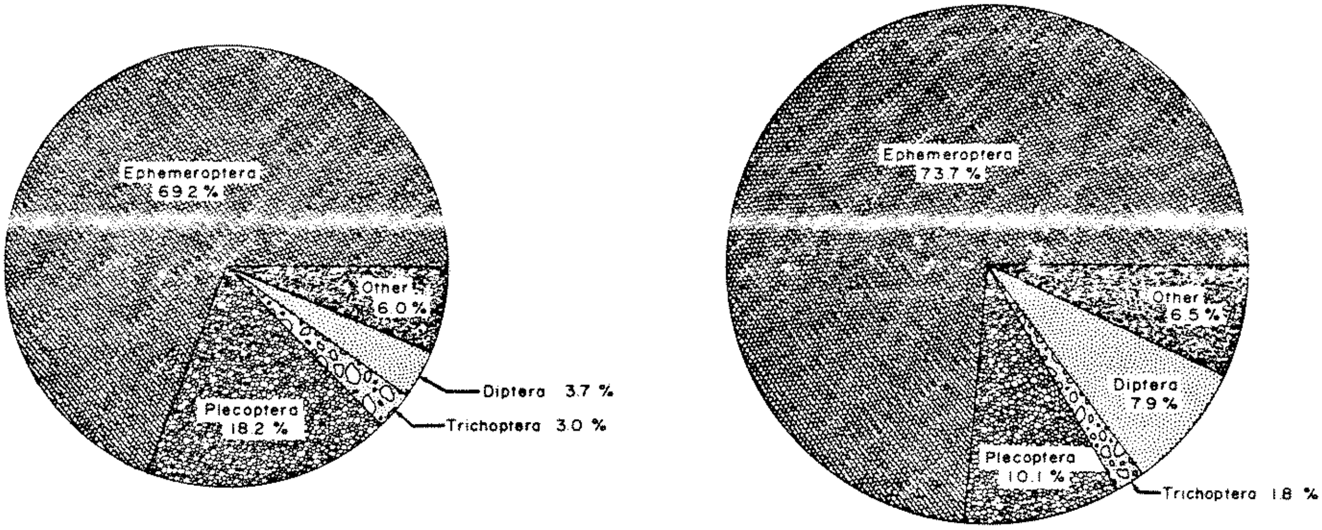
COMPOSITION OF BOTTOM FAUNA

Skagit River System

1971



AREA F **AREA U**



AREA M **AREA A**

514-C615

The size of a circle in the diagram is proportional to the total numbers of organisms collected in that area.

The Ephemeroptera made up the majority of the sample populations while the Plecoptera were generally second in abundance followed by Trichoptera and Diptera. The other organisms found included nematodes (roundworms), turbellarians (flat worms), lepidopterans (moths), hemipterans (true aquatic bugs), coleopterans (beetles), hydrachnids (water mites) and a few very infrequent groups such as anurans (frogs), ostracods and amphipods (crustaceans). The dipterans consisted mainly of Tendipedidae (midges), Simulidae (black flies), Culicidae (mosquitoes) and a few Tabanidae (deer flies). Appendix 37 lists the taxa as determined by Dr. Scudder.

3.4.7 Food Utilized by Trout

(by F.F. Slaney and Company)

3.4.7.1 Methods

Stomach samples were collected from fish from the Skagit River, Ross Lake and their tributaries. The fish were taken during scientific sampling programs and from anglers during the creel census. Individual stomachs were labelled and stored in separate containers. Ten percent formalin solution was used as a preservative. Sample number, time, date and location of capture was recorded. In the lab, stomachs were opened and contents sorted and classified according to the master collection of type specimens (see Section 3.4.1.2).

Volumes of the stomach contents by taxa were determined for individual stomachs and numbers of organisms counted when possible. Zooplankton numbers were determined by actual count of sub-samples of plankton and extrapolation of the count to the total volume. Volumes were measured by displacement of water for zooplankton, benthos and stream bottom fauna as well as allochthonous materials and unidentifiable debris in the stomachs.

3.4.7.2 Ross Lake

28 stomachs of fish taken from Ross Lake in October, 1970, were analyzed; 469 collected between May and October 1971 were also examined. Fish were divided into three length groups referred to here and subsequently as "small", "medium", and "large". "Small" fish were those between 15.0 and 24.9 centimeters long; "medium" were from 25.0 centimeters to 29.9 centimeters while "large" included all fish 30.0 centimeters or larger. Analysis of the data on stomach contents was done by size group.

Ross Lake trout fed on five major types of food. These were Cladocera, Tendipedidae, aquatic stages of insects, other aquatic organisms and terrestrial organisms. Cladocerans are small planktonic crustaceans sometimes referred to as "water fleas". Tendipedidae are the aquatic larvae of midges. Aquatic stages of three Orders of insects (Ephemeroptera, Trichoptera and Plecoptera; Mayflies, Caddisflies and Stoneflies respectively) are also represented. Other aquatics include such animals as snails (Gastropods), Amphipods, worms (Oligochaetes) and fish. The terrestrial group includes beetles (Coleoptera), flying ants and wasps (Hymenoptera), bugs (Hemiptera) and adult flies (Diptera).

The results are summarized in Figure 3.4-18 and Figure 3.4-19. Figure 3.4-18 shows percentage composition by volume of food utilized by month in 1971 for the three length groups. Figure 3.4-19 compares the percentage composition by volume of foods eaten in October 1970 with that of October 1971. In some cases the two length groups smaller than 30.0 centimeters have been lumped together.

During June, July, August and September 1971 (Figure 3.4-18), cladocerans were a major food item of Ross Lake trout. Cladocera composed 76 percent of food eaten during June and 41 percent of food eaten during September. May and October show values of 24 and 22 percent Cladocera.

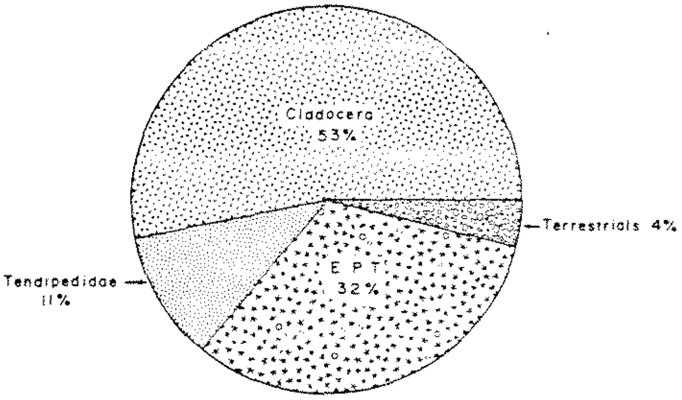
Tendipedidae never made up a major portion of food during any month of the study. Sometimes a valuable food source for trout in other areas, the largest proportion of Tendipedidae in stomachs of Ross Lake rainbow trout was nine percent during the month of October.

The aquatic stages of Ephemeroptera, Plecoptera and Trichoptera (E, P, T) are of major importance during August and October. During October, 98 percent of the E.P.T. eaten were emergent adult trichopterans.

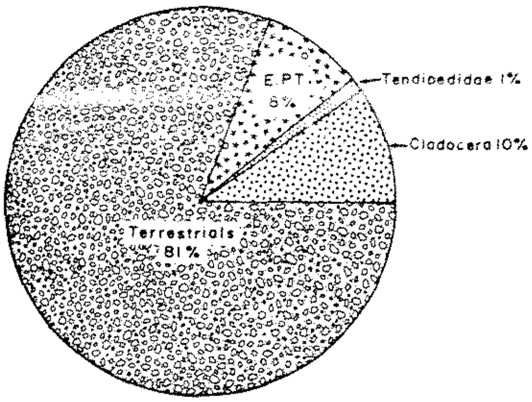
Other aquatic organisms were at times important foods. Snails and amphipods appear as major proportions of fish diets during September and October. Other aquatics as a group are of some importance during June and July.

Terrestrial foods occasionally formed a major item of the fish diet. During May, flying ants and beetles were a large percentage of food eaten by trout. Fish did not feed extensively on terrestrial foods during summer or early fall months.

MAY

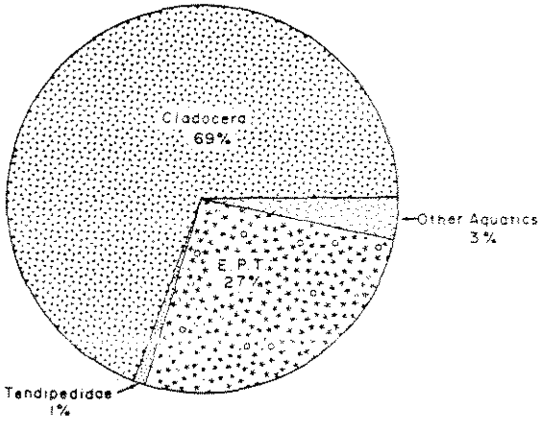


< 30 cm
10 Fish

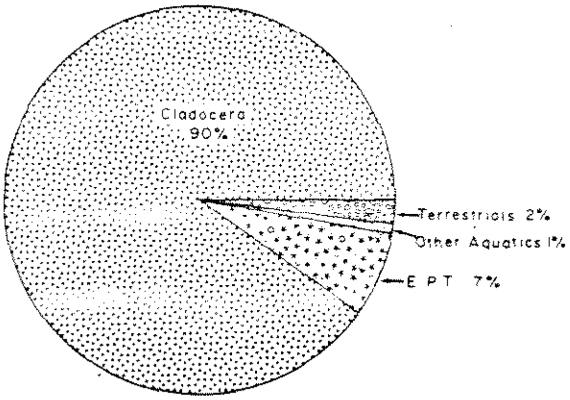


≥ 30 cm
14 Fish

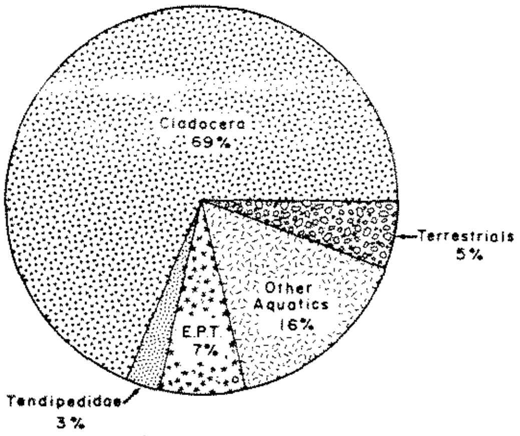
JUNE



≤ 24.9 cm
22 Fish



25 to 29.9 cm
42 Fish



≥ 30 cm
50 Fish

FIG

FOOD U

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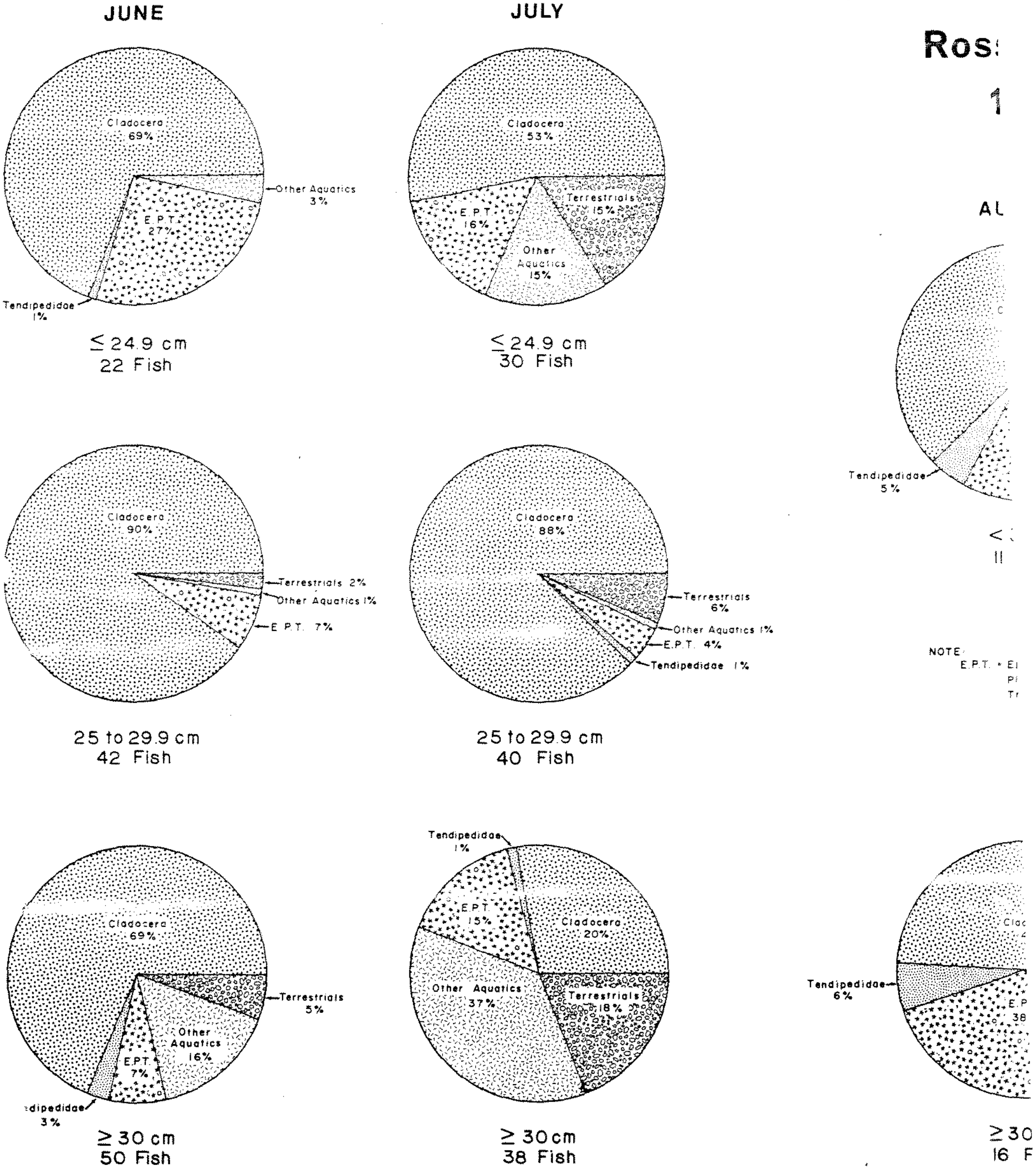
1



3.4-18

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Lake

1

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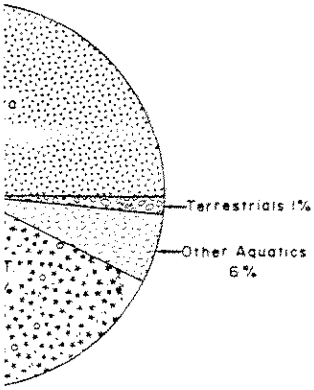

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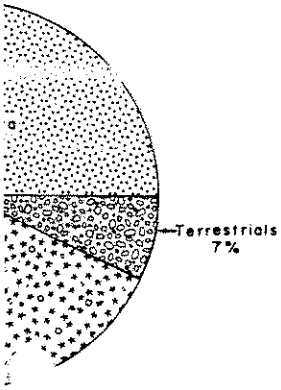

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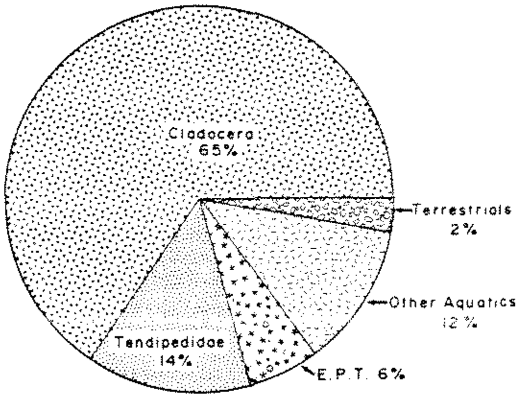
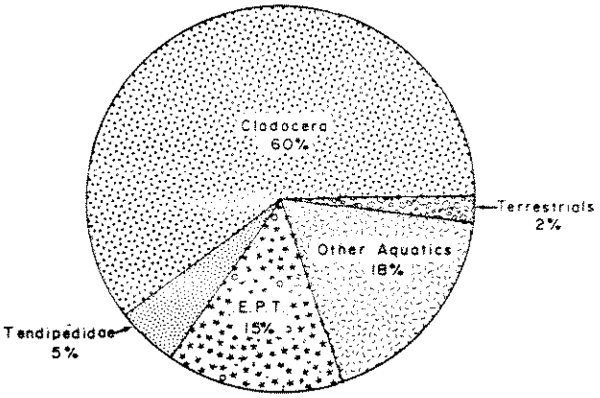
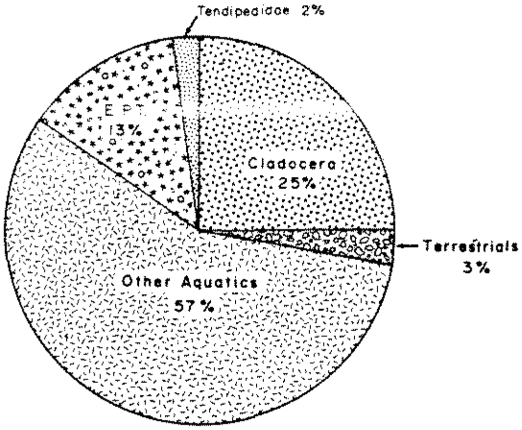
SEPTEMBER



≤ 24.9 cm
28 Fish

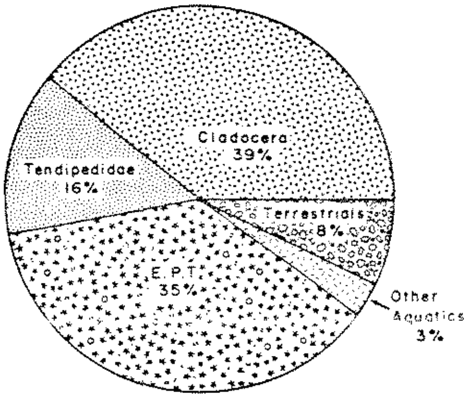


25 to 29.9 cm
23 Fish

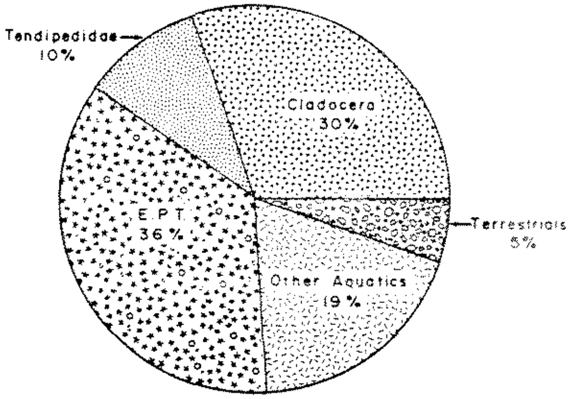


≥ 30 cm
45 Fish

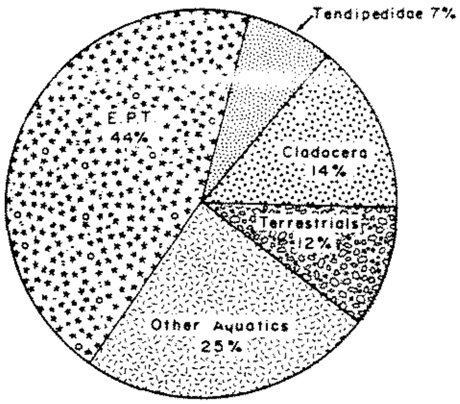
OCTOBER



≤ 24.9 cm
17 Fish



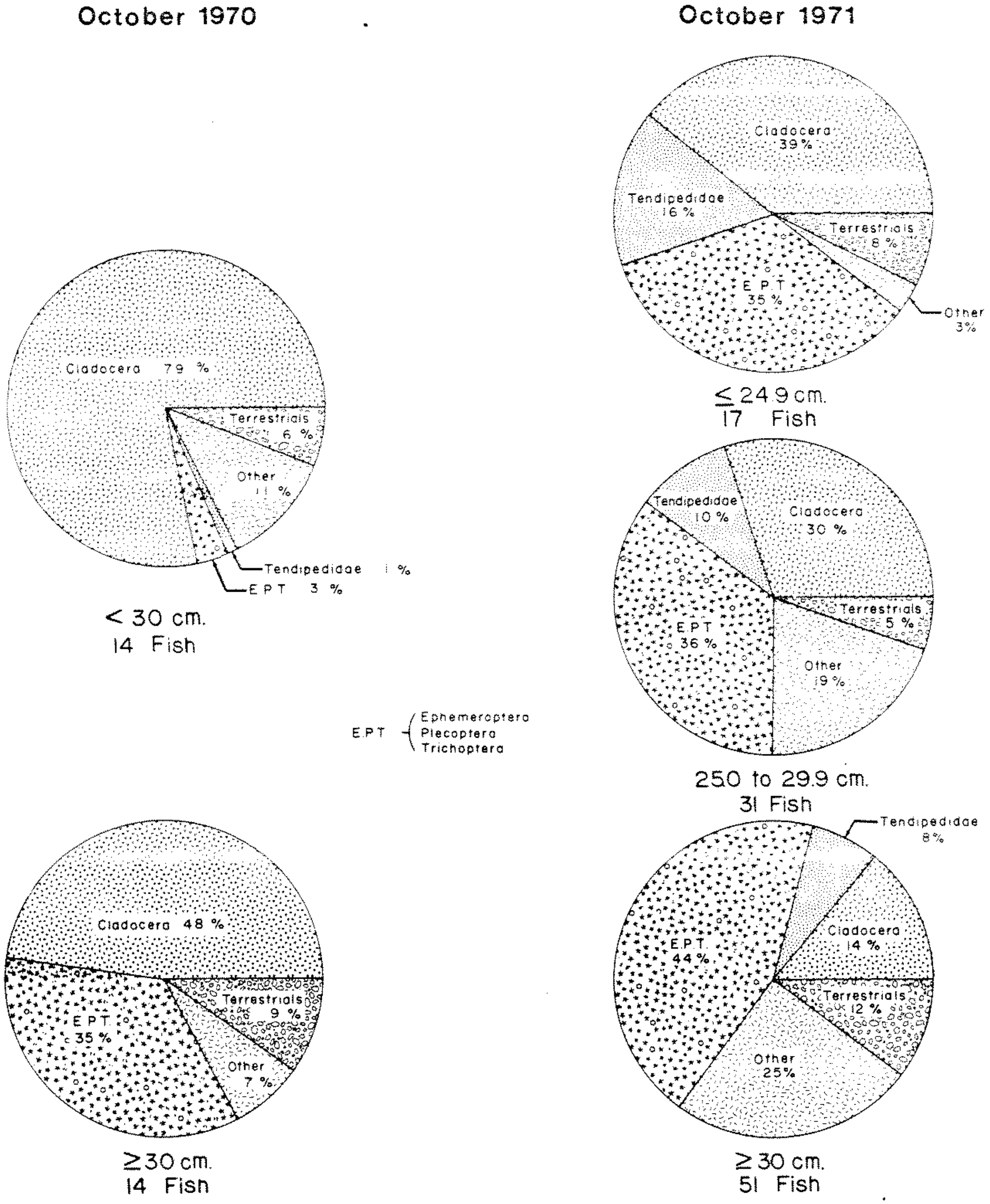
25 to 29.9 cm
31 Fish



≥ 30 cm
51 Fish

FIGURE 3.4-19

FOOD UTILIZATION
October '70 & October '71
Ross Lake



A comparison of the length groups of fish shows that larger fish take smaller proportions of cladocerans and greater proportions of other food items when available. For example, during May, large fish ate large volumes of terrestrial insects. During July, August, September and October, larger fish ate either terrestrial forms, other aquatics or E.P.T. extensively at times when smaller fish had greater proportions of Cladocera in their diets.

The terrestrial diet of large fish sampled during May was made up of 79 percent ants and 19 percent beetles. In July, the terrestrial foods of large fish included 40 percent beetles and 26 percent ants. Other aquatics in July were 70 percent amphipods and 29 percent snails. Other aquatics during October were 69 percent snails and 31 percent amphipods.

Large fish sampled in October, 1970 (Figure 3.4-19) tended to eat more large food items and a smaller proportion of cladocerans. The major difference between years is that October, 1970 fish foraged more on cladocerans, while October 1971, fish fed primarily on other aquatics, E.P.T. and Tendipedidae.

Although the sample size for October 1971 is 71 fish larger, it appears that the differences between years are real. With the present data, it is not possible to identify the reasons for the differences. Perhaps differences can be attributed to variability of food supply between years and the opportunistic food habits of fish.

3.4.7.3 Skagit River System

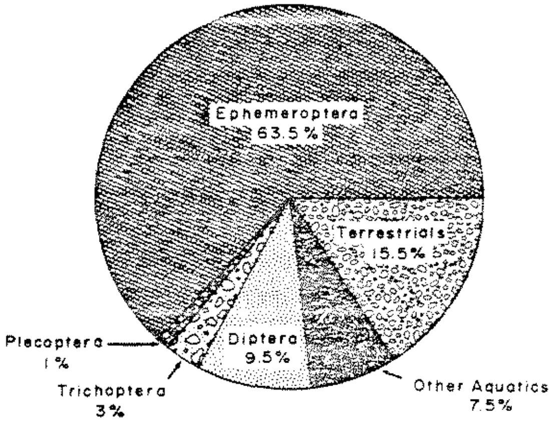
(by F. F. Slaney and Company)

The results of stomach analyses from 357 fish collected in the Skagit River in 1971 are shown in Figure 3.4-20. The fish stomach contents were counted and divided into six categories. The number of individuals in each category was used to calculate the percentage composition of the stomach contents. Mean percentage compositions by sampling month and size-class of fish are shown in the figure.

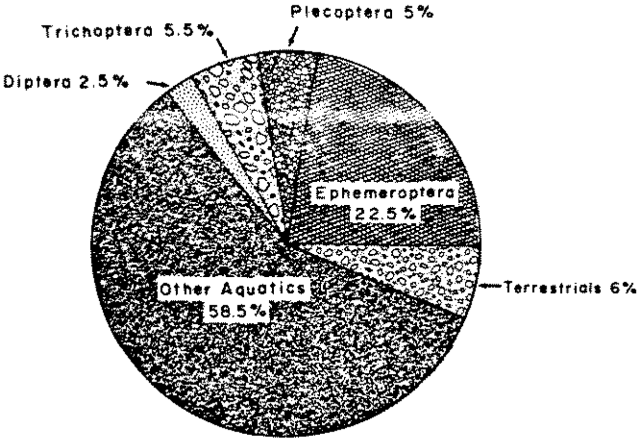
Small fish (≤ 24.9 cm) are distinguished from medium fish (25 to 29.9 cm) only in the summer months when sample sizes are larger. The sample sizes are also shown on the figure for each size class in each month.

Ephemeroptera (Mayfly) nymphs were the most important food item, varying between 23 percent and 71 percent of total numbers of organisms combined. They were especially abundant in July (62 percent) and August (71.5 percent). Plecoptera (Stonefly) nymphs were consistently a small percentage. Trichoptera (Caddisfly) larvae and pupae were taken in considerable numbers in June, July and September, and to a lesser extent in August and October. Diptera (True fly) larvae and pupae, mainly Tendipedidae (midges), were eaten in relatively small numbers in all months except October when 49 percent of the diet of large fish (30.0 cm) consisted of dipterans. "Other Aquatics" included Oligochaeta (earth worms), Gastropoda (snails), Amphipoda, other fish and fish eggs, (excluding bait used by anglers). Large

MAY

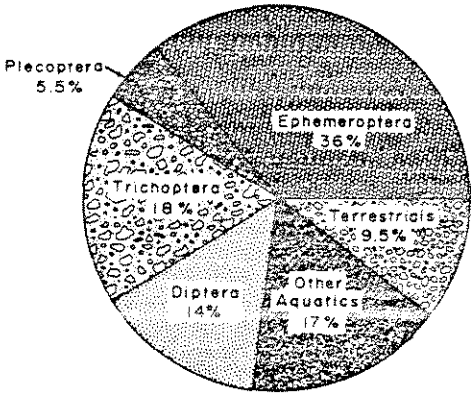


≤29.9 cm
5 Fish

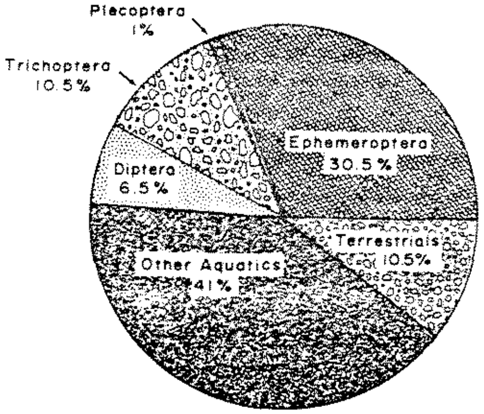


≥30 cm
32 Fish

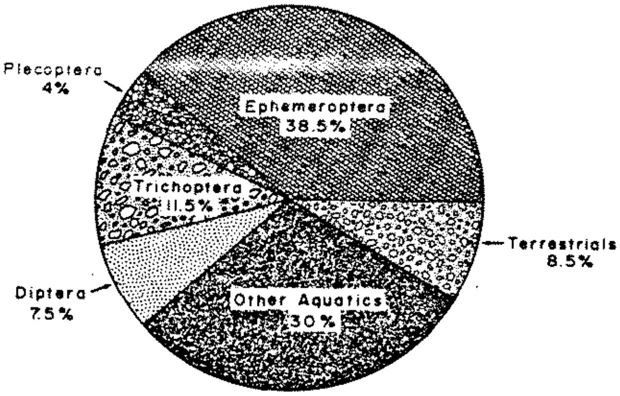
JUNE



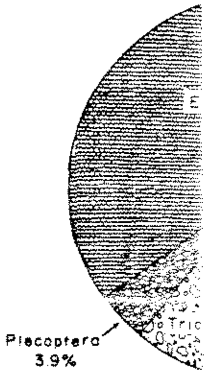
≤24.9 cm
24 Fish



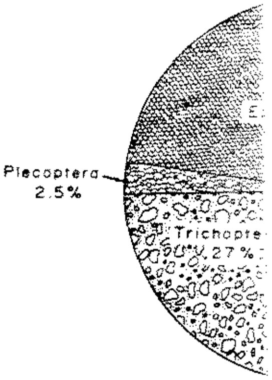
25 to 29.9 cm
27 Fish



≥30 cm
60 Fish



≤



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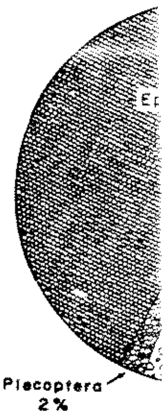


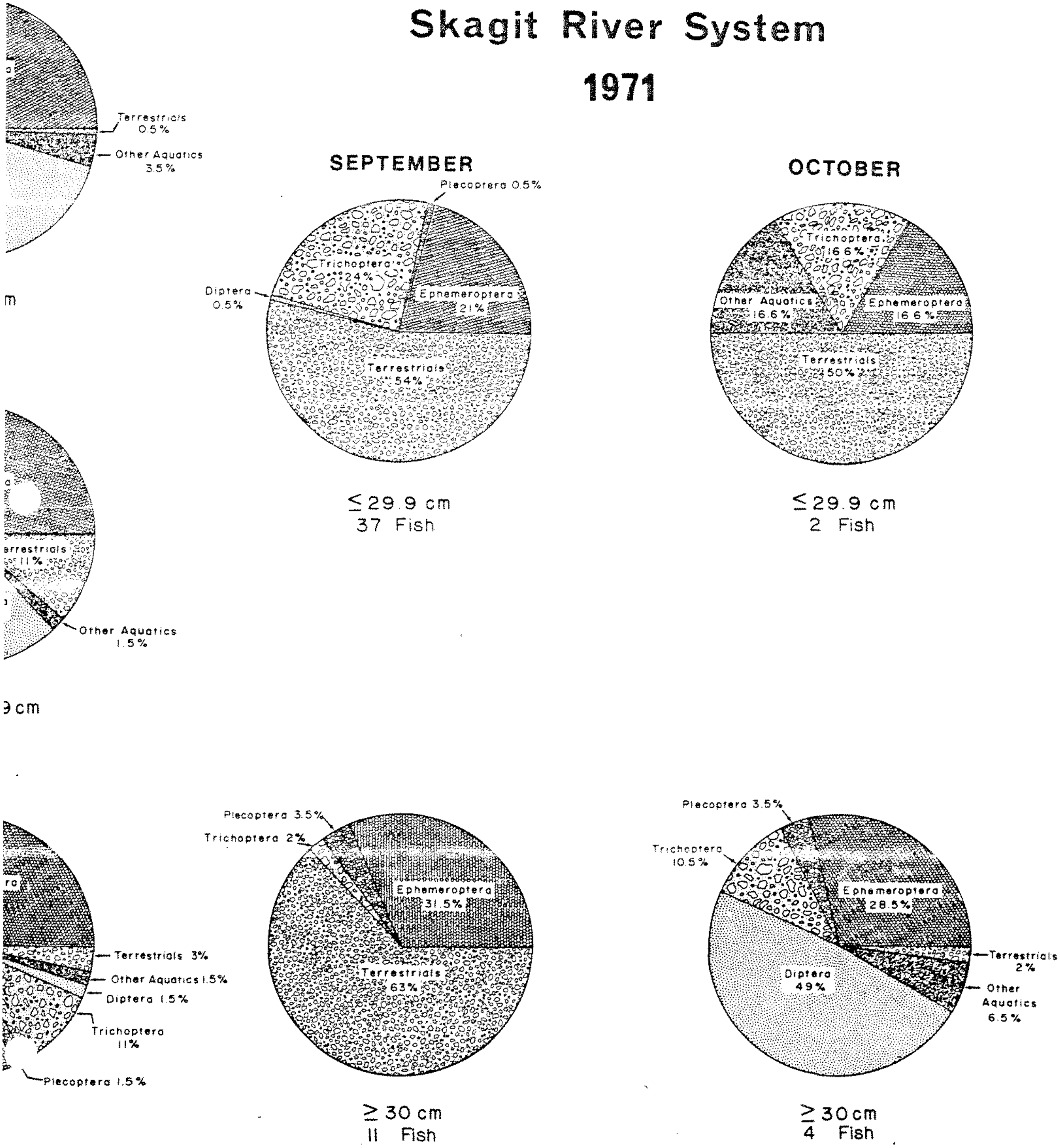
≥

FIGURE 3.4-20

FOOD UTILIZATION

Skagit River System

1971



numbers of oligochaetes and rainbow trout eggs were found to have been taken by fish in May and June. In July, the fish apparently utilized Ephemeroptera and Trichoptera nymphs for most of their food. Terrestrial organisms included Hymenoptera (ants and wasps), Coleoptera (beetles), Arachnida(spiders), and adult aquatics (flying adults of the four categories of aquatic insects). These were taken by trout in relatively small numbers throughout the season, but constituted 55 percent of the stomach contents in September.

Considerable differences in the food preferences of large and small fish can be seen, possibly reflecting the size of the food organisms. In May, small fish preferred Ephemeroptera (63.5 percent) and terrestrial organisms (15.3 percent, mainly Hymenoptera and Coleoptera), while large fish fed on other aquatics (58.5 percent - mainly earthworms and rainbow eggs) and Ephemeroptera, (22.5 percent). In June, small fish had more diversified diets. Medium and large fish ate Ephemeroptera and other aquatics (worms and eggs). Ephemeroptera were preferred by all groups in July, and medium fish took almost twice the percentage of Trichoptera as did the other sizes in this period. In August Ephemeroptera remained the major food item for all sizes, especially the large fish (81.5 percent). Small fish also ate Diptera larvae and pupae. Medium fish took dipterans and terrestrial fauna as secondary food sources, while large fish continued to consume trichopterans (11 percent).

Ephemeroptera dropped in importance for large (31.5 percent) and small fish (21 percent) in September, and were replaced by terrestrial forms, (63 and 54 percent respectively). In both size groups, the terrestrial forms consisted of about two-thirds adult aquatics, and one-third Hymenoptera. Small fish also ingested a substantial number of Trichoptera larvae and pupae (24 percent of total stomach contents). The stomachs of small fish in October were mostly empty; of the small number of food organisms found in stomachs half were terrestrial. Large fish utilized Diptera as the major food item, with smaller numbers of Ephemeroptera, Trichoptera and other aquatics also being taken.

A comparison of 1970 and 1971 stomach analyses (see Figures 3.4-21 and 3.4-22) shows marked differences in food habits, both by size-class and by month. Only in August and September 1970 were sizeable numbers of fish collected (24 in August and 51 in September). Twenty-two of the August fish were from F-3 and above, while 30 of the September fish were from F-1 and F-2. Thus, the representation of fish from the river-mouth area is low in August and high in September, 1970.

The small fish sampled in August, 1970 (see Figure 3.4-21) contained 81.2 percent terrestrial food, while those from August 1971 had eaten 60.9 percent Ephemeroptera. The large fish caught in August 1970 contained primarily Diptera (37.8 percent). In August 1971 the fish had 81.5 percent Ephemeroptera and only 8 percent Diptera in their stomachs. The terrestrial organisms selected in 1970 were about one-third adult aquatics, and two-thirds Hymenoptera. "Other aquatics" were commonly small fish.

Small fish in September 1970 (see Figure 3.4-22) took other aquatics preferentially (about 80 percent Amphipoda and 20 percent Gastropoda (snails). Large fish ate 70.5 percent Diptera larvae and pupae, and 21.2 percent terrestrials, (mostly Hymenoptera with some adult aquatics). All fish in September 1971 took terrestrial forms preferentially; (about two-thirds adult aquatics and one-third Hymenoptera) while Ephemeroptera comprised 21 and 31.5 percent of food organisms found in small and large fish respectively.

FIGURE 3.4-21

FOOD UTILIZATION

August '70 & August '71

Skagit River System

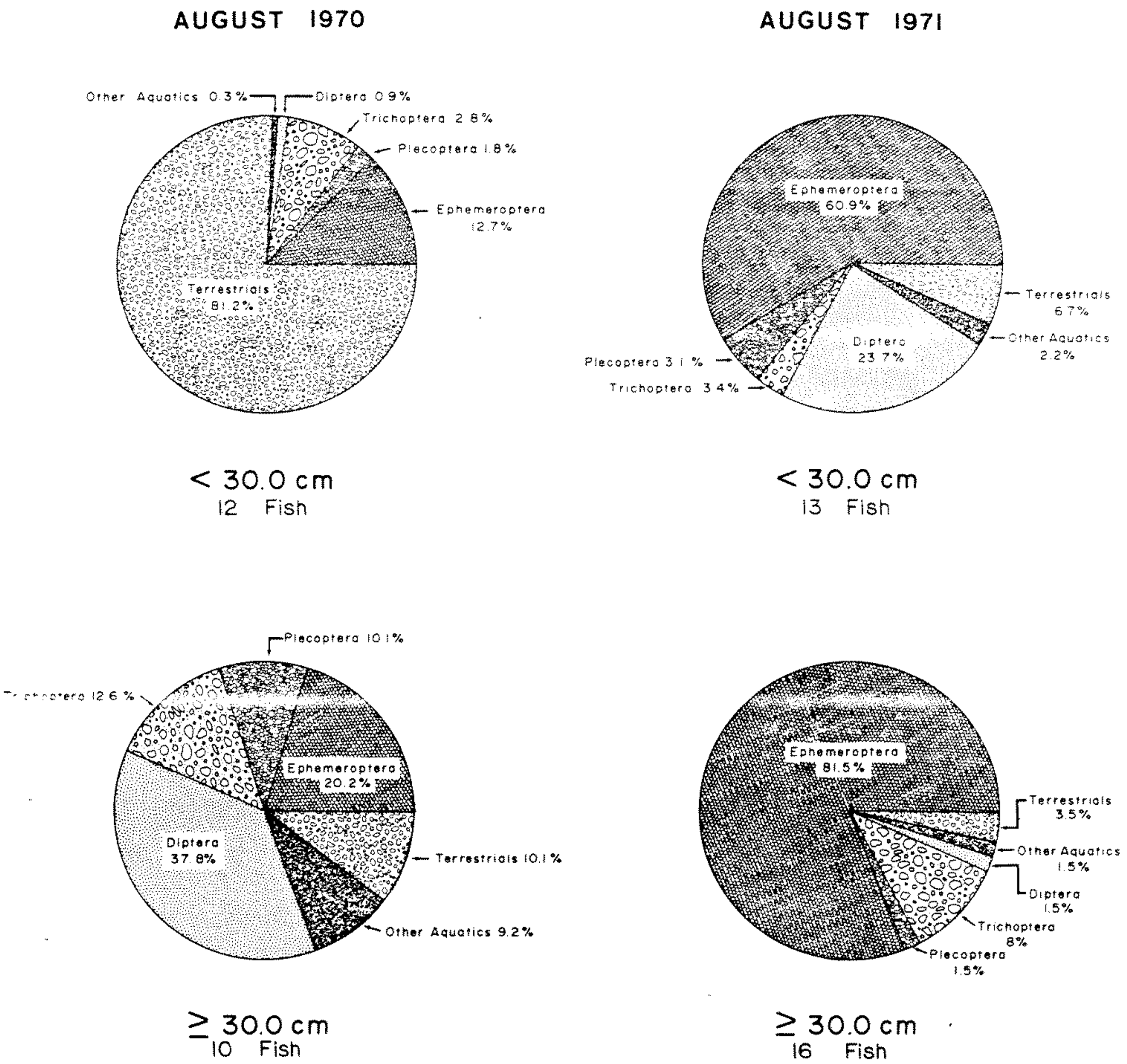


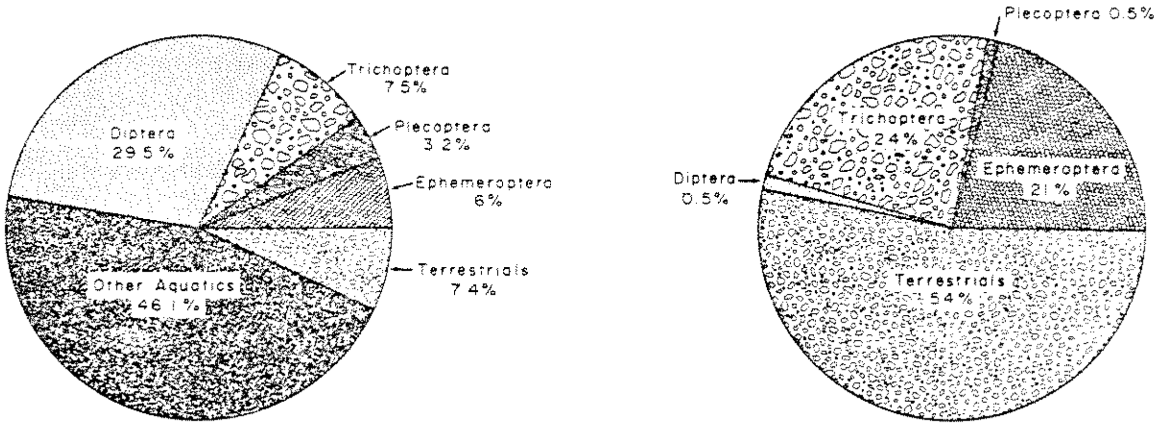
FIGURE 3.4-22

FOOD UTILIZATION

September '70 & September '71

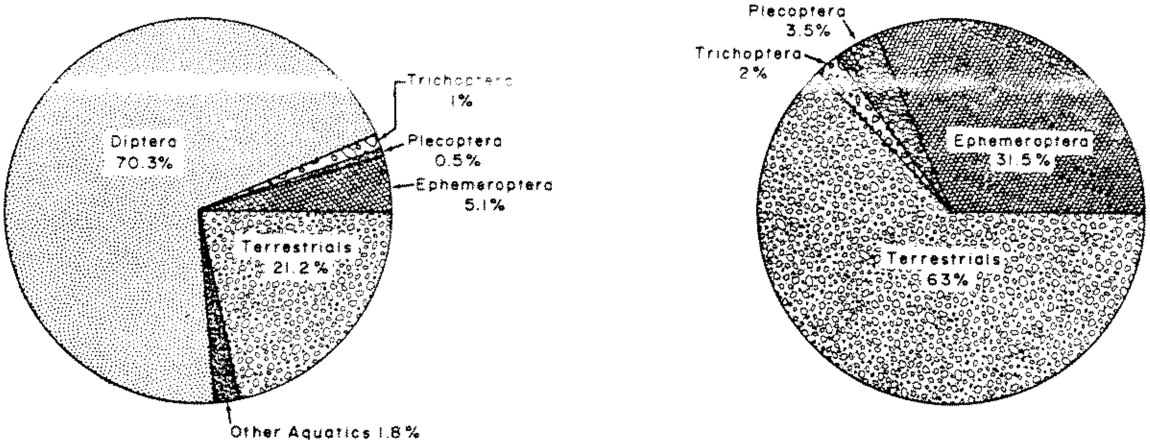
Skagit River System

SEPTEMBER 1970 **SEPTEMBER 1971**



< 30.0 cm
7 Fish

< 30.0 cm
37 Fish



≥ 30.0 cm
8 Fish

≥ 30.0 cm
11 Fish

The August and September results for 1970 and 1971 seem to indicate that there is considerable yearly variation in numbers of Diptera and terrestrial organisms utilized as fish food.

3.4.8 Discussion

3.4.8.1 Ross Lake - 1970 and 1971

(by Fisheries Research Institute and F. F. Slaney and Company)

The trout were highly selective in their feeding on zooplankton. Although copepods were present in considerable numbers, only four trout stomachs contained measurable volumes of copepods. No rotifers were found in stomachs examined. Cladocerans formed the basic diet of the fish in June, July, and August and were important in May, September, and October as well. Of the cladocerans, only Daphnia and Leptodora were consumed in great numbers. Leptodora, roughly three times the size of Daphnia, was heavily selected by the trout even though Daphnia was many times as abundant. Calculations of average volumes of Daphnia and Leptodora per fish stomach and per m^2 in the water column indicate the degree of selectivity (Table 3.4-13). Efficiency of feeding on plankton by the trout is undoubtedly influenced by visibility and mobility of the plankton, their patchiness and depth distribution, and their individual size.

Although tendipedid larvae comprised the largest biomass in benthic samples, tendipedidae never comprised a major volume of food during any month of the study. This may result to some extent from the fact that in summer the trout may tend to feed inshore, consequently over areas of exposed bottom during winter drawdown, where production of insects is low.

TABLE 3.4-13

CALCULATED RELATIVE VOLUME OF DAPHNIA AND LEPTODORA IN THE LAKE AND IN FISH STOMACHS

A. Mean ml/m^2 in water column, all stations sampled.

Date	Daphnia	Leptodora
7 and 20 May	7.6	0.0
28 June	25.9	1.2
9 July	26.8	4.2
20 September	71.0	0.5

B. Mean volume (ml) per fish stomach, 1971.

Month	Daphnia	Leptodora
May	0.29	0.01
June	0.29	0.94
July	0.22	0.80
August	0.77	0.23
September	0.29	0.23
October	0.39	0.07

Oligochaetes, second in biomass in benthic samples, were not utilized to any extent, probably because they are unavailable in the bottom substrate.

In July, September and October gastropods were utilized in proportions considerably greater than those present as "available benthos" and "other aquatics". This was especially true for larger fish in which snails formed up to 90 percent of the benthos utilized. Similarly, amphipods were consumed in greater proportions than those available, sometimes making up 70 percent of the benthos utilized.

Benthic sampling was done at tributary mouths and, as well, along transects in the reservoir proper. No apparent differences were observed, however, in the relative amounts of benthic groups between these sampling areas.

For the period May to October, 1971 material originating outside the reservoir, whether aquatic or terrestrial made up 28 percent of the overall fish diet. This food included mayfly, stonefly and caddis fly nymphs, as well as terrestrial organisms that originated in, or were carried by rivers and streams.

The fact that many of the fish sampled from the reservoir were probably taken from stream mouth areas may account for the presence of these allochthonous materials in the stomachs analyzed. In absolute numbers of food organisms, the creek and river mouth areas are considerably more productive. It is possible that the greater productivity in stream mouth areas would result in greater densities of fish there.

3.4.8.2 Skagit River System

Figure 3.4-23 depicts the relative proportions of food utilized by the fish in the Skagit River in 1971 and shows the percentage composition of fauna available for food. This figure represents a comparison of the results already discussed in Sections 3.4.4.2 (Results Skagit River System Fauna) and 3.4.5.3 (Food Utilized, Skagit River System).

The "other" organisms included in the food available are mainly nematodes (round worms), but also include lepidopterans, coleopterans, hymenopterans, anurans (frogs), turbellarians (flatworms), and various groups taken infrequently (Appendix 19).

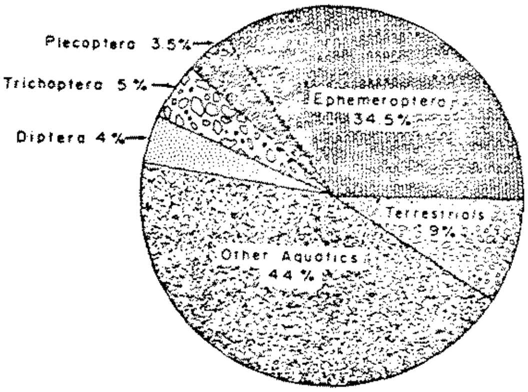
The Ephemeroptera formed a major component of food for fish and were under-utilized generally, except in August, in 1971. Plecopterans made up a fairly constant proportion of the diet and were taken in smaller proportions than available. Except for October 1971 when dipterans were extensively consumed by the fish, the Diptera were generally taken in about the same proportion as they were available.

During the spring freshets and spawning season (May through July) other aquatic organisms were extensively utilized as fish food. In 1971 these organisms included mainly oligochaetes and fish eggs but coleopterans (beetles), megalopterans (alderflies), and gastropods (snails) were also taken. In September there was a marked increase in utilization of terrestrial organisms as food. These included coleopterans, hymenopterans (ants and wasps) and lepidopterans (caterpillars).

FOOD UTILIZATION

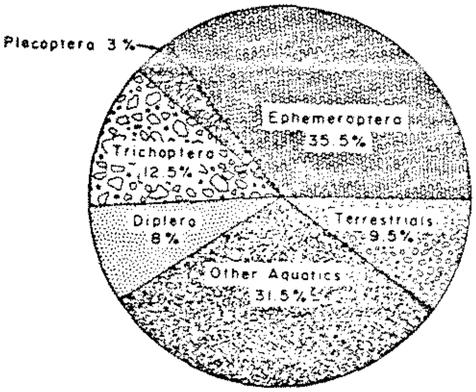
FOOD UTILIZATION

MAY

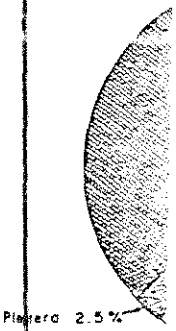


37 Fish

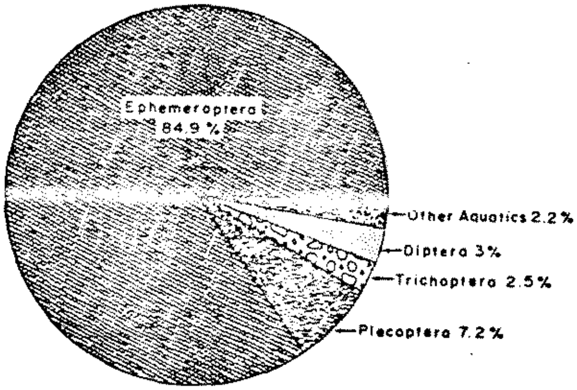
JUNE

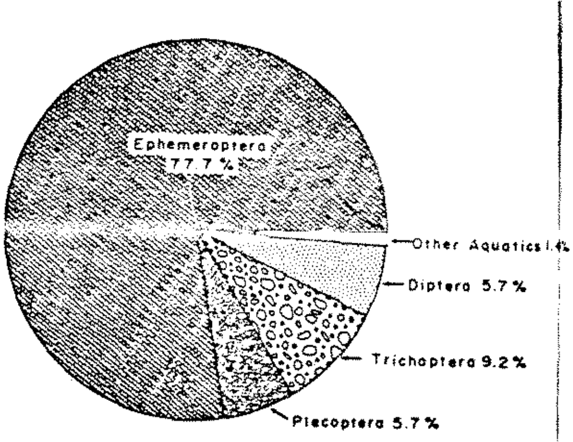


III Fish



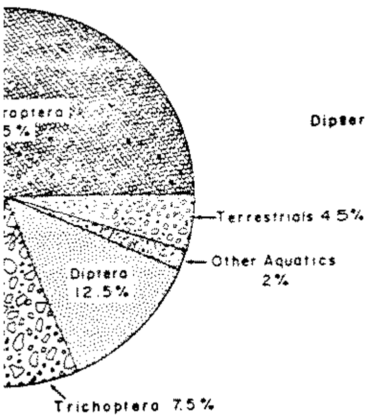
BOTTOM FAUNA





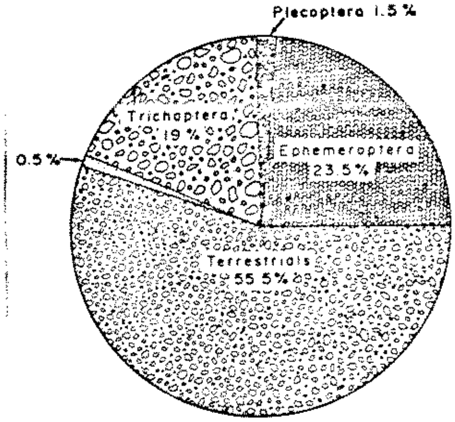
OF BOTTOM FAUNA

UST



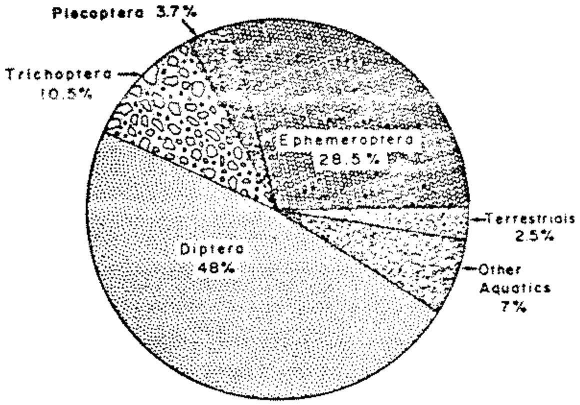
F' h

SEPTEMBER

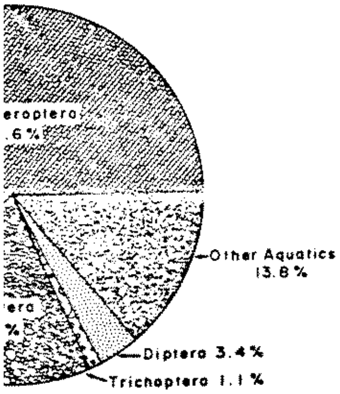


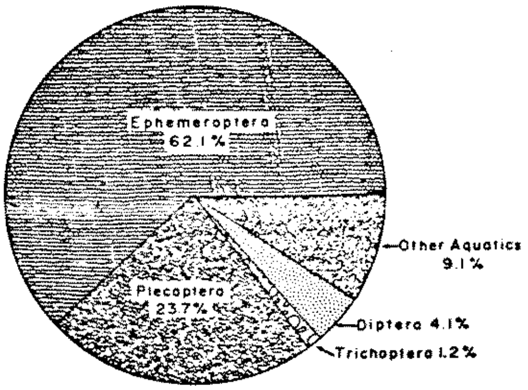
48 Fish

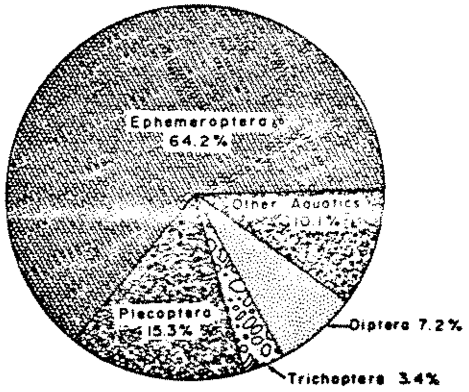
OCTOBER



6 Fish







3.5 AGE, GROWTH AND CONDITION

3.5.1 Introduction

Studies of the age, length-weight relationship, and growth rates of fish species provide basic data for the understanding of the population dynamics of these species.

3.5.2 Methods

3.5.2.1 Age Determination
(by Fisheries Research Institute)

Scales taken from live fish released in the tagging experiments and dead fish in anglers' catches and scientific sampling were used in age determination. The methods of field collection of scales were described in Section 3.2.2.2 . Most scales were mounted on gummed cards in the field with identifying numerical codes to relate to individual fish data. Unmounted scales taken at the beginning of the study were mounted in the laboratory by cleaning, moistening and placing them in position on the gummed cards with the sculptured surface of the scales facing up. Scale impressions and identifying labels were then transferred to cellulose acetate cards according to the method described by Koo (1962). An Eberbach projection machine with Bausch and Lomb objectives was used in examination and measurement of scales. The scale image was projected onto a glass screen utilizing a 16 mm macrolens producing a magnification of 85 diameters.

Information on the length of the fish was ignored at the time the scales were read, so that the identification of annuli was not directly influenced by the size of the fish concerned. The date of capture was made available to the scale reader to help evaluate questionable annuli near the scale margin. From the projected image a distance extending from the focus to the outermost circulus in the antero-lateral field was measured by the placing of a ruler on the longitudinal axis of the scale. The full distance of the axis was recorded as well as the distance from the focus to each annulus.

The number of winter annular marks determined the age of the fish from time of emergence. The distance from focus to first annulus and between adjacent annuli provided the measure of annual scale growth. The total radius from focus to scale edge was measured to correlate scale size with fish size.

Only those scales for which annular marks could be read with confidence were used in age and growth analyses. Scales with regenerated central portions and doubtful annular marks were excluded. If only one scale was readable in the group of scales from a single fish, the age reading also was not used because of the inability of the reader to check his interpretation of annular marks by examination of another scale from the same fish. Rainbow trout of Ross Lake do not form as distinct annular marks on their scales as do most trout populations. However, in spite of these restrictions, a large majority of the scales could be utilized in analysis.

3.5.2.2 Size, Condition, and Maturity
(by F.F. Slaney and Company and Fisheries Research Institute)

Processing of trout samples in the field to obtain data on length, weight, and maturity stage was described in Section 3.2.2.2. Relationship between weight and length of the fish was determined as formulated under Section 3.5.3.2 below.

3.5.3 Results

(by F.F. Slaney and Company and Fisheries Research Institute)

3.5.3.1 The Sample

The growth analysis for 1971 is based on the sample of rainbow trout taken during creel census and scientific sampling programs in 1971. The total sample of 1644 rainbow trout was used in the length frequency and weight frequency analysis (Figs. 3.5-1 and 3.5-2).

A stratified subsample (Appendix 38) was taken from the total sample and utilized for scale reading and length-age analysis.

The average length and weight of rainbow trout in the sport catch in 1971 was 282 mm and 275 grams respectively (based on 814 fish sampled during creel census).

The growth analysis for 1972 is based on the sample of rainbow trout taken during creel census and scientific sampling programs in 1972. A total of 1764 rainbow trout was utilized in the length-frequency and weight-frequency analysis (Figs. 3.5-3 and 3.5-4). A stratified subsample (Appendix 39) was taken from the total sample to be utilized for scale reading and length age analysis.

The average length and weight of rainbow trout in the 1972 sport catch was 303 mm (fork length) and 328 grams respectively (based on 572 fish sampled during creel census).

FIGURE 3.5-1

LENGTH·FREQUENCY DISTRIBUTION
SKAGIT·ROSS RAINBOW TROUT
1971

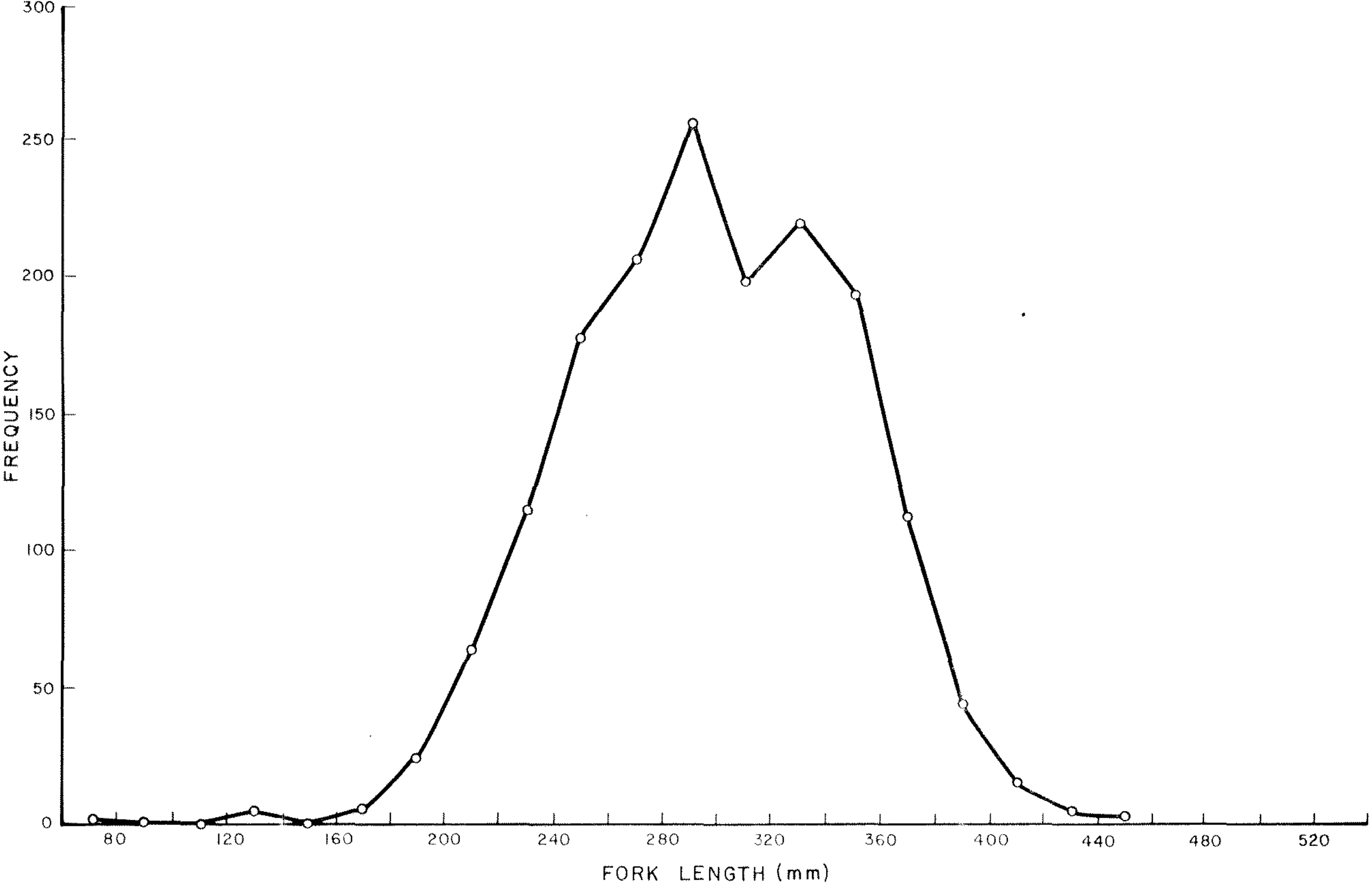


FIGURE 3.5-2

WEIGHT-FREQUENCY DISTRIBUTION

SKAGIT·ROSS RAINBOW TROUT

1971

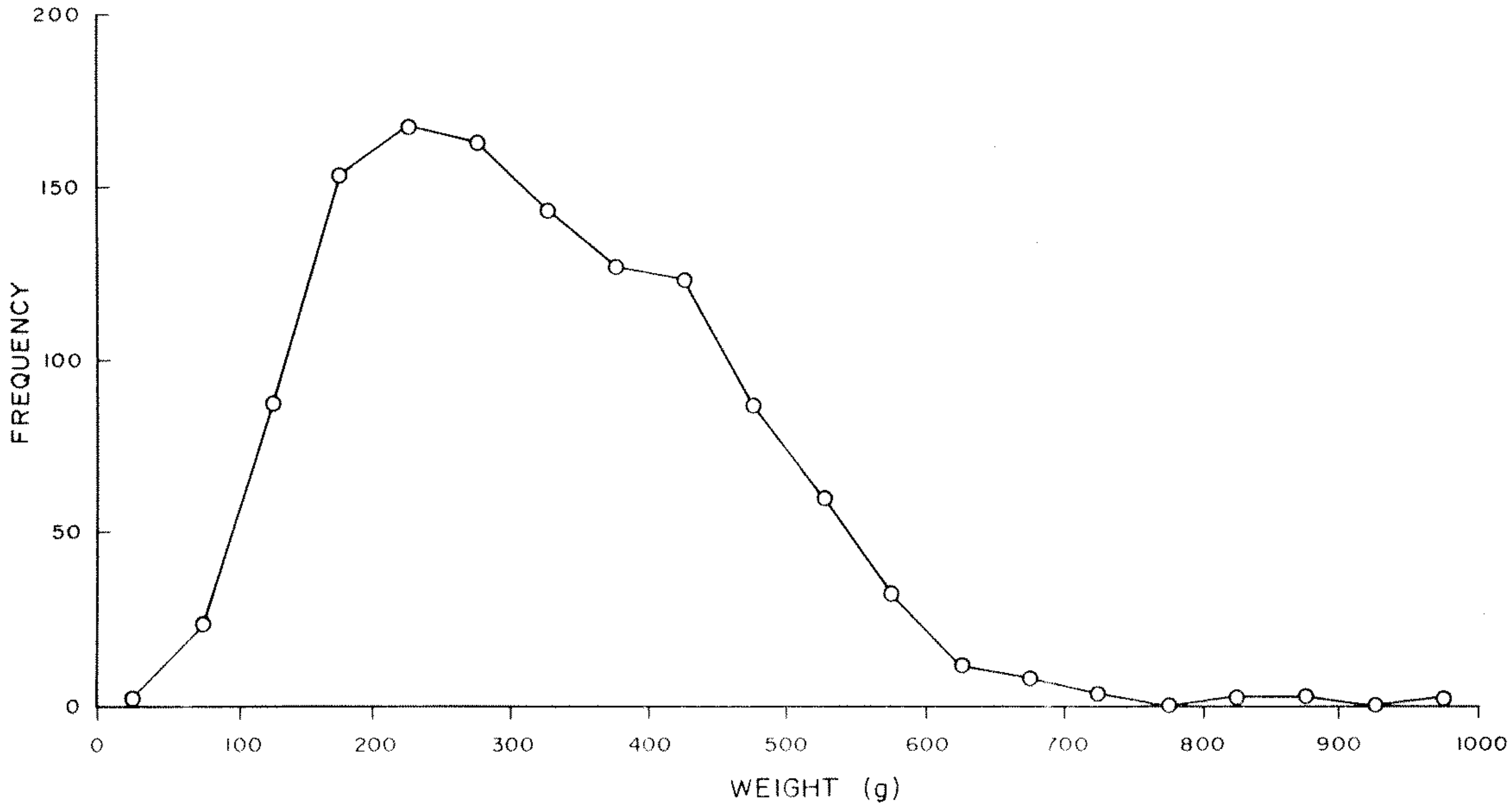


FIGURE 3.5-3

LENGTH·FREQUENCY DISTRIBUTION
SKAGIT·ROSS RAINBOW TROUT
1972

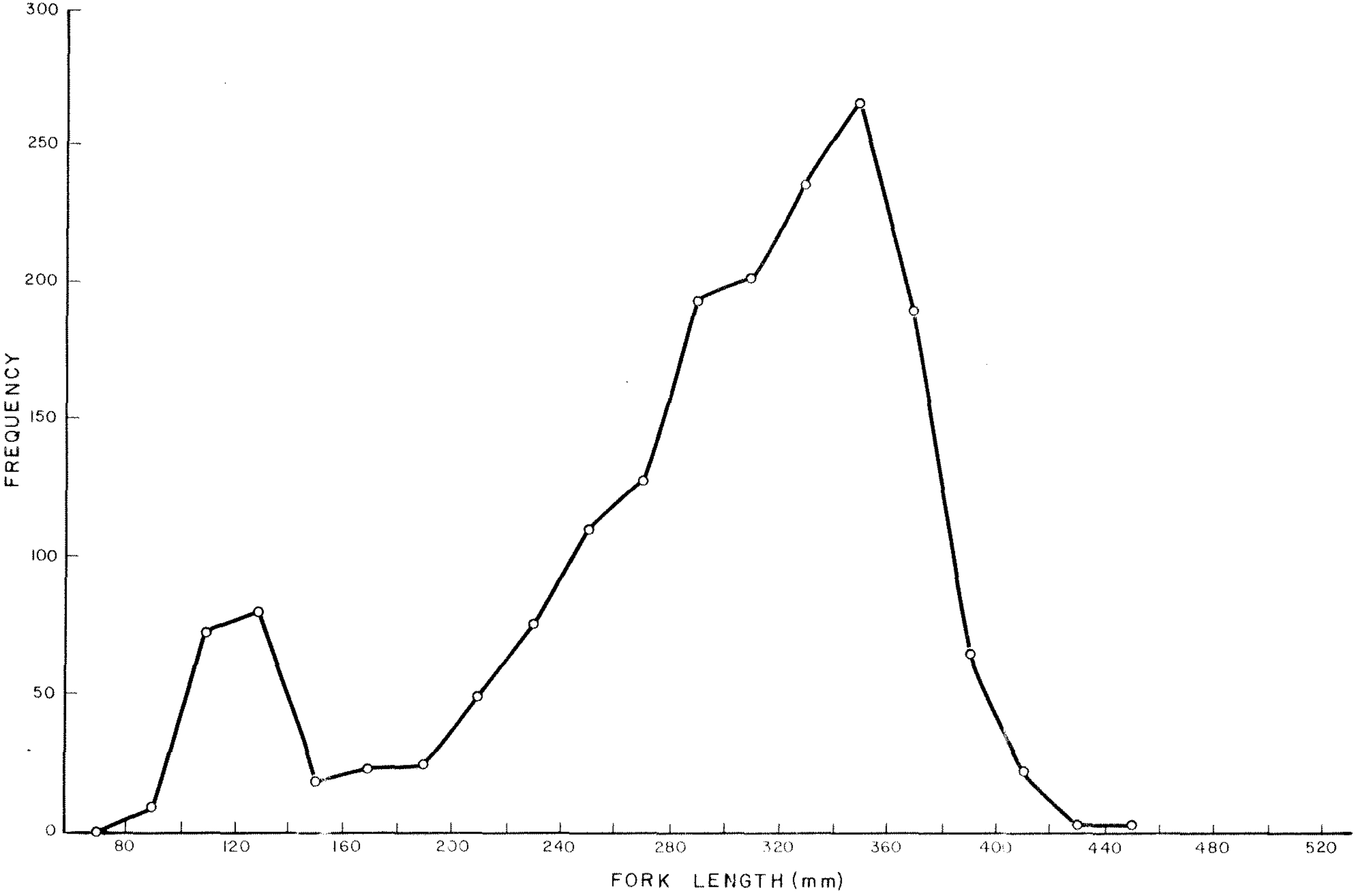
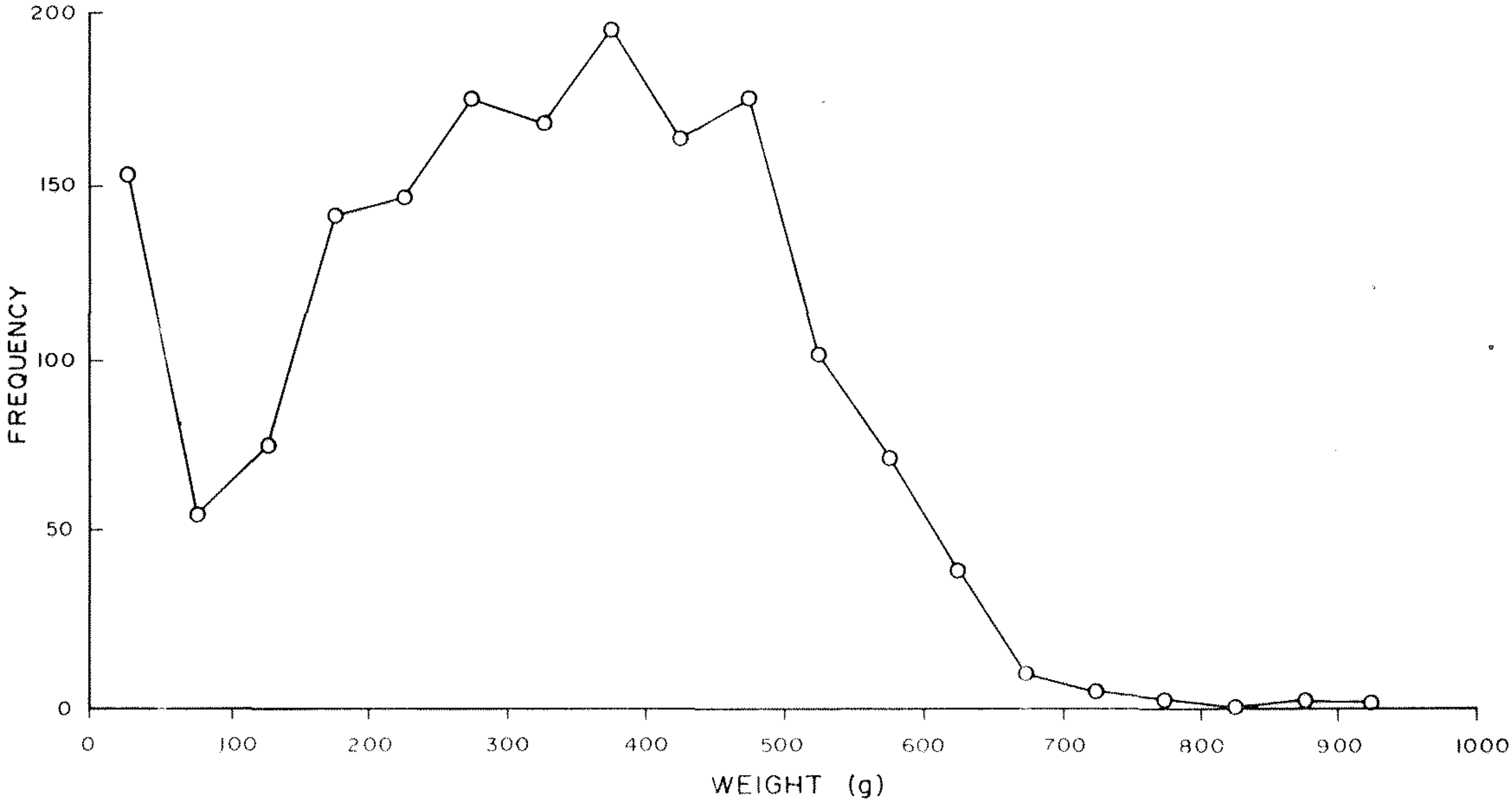


FIGURE 3.5-4

WEIGHT-FREQUENCY DISTRIBUTION

SKAGIT·ROSS RAINBOW TROUT

1972



3.5.3.2 Length-Weight Relationship

Fork length (mm) and weights (g) were fitted to the logarithmic form of the general length-weight equation; $W = \propto L^B$ for both 1971 and 1972 rainbow trout for which both lengths and weights were available.

The logarithmic equation,

$$\text{Log}_{10} W = \text{Log}_{10} \propto + B \text{ Log}_{10} L$$

is the linear equivalent of

$$Y = \propto + B X$$

The length-weight relationships for males, females, and the total sample are presented below for both years (1971 and 1972).

1971 Total Sample N = 1225

$Y = - 4.17072 + 2.68319 \ X$

Correlation Coefficient = 0.971

1971 Males N = 381

$Y = - 4.22776 + 2.70371 \ X$

Correlation Coefficient = 0.977

1971 Females N = 491

$Y = - 4.29392 + 2.73233 \ X$

Correlation Coefficient = 0.971

1972 Total Sample N = 1673

$Y = - 4.52048 + 2.82428 \ X$

Correlation Coefficient = 0.985

1972 Males N = 574

$Y = - 4.41247 + 2.77823\ X$

Correlation Coefficient = 0.985

1972 Females N = 687

$Y = - 4.53341 + 2.82957\ X$

Correlation Coefficient = 0.984

The length-weight relationship for the males, females and total samples for 1971 and 1972 are illustrated in Figures 3.5-5 and 3.5-6 respectively.

The female rainbow trout were slightly heavier per unit of length than the males. In both years, the females showed a slightly higher coefficient of condition (B in the equation) than the males (2.73 and 2.70 respectively in 1971, 2.83 and 2.79 respectively in 1972). Overall, the rainbow trout in 1972 were in better condition than in 1971 (B = 2.68 in 1971, B = 2.82 in 1972).

3.5.3.3 Growth Rate

The analysis of growth rate is based on the stratified subsamples described in Section 3.5.3.1 for 1971 and 1972 respectively. The regression of body length on scale diameter for 1971 (N = 432) is:

$Y = - 14.713 + .550\ X$

with a correlation coefficient of 0.836

The regression of body length on scale diameter for 1972 (N = 484) is:

$Y = - 21.810 + .579\ X$

with a correlation coefficient of 0.931

FIGURE 3.5-5

LENGTH-WEIGHT RELATIONSHIP
SKAGIT · ROSS RAINBOW TROUT
1971

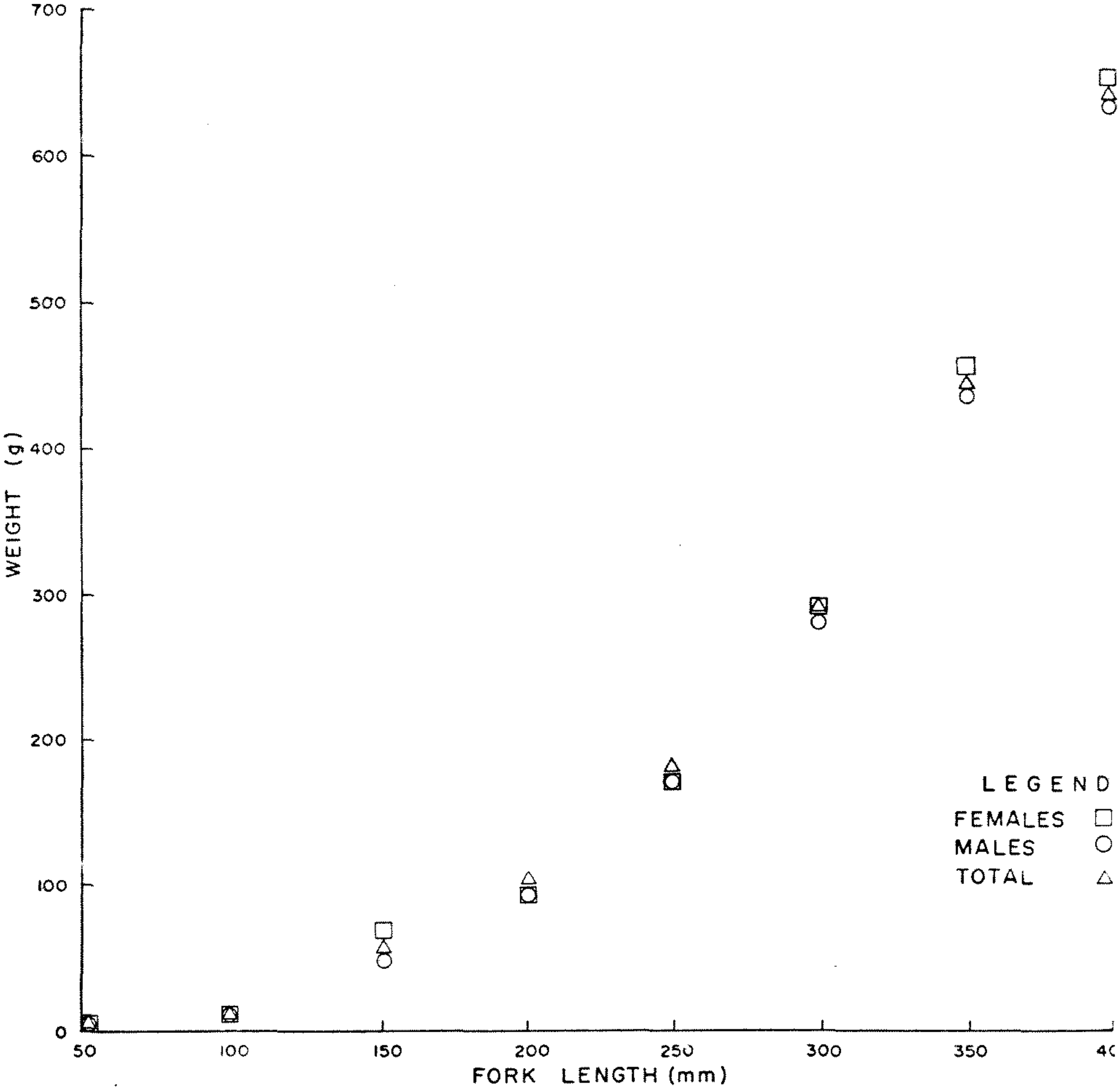
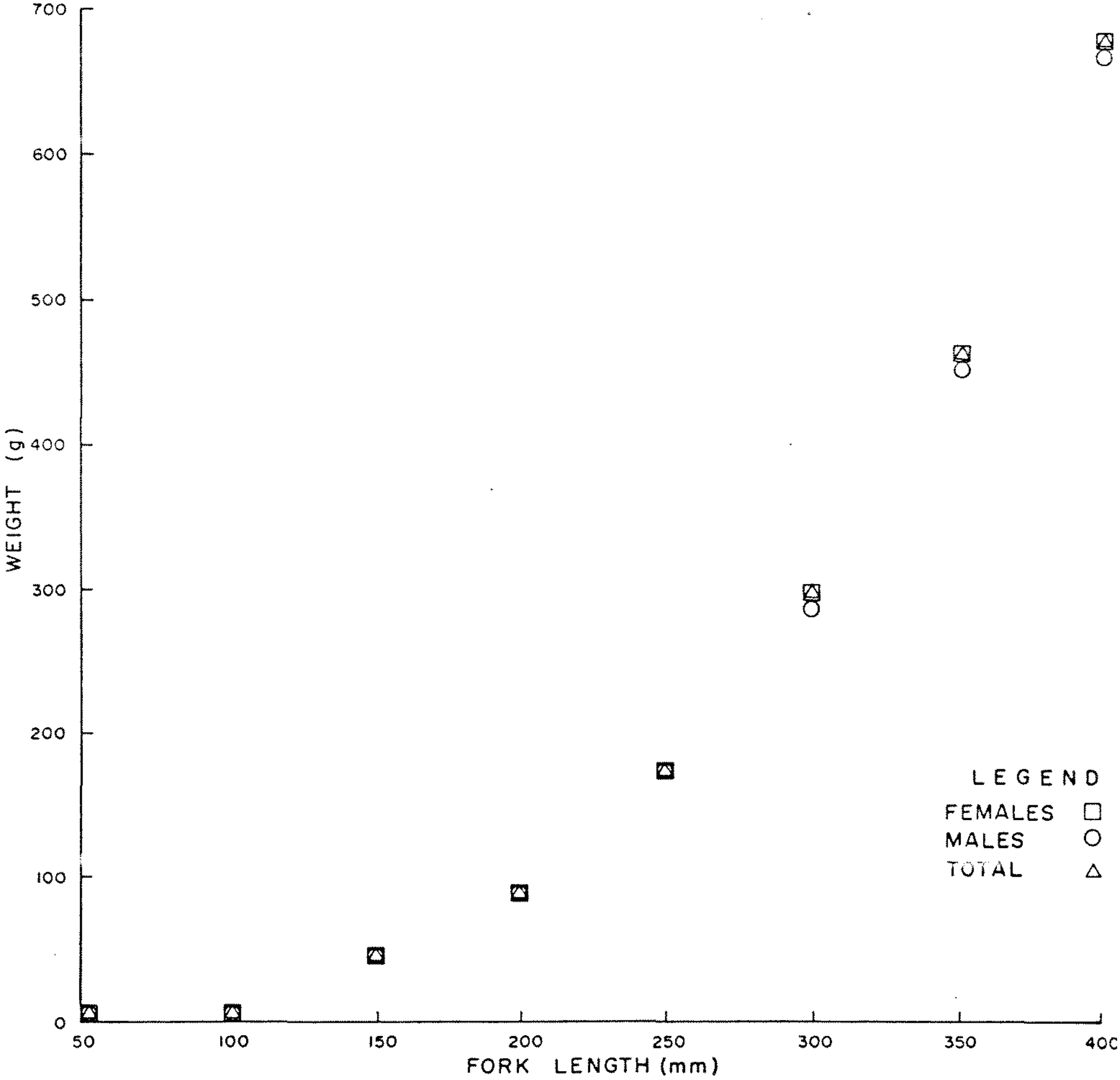


FIGURE 3.5-6

LENGTH-WEIGHT RELATIONSHIP
SKAGIT · ROSS RAINBOW TROUT
1972



Growth rates for 1971 rainbow trout are shown in tabular form in Tables 3.5-1 to 3.5-3 and graphically in Figs. 3.5-7 to 3.5-9. Average length to last annulus at each age for the total subsample and for males and females separately are presented in Table 3.5-1 and Fig. 3.5-7. Weight at mean length at each age for the total subsample and for males and females separately are presented in Table 3.5-2 and Fig. 3.5-8. Average increments of growth in length at each age for the total subsample and for males and females separately are presented in Table 3.5-3 and Fig. 3.5-9.

Growth rates for 1972 rainbow trout are shown in tabular form in Tables 3.5-4 to 3.5-6 and graphically in Figures 3.5-10 to 3.5-12. Average length to last annulus at each age for the total subsample and for males and females separately are presented in Table 3.5-4 and Fig. 3.5-10. Weight at mean length at each age for the total subsample and for males and females separately are presented in Table 3.5-5 and Fig. 3.5-11. Average increments of growth at each age for the total subsample and for males and females separately are presented in Table 3.5-6 and Fig. 3.5-12.

Generally, the length and weight data for 1971 and 1972 indicate the following:

1) that the greatest growth in length occurs in the second year and that growth rate in length decreases in each succeeding year;

2) the greatest growth in weight occurs in the third year; growth rate in weight decreases with each succeeding year.

TABLE 3.5-1

AVERAGE LENGTH TO LAST ANNULUS

RAINBOW TROUT, 1971

	TOTAL		MALES		FEMALES	
AGE	** NO.	Aver.* Length to Annulus (mm)	** NO.	Aver.* Length to Annulus (mm)	** NO.	Aver.* Length to Annulus (mm)
1	39	62	20	65	18	57
2	170	220	76	220	66	222
3	127	302	28	275	55	305
4	60	348	12	343	17	355
5	15	377	0		8	387

* Average back-calculated length.

** Sample size after removal of 10% from each tail of respective distribution.

TABLE 3.5-2

WEIGHT AT MEAN BACK-CALCULATED LENGTH

RAINBOW TROUT, 1971

	TOTAL		MALES		FEMALES	
AGE	** NO.	Weight of Aver. Fish at Annulus (g)	** NO.	Weight of Aver. Fish at Annulus (g)	** NO.	Weight of Aver. Fish at Annulus (g)
1	39	4.3	20	4.7	18	3.2
2	170	130	76	125	66	131
3	127	312	28	233	55	312
4	60	445	12	424	17	472
5	15	552	0		8	598

** Sample size after removal of 10% from each tail of respective distribution.

TABLE 3.5-3

AVERAGE INCREMENTS OF GROWTH IN LENGTH

RAINBOW TROUT, 1971

	TOTAL		MALES		FEMALES	
AGE	** NO.	Aver. Increment of Growth (mm)	** NO.	Aver. Increment of Growth (mm)	** NO.	Aver. Increment of Growth (mm)
1	39	62	20	65	18	57
2	170	158	76	155	66	165
3	127	82	28	55	55	83
4	60	46	12	68	17	50
5	15	29	0		8	32

** Sample size after removal of 10% from each tail of respective distribution.

FIGURE 3.5-7

MEAN CALCULATED LENGTH

SKAGIT·ROSS RAINBOW TROUT

1971

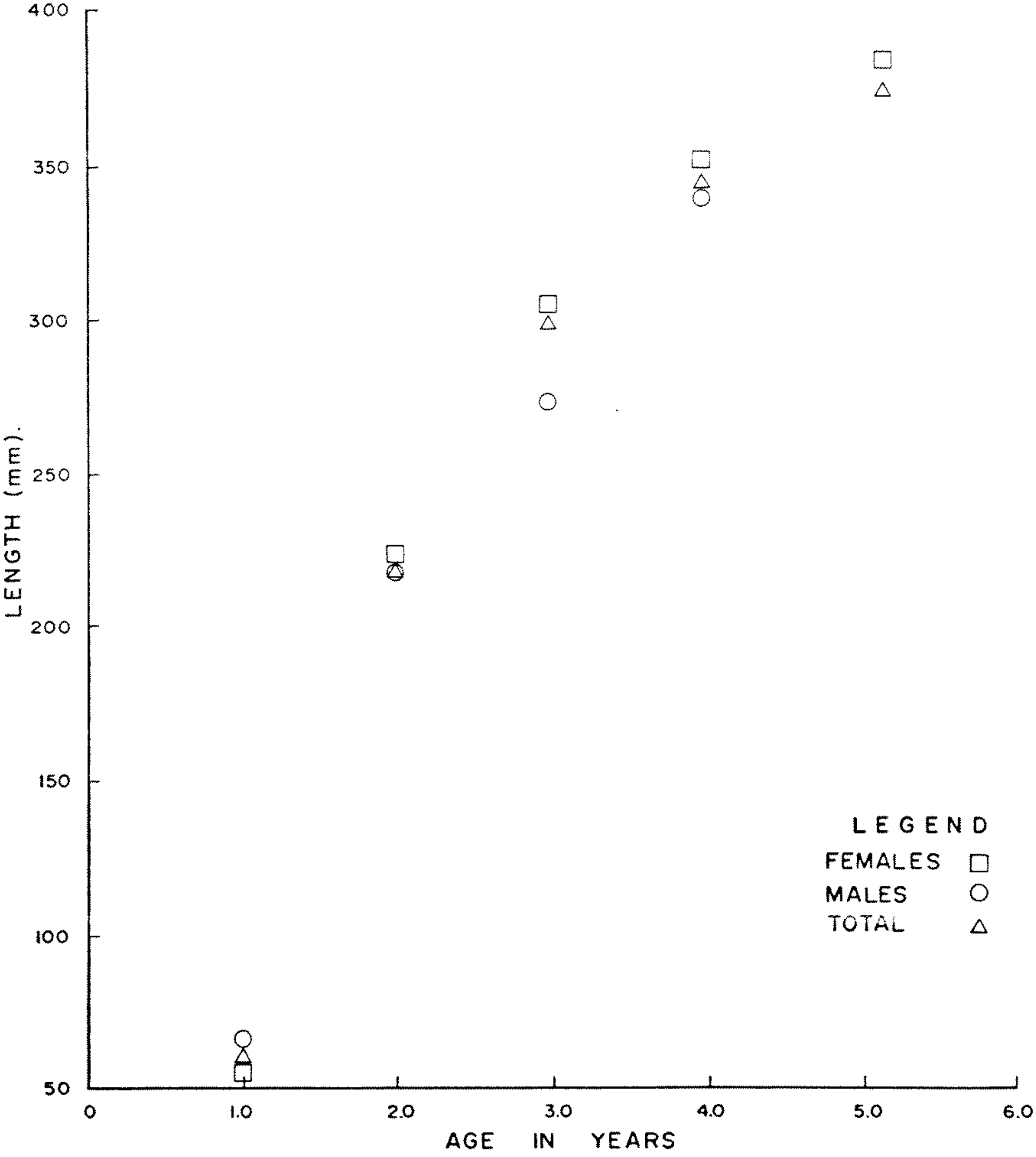


FIGURE 3.5-8

CALCULATED WEIGHT OF AVERAGE FISH

SKAGIT·ROSS RAINBOW TROUT

1971

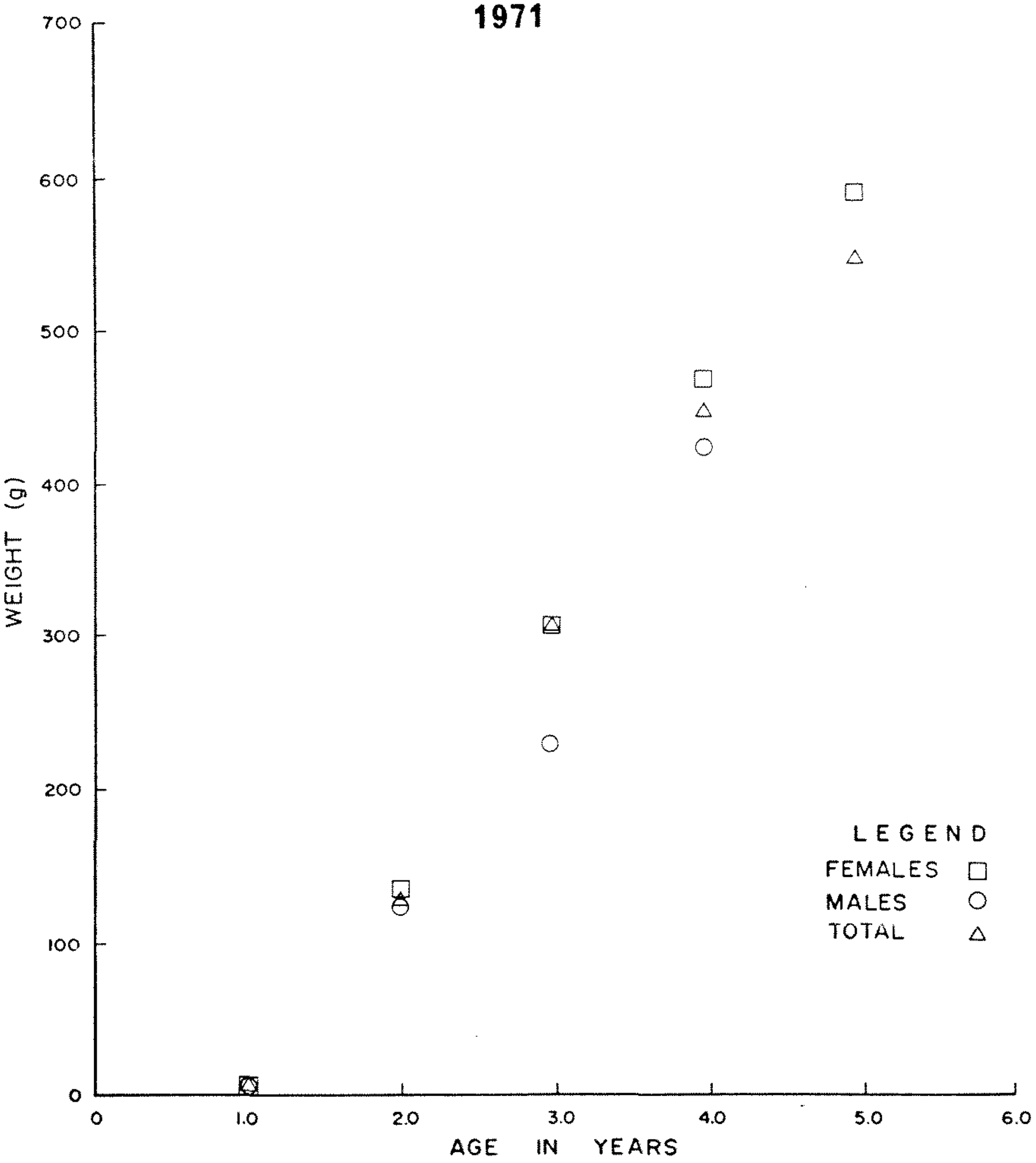


FIGURE 3.5-9

MEAN INCREMENT OF GROWTH IN LENGTH

SKAGIT·ROSS RAINBOW TROUT

1971

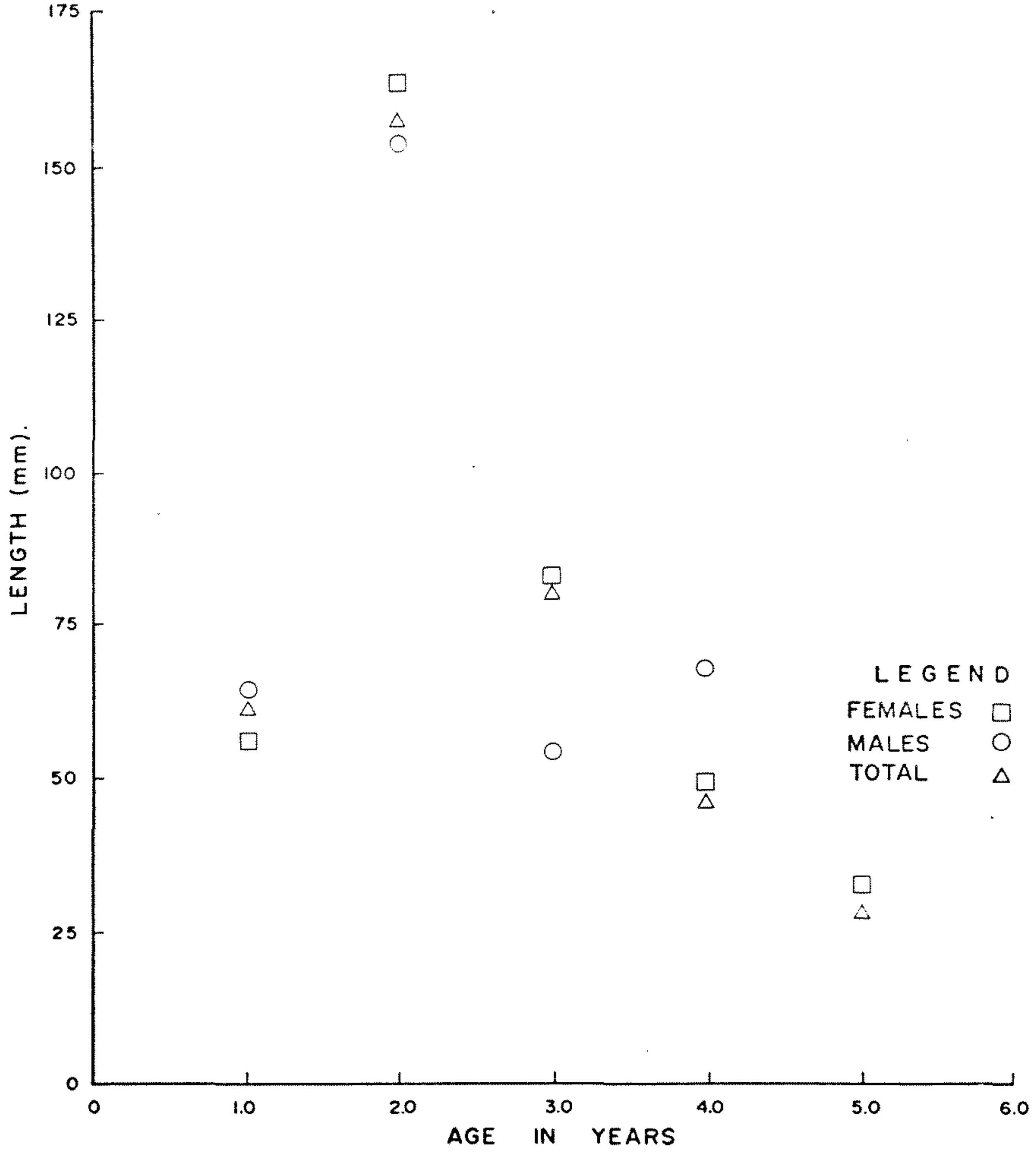


TABLE 3.5-4

AVERAGE LENGTH TO LAST ANNULUS

RAINBOW TROUT, 1972

	TOTAL		MALES		FEMALES	
AGE	** NO.	Aver.* Length to Annulus (mm)	** NO.	Aver.* Length to Annulus (mm)	** NO.	Aver.* Length to Annulus (mm)
1	101	55	37	54	29	52
2	180	215	75	229	57	212
3	112	320	28	324	49	318
4	46	364	13	358	25	367
5	8	378	2	394	6	383

* Average back-calculated length.

** Sample size after removal of 10% from each tail of respective distribution.

TABLE 3.5-5

WEIGHT AT MEAN BACK-CALCULATED LENGTH

RAINBOW TROUT, 1972

	TOTAL		MALES		FEMALES	
AGE	** NO.	Weight of Aver. Fish at Annulus (g)	** NO.	Weight of Aver. Fish at Annulus (g)	** NO.	Weight of Aver. Fish at Annulus (g)
1	101	2.5	37	2.5	29	2.1
2	180	117	75	139	57	112
3	112	359	28	365	49	353
4	46	516	13	482	25	529
5	8	575	2	628	6	597

** Sample size after removal of 10% from each tail of respective distribution.

TABLE 3.5-6

AVERAGE INCREMENTS OF GROWTH IN LENGTH

RAINBOW TROUT, 1972

	TOTAL		MALES		FEMALES	
AGE	** NO.	Aver. Increment of Growth (mm)	** NO.	Aver. Increment of Growth (mm)	** NO.	Aver. Increment of Growth (mm)
1	101	55	37	54	29	52
2	180	160	75	175	57	160
3	112	105	28	95	49	106
4	46	44	13	34	25	49
5	8	14	2	36	5	16

** Sample size after removal of 10% from each tail of respective distribution.

FIGURE 3.5-10

MEAN CALCULATED LENGTH

SKAGIT · ROSS RAINBOW TROUT

1972

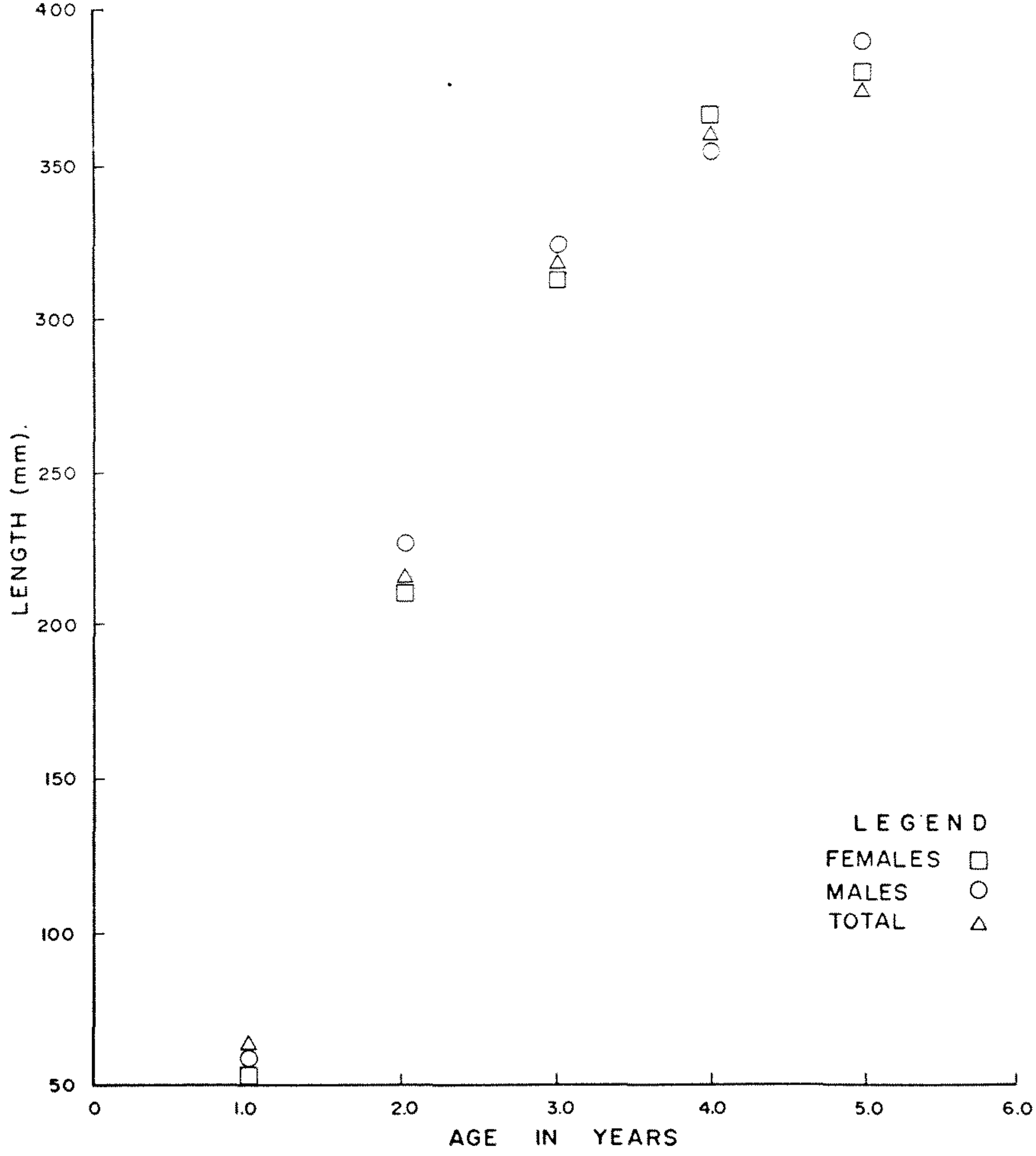


FIGURE 3.5-11

CALCULATED WEIGHT OF AVERAGE FISH

SKAGIT · ROSS RAINBOW TROUT

1972

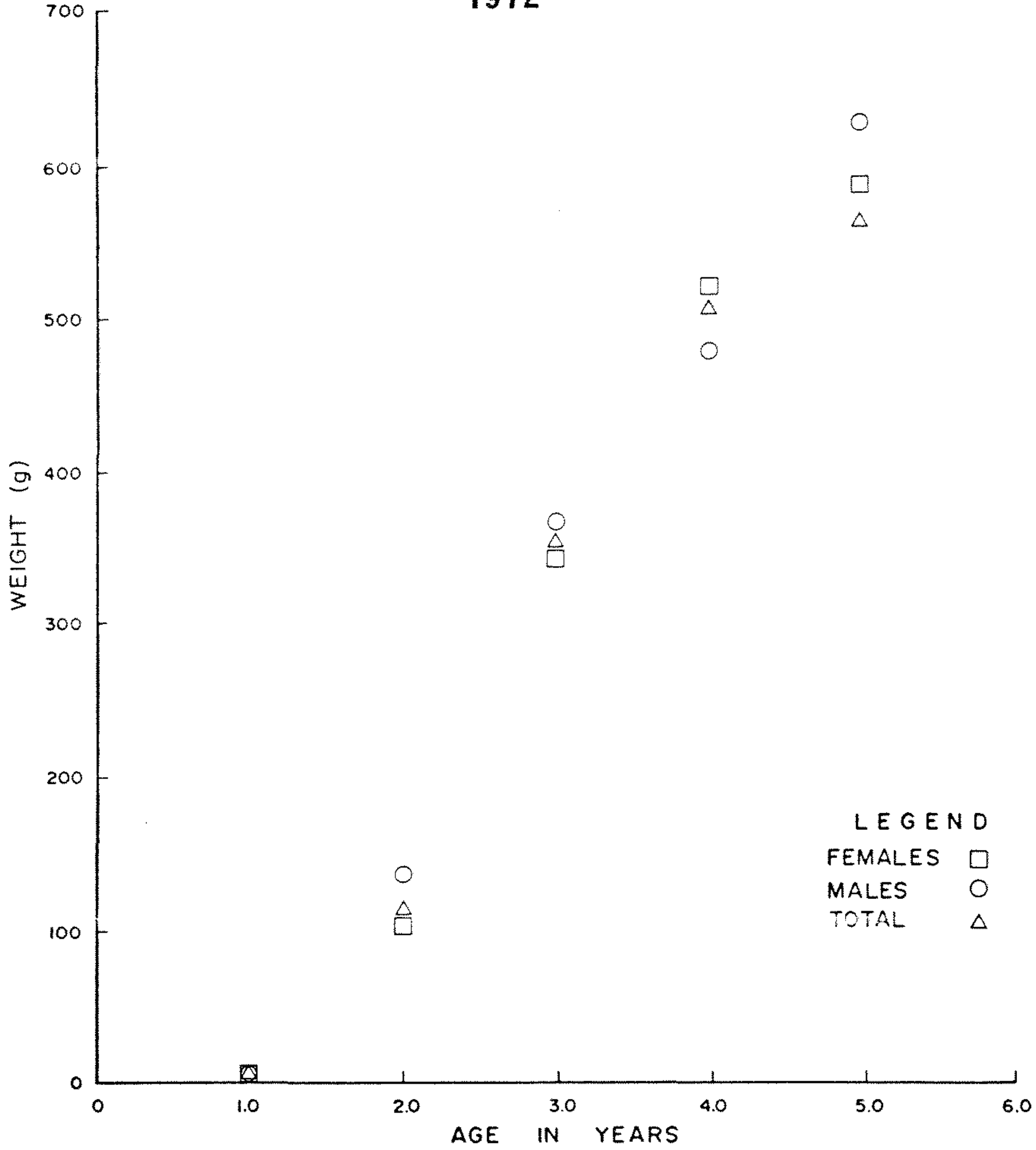
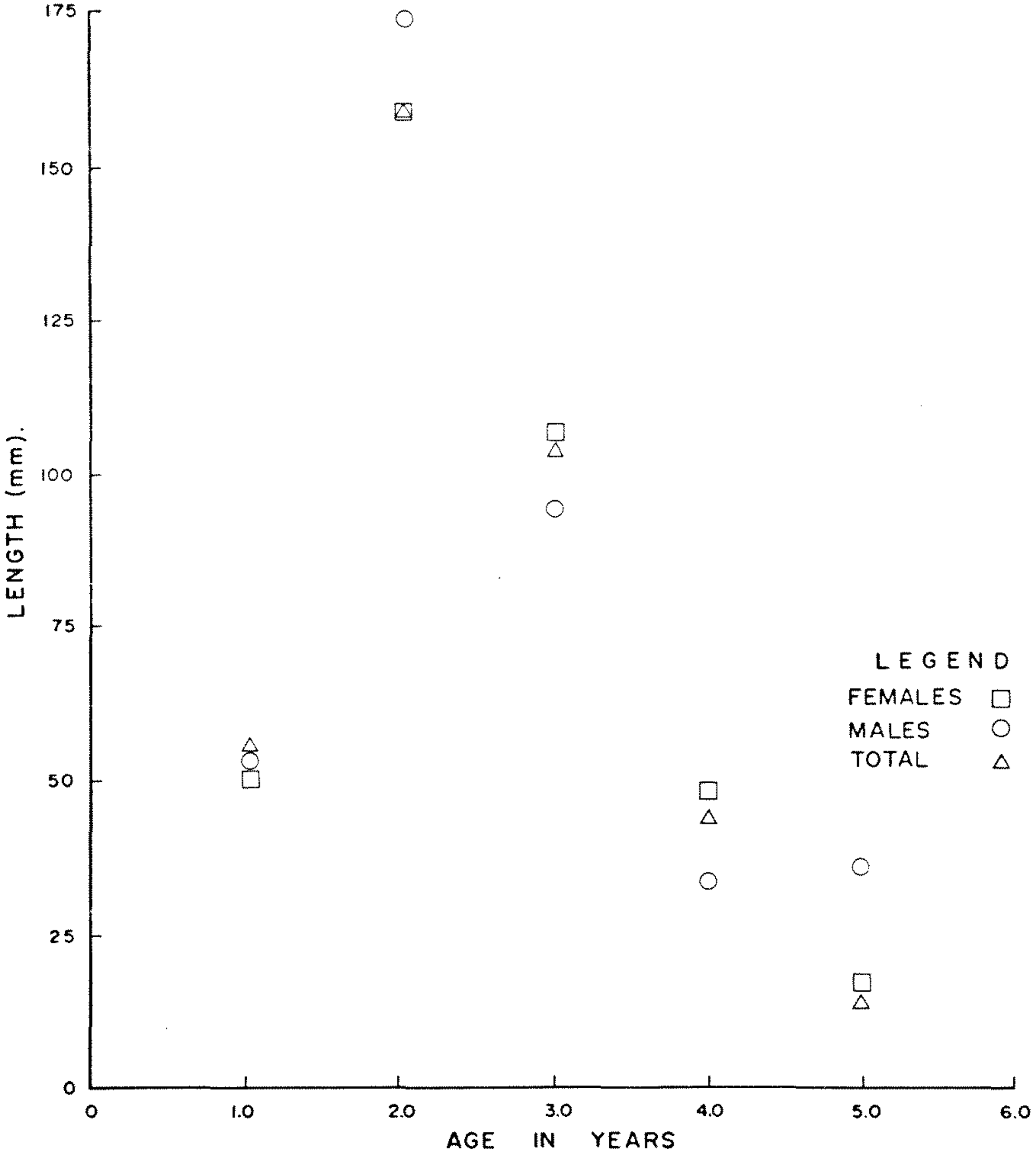


FIGURE 3.5-12

MEAN INCREMENT OF GROWTH IN LENGTH

SKAGIT · ROSS RAINBOW TROUT

1972



3.5.3.4 Length - Age

Utilizing the total subsamples for both 1971 and 1972 length-age distributions of back-calculated length to last annulus for each age and each year were computed. These distributions for 1971 and 1972 are illustrated in Figures 3.5-13 and 3.5-14 respectively.

FIGURE 3.5-13

LENGTH·AGE DISTRIBUTION

UTILIZING BACK CALCULATED LENGTH TO LAST ANNULUS

SKAGIT·ROSS RAINBOW TROUT

1971

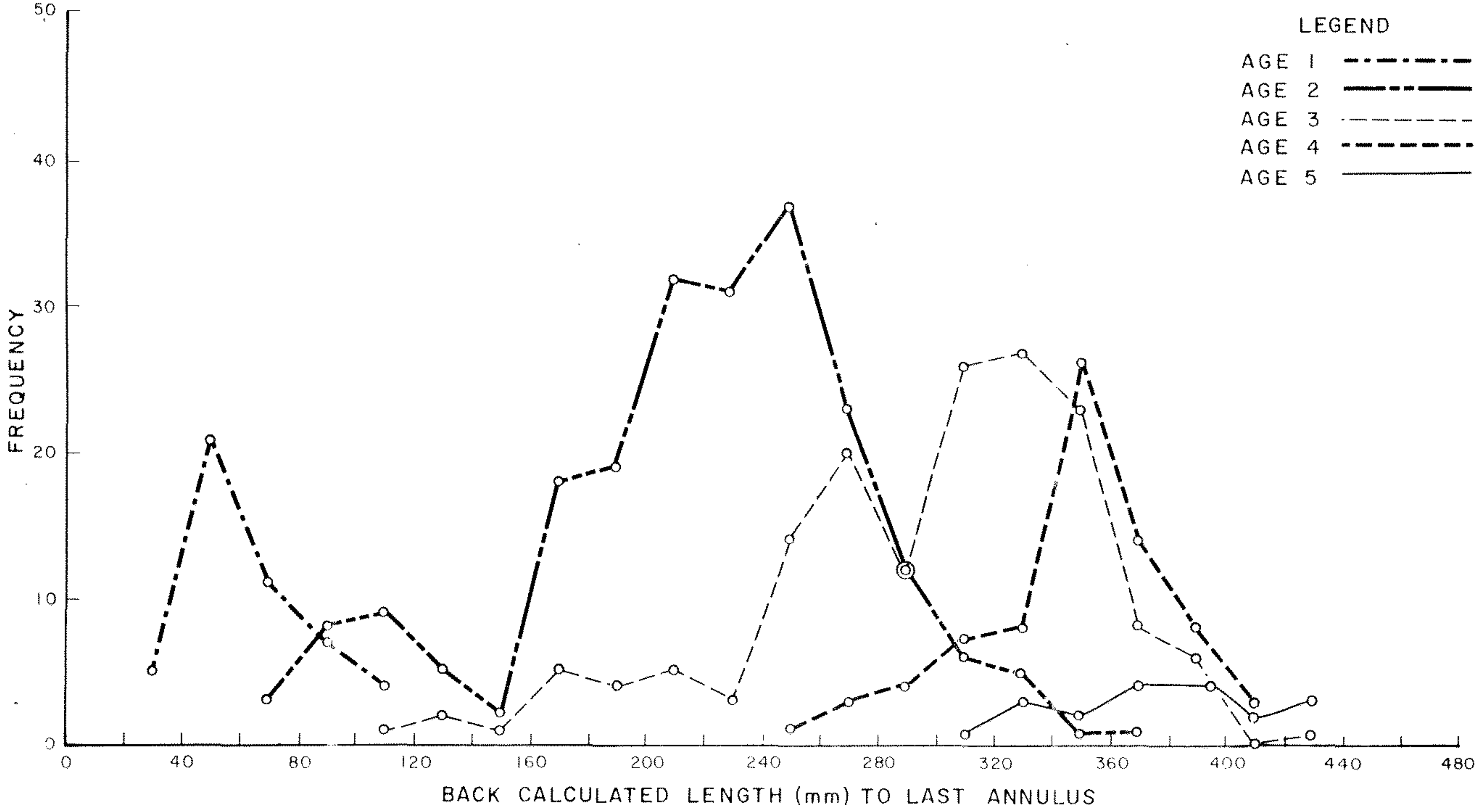
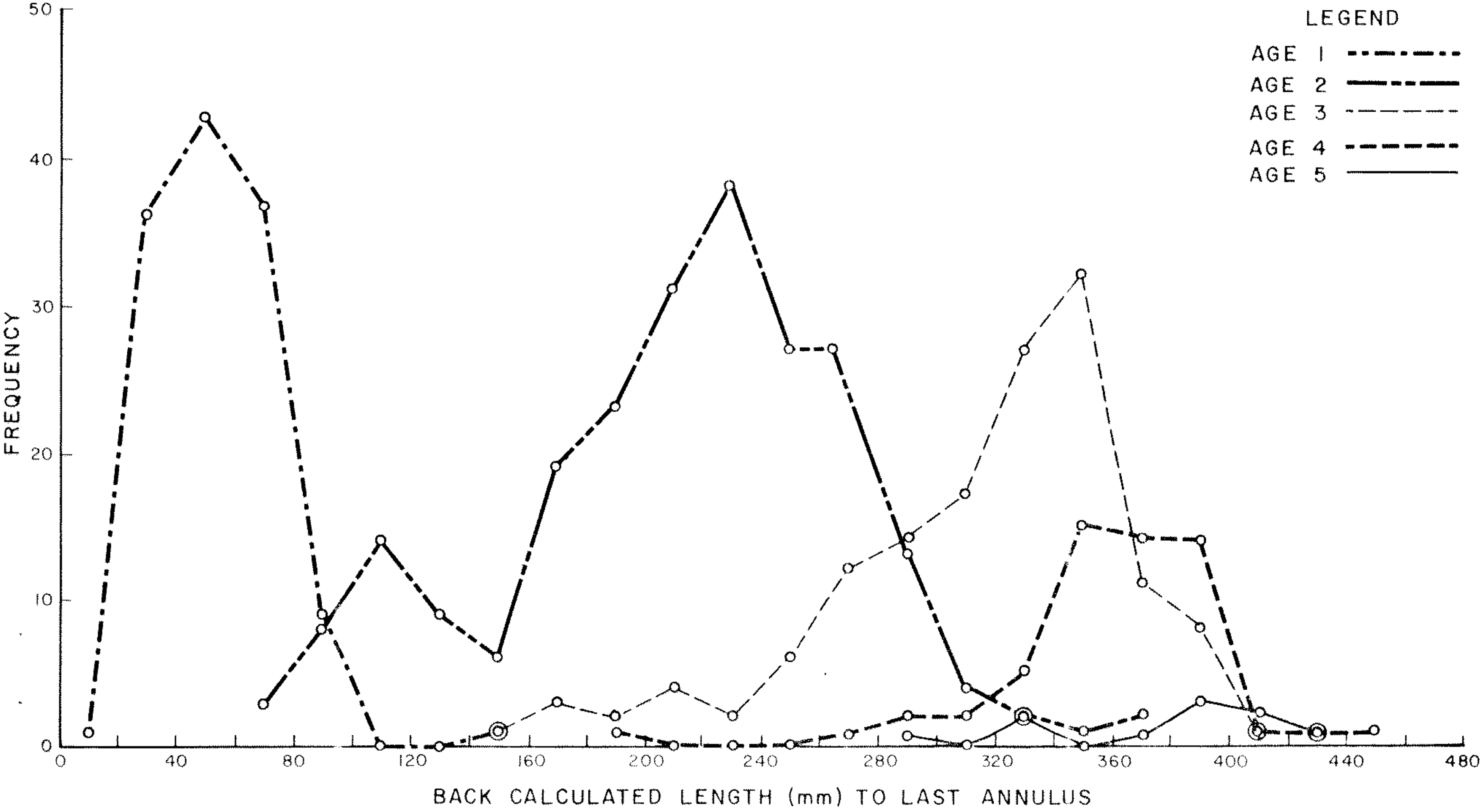


FIGURE 3.5-14

LENGTH·AGE DISTRIBUTION
UTILIZING BACK CALCULATED LENGTH TO LAST ANNULUS
SKAGIT·ROSS RAINBOW TROUT
1972



3.6 THE FISHERY

3.6.1 History of Fishery

3.6.1.1 Washington

(by Washington Department of Game)

A list of open seasons, closed waters and bag limits affecting the fishery of water tributary to or presently occupied by Ross Lake from 1933 to 1971 are shown in Table 3.6-1. Throughout this period the minimum size of trout that could be legally kept by anglers fishing Washington waters was fixed at six inches. Prior to 1933, regulations were set by the individual counties of Washington for waters within their boundaries, with the State holding only advisory power, for management and regulations of fish and wildlife over county authorities.

Closures of varying degree for waters upstream from Ross Dam, concurrent with major construction phases of the project, were instituted to protect the fishery resource for future public use. Later, in 1950, area restrictions on streams tributary to Ross Lake were designed to protect trout on spawning migration. Open season dates, later than were customary for this area, were directed to this end as well.

Fisherman success data for Ross Lake from 1941 to 1970 are shown in Table 3.6-2 and Figure 3.6-1. A general decline in catch per fisherman-day is indicated. Statewide daily trout catch limits were reduced twice over this period (Table 3.6-2 and Figure 3.6-1), a condition that could be partly responsible. Increased angler usage and intensity could also exert a negative influence on catch per fisherman-day. However, information regarding the proportion of anglers taking "limit" catches and trends in angler activity on

TABLE 3.6-1

WASHINGTON STATE ROSS LAKE AND TRIBUTARY STREAMS OPEN SEASONS, AREA RESTRICTIONS AND CATCH LIMITS

Year	Closed Waters	Open Season	Limits
1933	None	Apr. 15 to Oct. 31	Not to exceed 10 pounds and 1 fish; provided the numbers so taken do not exceed 20 in number.
1934	None	Apr. 10 to Nov. 30	Same as 1933
1935	None	Apr. 14 to Oct. 31	Same as 1933
1936	None	Apr. 5 to Oct. 31	Same as 1933
1937	Skagit River and all tributaries, including Ruby Creek, from mouth of Ruby Creek to the Canadian border.	Apr. 25 to Oct. 31	Same as 1933
1938	Skagit River and all tributaries, including Ruby Creek, from mouth of Ruby Creek to Canadian border; Beaver Lake, at head of Beaver Creek; Devils Lake, Hozomeen Lake; No Name Lake at head of No Name Creek.	Apr. 24 to Oct. 31	Same as 1933
1939	Skagit River and all tributaries, from the mouth of Beaver Creek to Canadian border, including Beaver Creek; Beaver Lake, at head of Beaver Creek; Ruby Creek and all its tributaries, from the mouth of Panther Creek to its source; Devils Lake; Hozomeen Lake; No Name Lake at head of No Name Creek.	Apr. 23 to Oct. 31	Same as 1933
1940	Same as 1939	Apr. 21 to Oct. 31	Same as 1933

TABLE 3.6-1 - Page 2

Year	Closed Waters	Open Season	Limits
1941	Devils Lake; Hozomeen Lake; No Name Lake at head of No Name Creek.	Apr. 6 to Oct. 31	Same as 1933
1942	Same as 1941	May 24 to Nov. 1	Same as 1933
1943	Same as 1941	May 23 to Oct. 31	Same as 1933
1944	Same as 1941	May 28 to Oct. 31	Same as 1933
1945	Same as 1941	May 27 to Oct. 31	Same as 1933
1946	None	May 26 to Oct. 31	Same as 1933
1947	Skagit River and all tributaries, including Ross Lake, from Ross Dam to Canadian border.	May 25 to Oct. 31	Same as 1933
1948	Skagit River and all tributaries, including Ross Lake, from Ross Dam to the Canadian border except Ruby Creek and its tributaries from mouth of Crater Creek-to its source.	May 23 to Oct. 31	Same as 1933
1949	Same as 1948	May 22 to Oct. 31	Same as 1933
1950	Big Beaver Creek and its tributaries; Ruby Creek and its tributaries from its mouth to Crater Creek.	May 21 to Oct. 31	Same as 1933
1951	Big Beaver Creek and its tributaries above posted marker on Ross Lake; Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from a line 300 yards out in Ross Lake to the Canadian border.	July 1 to Oct. 31	Same as 1933

TABLE 3.6-1 - Page 3

Year	Closed Waters	Open Season	Limits
1952	Big Beaver Creek and its tributaries above posted marker on Ross Lake; Devils Creek from posted marker on Ross Lake for one mile upstream; Lightning Creek from posted marker on Ross Lake for one mile upstream; Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from a line 300 yards out in Ross Lake to the Canadian border.	June 29 to Oct. 31	15 fish, the weight of which shall not exceed 7½ pounds and 1 fish
1953	Big Beaver and its tributaries above posted marker on Ross Lake; Devils Creek from posted marker on Ross Lake for one mile upstream; Lightning Creek from posted marker on Ross Lake for one mile upstream; Ross Lake, that portion lying between the Canadian border and the following established line: from a point on the north side of the mouth of Little Beaver Creek directly east to a marker on the east shore of Ross Lake; Ruby Creek and its tributaries from posted marker on Ross Lake to Crater Creek; Skagit River from Ross Lake to the Canadian border.	June 28 to Oct. 31	Same as 1952
1954	Same as 1953	June 27 to Oct. 31	Same as 1952
1955	Big Beaver Creek and its tributaries above posted closed water markers on Ross Lake; Devils Creek from posted closed water marker in Ross Lake for one mile upstream; Lightning Creek from posted closed water marker in Ross Lake for one mile upstream; Ruby Creek and its tributaries from posted closed water marker on Ross Lake to Crater Creek.	July 1 to Oct. 31	Same as 1952

TABLE 3.6-1 - Page 4

Year	Closed Waters	Open Season	Limits
1956	Same as 1955	July 1 to Oct. 31	Same as 1952
1957	Same as 1955	July 1 to Oct. 31	Same as 1952
1958	Same as 1955	July 1 to Oct. 31	Same as 1952
1959	Same as 1955	July 1 to Oct. 31	Same as 1952
1960	Same as 1955	July 3 to Oct. 31	Same as 1952
1961	Same as 1955	July 1 to Oct. 31	Not to exceed 6 pounds and 1 fish; provided the numbers taken do not exceed 12 fish.
1962	Same as 1955	July 1 to Oct. 31	Same as 1961
1963	Same as 1955	July 1 to Oct. 31	Same as 1961
1964	Big Beaver and its entire drainage above closed water markers on Ross Lake; Devils Creek from closed water markers in Ross Lake for one mile upstream; Lightning Creek from closed water markers in Ross Lake for one mile upstream; Ruby Creek and its tributaries from closed water markers in Ross Lake to Crater Creek.	July 1 to Oct. 31	Same as 1961
1965	Same as 1964	June 27 to Oct. 31	Same as 1961
1966	Same as 1964	June 26 to Oct. 31	Same as 1961
1967	Same as 1964	June 25 to Oct. 31	Same as 1961
1968	Same as 1964	June 23 to Oct. 31	Same as 1961
1969	Same as 1964	June 22 to Oct. 31	Same as 1961
1970	Same as 1964 except: Ruby Creek from closed water markers in Ross Lake to Crater Creek.	June 21 to Oct. 31	Same as 1961
1971	Same as 1970	June 19 to Oct. 31	Same as 1961
1972	Same as 1970	June 17 to Oct. 31	Same as 1961

TABLE 3.6-2

CREEL CHECK DATA FOR YEARS 1941 THROUGH 1970 FROM ROSS LAKE

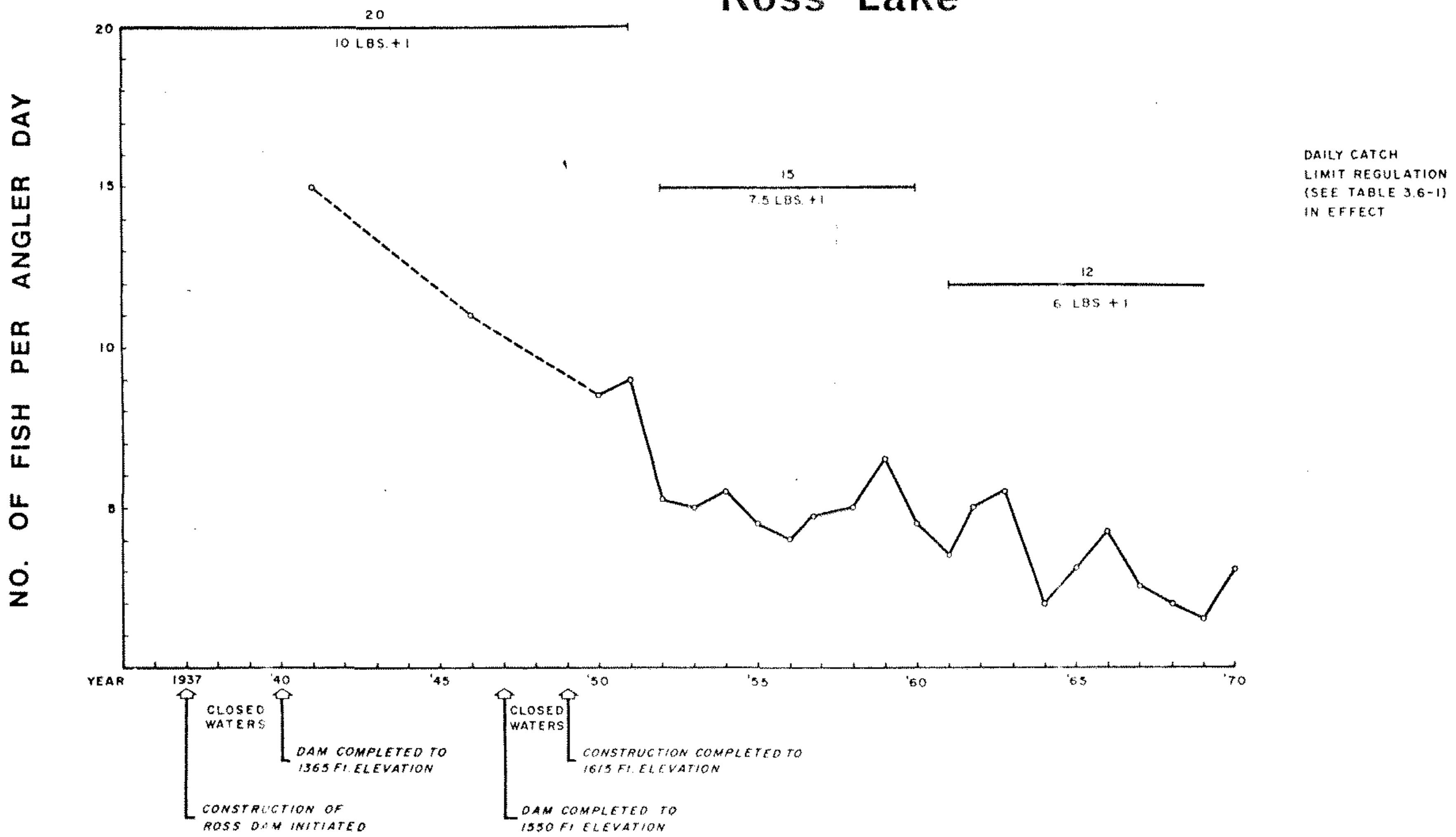
		Recorded Catch					
Year	Number of Anglers Checked	Rainbow	Cutthroat	Eastern Brook	Dolly Varden	Total	Catch Per Angler Day
1941	14	212				212	15.1
1946	12	144			3	147	12.2
1950	364	2213	769	6	159	3147	8.6
1951	160	1371		2	36	1409	8.8
1952	243	1146	46		68	1260	5.2
1953	165	735	58	2	12	807	5.0
1954	277	1413	55	6	27	1501	5.4
1955	261	964	60	26	49	1099	4.2
1956	218	642	88	42	65	837	3.8
1957	64	222	8	39	24	293	4.6
1958	70	323	4	19		348	5.0
1959	290	1933			26	1959	6.7
1960	585	2452	4	40	84	2580	4.4
1961	675	2248	2	17	212	2479	3.7
1962	907	4334	4	81	107	4526	5.0
1963	484	2598		1		2599	5.4
1964	42	87	3		3	93	2.2
1965	162	515				515	3.2
1966	458	1928		63	6	1997	4.4
1967	336	940	1	7	4	952	2.8
1968	520	1392			4	1396	2.6
1969	366	751	6		8	765	2.1
1970	717	2593	5		17	2615	3.6

FIGURE [illegible]6-[illegible]

CATCH PER ANGLER DAY AND DAILY CATCH REGULATIONS

For Years 1941 Through 1970

Ross Lake



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Ross Lake is insufficiently comprehensive or detailed to define the specific influence of these factors versus changes in biological conditions.

Also, variation, from year to year, in the relative contribution of the several trout species is evident. Several possible explanations exist, but little evidence is available which could point to specific factors. In spite of a substantial plant of cutthroat trout to Ross Lake (slightly in excess of 100,000 were planted between 1952 and 1954), they were of minor importance to catch records for succeeding years.

Features of the catch data presented in Table 3.6-2 and Figure 3.6-1 as well as conclusions drawn from them must be qualified in that the manner and frequency with which they were collected was not necessarily consistent from one year to another, or systematic for any single year. They were for the most part collected during, and are representative of, intensive use periods (e.g. weekends, holidays, etc.).

Insufficient data exists to define changes in size of trout entering angler catches over the history of Ross Lake. However, size ranges of trout observed by Smith and Anderson (1921) (prior to construction of Ross Dam) from Ruby Creek (rainbow of six to 10.75 inches in length), Big Beaver Creek (cutthroat 5.5 to 13.5 inches in length) and the main Skagit River (rainbow six to 17 inches in length and Dolly Varden to nine pounds) are certainly comparable to those observed today.

3.6.1.2 British Columbia

(by British Columbia Fish and Wildlife Branch)

The Skagit River and Ross Lake fishery have always been highly esteemed. However, the collection of creel census information on this system on the Canadian side of the border, only dates back to 1962.

Table 3.6-3 indicates the catch statistics on the Canadian Skagit from 1962-67. Included in the table are total catch, differentiation of catch by size and species and catch per unit effort (per hour).

The majority of fish which were landed were rainbow trout and the majority of these fish were 10 inches or larger. The catch success is remarkably consistent and success data suggests a catch of one fish per every two hours of angling.

It could not be determined if all creel information referred to river catch, lake catch or a combination of both.

Management Regulations on the Skagit River

B. C. Fish and Wildlife Branch Headquarters fishing regulation records date back to 1931. There are, however, many years for which fishing regulation records were not kept and consequently information for these years is unavailable.

The following are bag limits, area and time closures dating from 1931:

1931 no time or area closure
bag limit of 15 fish per day

1946	no time or area closure bag limit of 15 fish per day (maximum of 25 pounds plus one fish)
1949	no time closure area closure - "No one shall fish for, catch or kill fish of any kind in that portion of the Skagit River and all tributaries thereof flowing into said river situate and lying south from where highway bridge of Silver-Skagit Logging Company Limited crosses the said Skagit River, including the Klesilkwa River and Upper Silver Creek flowing into Silver Lake." bag limit - 15 per day (maximum of 25 pounds plus one fish) three day possession limit
1950-52	same
1953	wording change - Skagit and tributaries closed south of where highway bridge of Silver-Skagit Logging Company crosses the Skagit River. bag limit - same
1954	no time closure bag limit - 12 daily limit but not more than 25 pounds and one additional fish (except kokanees and steelhead).
1955-59	time closure on the Skagit River and its tributaries, excluding Sumallo Creek but including Ross Lake from March 1 to June 30. bag limit - same three day possession limit

1960	time closure and possession limit - same bag limit - 12 per day but not more than 25 pounds and one additional fish (except Kokanee)
1961	same as for 1960
1962-63	no time or area closure bag limit - 12 fish possession limit - 36 fish
1964-66	time and area closure - Skagit River and tributaries and Ross Lake (excluding Sumallo River) closed from April 1 to June 25. daily limit - 12, two of which can be over 20 inches possession limit - 36 fish
1967	time closure - date change from April 1 - June 24
1968	time and area closures unchanged bag and possession limit changed to 8 and 24, respectively
1969-70	time closure changed to April 1 - June 21 limits unchanged
1971	time closure changed to April 1 - June 18 limits unchanged

The management regulation trend on the Canadian Skagit has attempted to protect the spawning adult population ascending the river from the lake in order to assure adequate escapement back to the lake. The regulations have also decreased catch limits, thus attempting to distribute the catch over a broader spectrum of the angling public.

TABLE 3.6-3

CREEL CENSUS DATA
SKAGIT RIVER-ROSS LAKE SYSTEM
1962-1967

			Fish Size				
Year	No. of Anglers	Hours Fished	Under 10"	10 - 14"	Over 14"	Total Fish	C.P.U.E.
1962	495	2208	67R* 65D* 5E*	510R 72D 15E	253R 8D 8E	1003	0.46
1963	758	2704	69R 59D 10E	687R 83D 10E	358R 25D 1E	1290	0.48
1964	273	900	28R 39D 4E	141R 43D	91R 3D	349	0.39
1965	235	758	30R 23D 2E	100R 8D	50R 1D	214	0.28
1966	93	343	7R 4D	110R 11D 5E	85R 10D 3E	234	0.68
1967	332	1625	11R 23D	355R 103D 40E 2C*	236R 16D 3E	789	0.49

* R = rainbow trout; D = Dolly Varden char; E = Eastern brook trout; C = cutthroat trout

Time Closures

A March 1 to June 30 closure on the Skagit River and its tributaries except Sumallo Creek but including Ross Reservoir was present in the Sport Fishing Regulations until 1962. These dates were no doubt originally set out to protect the rainbow trout on the spawning migration.

The 1962 and 1963 fishery regulations did not set out time closures for the Skagit River. This closure was lifted in an effort to conduct an intensive creel census program which would provide the necessary information "to facilitate an evaluation of the unregulated fishery. The evaluation was required to indicate any regulation requirements and the extent of them". (C.E. Stenton, Reg. Fish. Biologist).

Based on the information collected in 1962 and 1963, in 1964, the B.C. Fishing Regulations delimited April 1 to June 25 as the new fishing closure dates. The date closure on the Skagit River since 1964 have closely approximated these dates.

Bag Limits

Up until 1967, the provincial daily and possession limits for game fish were 12 and 36 respectively. In 1968, the regulations were amended to a daily limit of 8 fish and possession limit of 24. These limits still are in effect for the Lower Mainland and thus for the Skagit River.

In recent years, the burgeoning Lower Mainland populations have sought out an increasing number of fishing lakes and have subjected these lakes to an ever increasing fishing pressure. This also holds true for the Skagit River Valley. An ever increasing number of recreationists and fishermen are making use of trailers and campers in order to take an increasing number of trips and the trips which are taken are probably of a longer duration.

This trend is true for the Skagit River. The river system is being subjected to an increasing number of anglers for more protracted periods of time and although comparative total catch figures for the Skagit system are not available for 1964 to 1970, a definite increase in the number of rainbow trout removed from the Skagit system is a safe assumption. Furthermore, there appears to be a disproportionate increase in the popularity of lake versus stream fishing. It is not known whether this reflects a decreasing stream productivity, a definite angler preference for a certain fishing technique or an aversion to a technique that requires more effort, experience and knowledge.

Creel Census

The Lower Mainland office has creel data dating to 1962. Table 3.6-3 summarizes the data on file.

It could not be determined if all creel information was river, lake or a combination of both.

Although the system is receiving an ever increasing fishing pressure, it appears to withstand this pressure very well. It is for this reason that little if any management, aside from the 1962-63 creel program and ensuing regulation change, has been undertaken on this system. A shortage of manpower has also predicated against any major management program.

3.6.2 Creel Census and Angler-Provided Data

(by F.F. Slaney and Company)

3.6.2.1 1970

Methods

A creel census of anglers fishing the Skagit River system was initiated on 24 August, 1970 and continued through 14 November of that year. Interviews of anglers and sampling of their catches took place over the four main Study Areas (F, M, U, A) in their shorter (approximately one-half mile) sections on the river (see Section 2.3.2 and Map 3). Some sampling of anglers at the north end of Ross Lake also took place. The sections of the river were sampled on a given day in random fashion in 1970. Sampling days were not selected in advance; sampling was carried out on every day that it was feasible.

Angler interviews accumulated data on place of residence, length of stay (day only vs camper), age, and sex of anglers with optional questions on fishing preference (lake vs stream) and subjective determination of fishing success. Length of fishing time, area fished, kinds and numbers of fish (legal and sub-legal size) taken, and type of bait used were also determined. A sample interview form is included as Appendix 40). Length, weight, sex and sexual condition were recorded for all fish when possible. Stomach and scale samples were also taken when possible (see methods outlined in Section 3.2.2).

The Sample

A total of 290 interviews of river and lake fishermen is the basis for the 1970 analysis. Interviews were conducted on 30 sampling days (19 of which were weekend days or holidays) between 24 August and 14 November. Interviews took place between 9 A.M. and 9 P.M. but 57.6 percent were done between 11 A. M. and 3 P.M.

Anglers

Of the 290 fishermen sampled, 245 (84.5 percent) were male and 45 (15.5 percent) female. Age distribution is shown in Table 3.6-4.

TABLE 3.6-4

AGE DISTRIBUTION OF ANGLER SAMPLE, 1970

Age	Number	Percent
Children	21	7.2
Teenagers	34	11.7
20 - 29	51	17.6
30 - 39	45	15.5
40 - 49	73	25.2
50 +	66	22.8

The sample included 225 residents of British Columbia, 61 from Washington, 2 from Oregon and 2 from Virginia.

Of those expressing their views, 167 (57.8 percent) anglers preferred to fish streams, 57 (19.7 percent) lakes and 65 (22.5 percent) had no preference. On the second optional question 25 (9.1 percent) of the anglers thought fishing to be excellent, 174 (63.3 percent) good and 76 (27.6 percent) found it poor.

Distribution of Anglers and Fishing Methods

The distribution of the fishermen in the sample peaked in the lower section of the Skagit River. The figures are shown in Table 3.6-5.

TABLE 3.6-5

DISTRIBUTION OF FISHERMEN IN 1970 SAMPLE

Area	Number	Percent
A	28	9.7
U	18	6.2
M	27	9.3
F	180	62.1
L	37	12.8

Where A, U, M, and F are the sampling areas in the system (See Map 3) and L is the north end of Ross Lake. The lake sample was small and limited and probably not typical of the lake as a whole. Techniques used in fishing are shown in Table 3.6-6.

TABLE 3.6-6

FISHING TECHNIQUES USED BY FISHERMEN IN 1970 SAMPLE

Method	Number	Percent
Flies	32	11.0
Lures	20	6.9
Bait	192	66.2
Combination	46	15.9

Total fishing effort in the sample was 1099.9 hours.

Catch

The total catch by anglers interviewed was 389 fish, 352 of which were of legal size and are utilized in subsequent analysis here. Legal catch was made up of 340 (96.6 percent) rainbow trout, 9 (2.6 percent) Dolly Varden char, 2 (0.6 percent) brook trout and 1 (0.3 percent) hybrid.

Total legal catch, overall catch per unit of effort (CPUE) and mean CPUE are shown in Table 3.6-7.

TABLE 3.6-7

CATCH, OVERALL AND MEAN CPUE BY AREA, 1970

Area	Catch	Overall CPUE	Mean CPUE
A	2	0.02	0.02
U	10	0.14	0.17
M	11	0.16	1.95
F	209	0.28	0.30
L	120	0.73	2.28
All areas	352	0.32	0.67

Overall CPUE is the total catch of legal fish divided by the total time spent in fishing by all anglers. Mean CPUE is the average of all the CPUE values determined for each individual angler. By both methods, fishing was better in the lake than in the river according to the 1970 sample.

3.6.2.2 1971

Ross Lake

(by F. F. Slaney & Company and Washington Department of Game)

Methods

The 1971 creel census on Ross Lake covered the complete fishing season from opening day on 19 June through the close of the season on 31 October. Sampling stations were set up at the north (Hozomeen Campground) and south (Dameron's Resort) ends of the lake. Due to the limited access of the south end, the sample approximated closely to a complete sample of all anglers. At the north end only a portion of all anglers could be sampled.

The sampling schedule was basically a 20 percent random sample by weekend day and weekday for each month. A total of 27 sample days were selected at random from the 135 days in the fishing season by month. Nine of the sample days selected were weekend days or holidays; the remaining 18 days were weekdays. 14 "selected" days which included holidays and special days (e.g., the opening weekend of fishing) not chosen in the random sample were also sampled. Thus, a total of 41 days was sampled throughout the season. The sampling days are shown in Appendix 41. At the north end of the lake during the 10 day period between 21 and 30 July inclusive, the sampling was done every day.

The angler interview format was the same as utilized in 1970 (see Section 3.6.2.1, Methods, and Appendix 40). Fishermen were also interviewed when they returned to shore in the vicinity of the check stations at each end of the lake. At the south end of the lake the single access route resulted in a virtually complete sample of anglers there; sampling at the north end check station covered only a portion of the anglers in that region. Fish were sampled as in 1970 (see Section 3.6.2.1, Methods) at the north end of Ross Lake throughout the creel census program. Sampling of fish at the south end of the lake was only done in conjunction with the creel census on opening weekend (19 and 20 June, 1971) . Other dates also.

The Sample

A total of 1527 interviews of lake anglers is the basis for this analysis. Interviews for the 1971 creel census (including both lake and river samples) were conducted between 6 A.M. and 10 P.M., but 66.8 percent were done between 11 A.M. and 4 P.M. (54.9 percent between 11 A.M. and 3 P.M.).

Anglers

Male fishermen made up 75.2 percent (1148) of those interviewed from the lake; females were 24.8 percent (379) of the sample. The age distribution of the anglers in the sample is shown in Table 3.6-8.

TABLE 3.6-8

AGE DISTRIBUTION OF LAKE ANGLERS, 1971 SAMPLE

Age	Number	Percent
Children	120	7.9
Teenagers	113	7.4
20 - 29	160	10.5
30 - 39	283	18.5
40 - 49	462	30.3
50 +	389	25.5

The sample included 1402 (91.8 percent) fishermen from Washington, 95 (6.2 percent) from British Columbia, 11 (.7 percent) from California and the remainder from other states. Thirty-nine of the anglers (2.5 percent) were day fishermen only while 1488 (97.5 percent) of the sample remained overnight in the area.

Of the lake anglers answering the question 86 (11.2 percent) preferred stream fishing, 576 (74.9 percent) preferred lake fishing and 107 (13.9 percent) had no preference. Of the anglers answering, 84 (11.0 percent) considered their success excellent with 362 (47.3 percent) reporting good success and 320 (41.8 percent) saying their success was poor.

Distribution of Anglers and Fishing Methods

Anglers in the sample were distributed across the seven sections of the lake (L-1 (south) to L-7 (north)); as shown by the figures in Table 3.6-9.

TABLE 3.6-9

DISTRIBUTION OF LAKE ANGLERS, 1971 SAMPLE

Area	Number	Percent
L-1 (Ruby Creek Area)	339	22.2
L-2 (Roland Point Area)	354	23.2
L-3 (Devils Creek Area)	56	3.7
L-4 (Lightning Creek Area)	28	1.8
L-5 (Little Beaver Area)	105	6.9
L-6 (Hozomeen Area)	552	36.1
L-7 (Ross Lake above International Border)	93	6.1

Techniques used in fishing by these fishermen are shown in Table 3.6-10. The "combination" was primarily bait (e.g. worms) and lures ("pop gear") that were trolled behind the boat. Total fishing effort in the sample was 6478.7 hours.

TABLE 3.6-10

FISHING TECHNIQUES USED BY LAKE ANGLERS, 1971 SAMPLE

Method	Number	Percent
Flies	17	1.1
Lures	72	4.7
Bait	183	12.0
Combination	1255	82.2

Fishing time started anywhere from midnight to 9 P.M. but 70.5 percent of the fishing started between 7 A.M. and noon.

Catch

The total catch by anglers in the sample was 3537 fish, 3228 of which were of legal size (6" in U.S., 8" in B.C.) and are utilized in subsequent analysis here. Species composition of the legal catch was 3153 (97.7 percent) rainbow trout, 50 (1.6 percent) Dolly Varden char, 17 (0.5 percent) brook trout and 8 (0.3 percent) others.

Total legal catch, overall CPUE and mean CPUE are shown in Table 3.6-11. There appears to be moderate variations in catch per unit of effort between lake sections in the 1971 sample.

TABLE 3.6-11

CATCH, OVERALL AND MEAN CPUE BY LAKE AREA, 1971 SAMPLE

Area	Catch	Overall CPUE	Mean CPUE
L-1	652	0.50	0.51
L-2	851	0.47	0.47
L-3	152	0.49	0.46
L-4	68	0.44	0.39
L-5	271	0.43	0.44
L-6	1121	0.53	0.54
L-7	113	0.46	0.48
All areas	3228	0.49	0.50

3.6.2.3 Skagit River System, 1971

(by F. F. Slaney and Company)

Methods

The creel census sampling on the Skagit River System in 1971 was carried out on the same days as the sampling at the north end of Ross Lake (see above). Thus, sampling was carried out on the days selected at random, on the additional "selected" days and on every day between 21 and 30 July.

The sampling sections (See Map 3) within the four areas (F, M, U, and A) of the Skagit River System were chosen at random for sampling. Due to ease of access in sampling, sections within areas F and M together or U and A together were sampled in random order on a given day. The choice of whether to do areas F and M or areas U and A on a given day was made randomly. On days when there was little fisherman activity a given section may have been sampled more than once. At these times when most sections were sampled more than once on a given day the sampling regime approached that of a complete sample.

The angler interview format was the same as that utilized in 1970 as described in Section 3.6.2.1., (Methods) and Appendix 40. The primary difference between interviews of lake and stream anglers is that the latter were usually in the midst of fishing while the former were interviewed at the end of their trip.

Fish were sampled as in 1970 (see Section 3.6.2.1 (Methods)) throughout the creel census program on the river system.

The Sample

The 1971 stream creel census analysis is based on interviews with 494 river fishermen.

Anglers

Male anglers made up 88.3 percent (436) of the river fishermen in the 1971 sample while 53 females were 11.7 percent of the sample. Age distribution of the anglers is given in Table 3.6-12.

TABLE 3.6-12

AGE DISTRIBUTION OF RIVER ANGLERS, 1971 SAMPLE

Age	Number	Percent
Children	58	11.7
Teenagers	57	11.5
20 - 29	96	19.4
30 - 39	116	23.5
40 - 49	125	25.3
50 +	42	8.5

The sample was made up of 448 (90.7percent) residents of British Columbia, 42 (8.5 percent) Washington residents, 2 (.4 percent) from California, and 2 (.4 percent) from Oregon. Of the total, 158 (32.0 percent) were day only fishermen while 336 (68.0 percent) were camping in the area.

Of the stream fishermen responding 285 (61.2 percent) preferred stream fishing, 111 (23.8 percent) favored lake fishing, and 70 (15.0 percent) had no preference. Thirty-nine of the respondents (9.0 percent) felt their success was excellent, 91 (21.1 percent) rated their success good while 301 (69.8 percent) thought their fishing success was poor.

Distribution of Anglers and Fishing Methods

Anglers in the sample were distributed between the four major areas of the Skagit River System as shown in Table 3.6-13.

TABLE 3.6-13

DISTRIBUTION OF RIVER FISHERMEN, 1971 SAMPLE

	Number	Percent
A	35	7.1
U	18	3.6
M	76	15.4
F	365	73.9

Techniques used in fishing by anglers sampled are shown in Table 3.6-14.

TABLE 3.6-14

FISHING TECHNIQUES USED BY ANGLERS, 1971 RIVER SAMPLE

Method	Number	Percent
Flies	49	9.9
Lures	21	4.3
Bait	346	70.0
Combination	78	15.8

Total fishing effort in the sample was 1270.5 hours. Average fishing period to the time of the interview on the stream was 2.57 hours.

Fishing time started anywhere from 4 A.M. to 6 P.M. in the sample but 49.0 percent started between 8 A.M. and noon.

Catch

Total catch in the river sample was 531 fish. Of these 367 (69.1 percent) were legal size and will be used in the subsequent discussion. Species composition of the legal catch was 329 (89.6 percent) rainbow trout, 36 (9.8 percent) Dolly Varden char and 2 (0.5 percent) brook trout.

Total legal catch, overall CPUE and mean CPUE are shown in Table 3.6-15. Best fishing on the river clearly occurs in Area M.

TABLE 3.6-15

CATCH, OVERALL AND MEAN CPUE BY AREA, 1971 SAMPLE

Area	Catch	Overall CPUE	Mean CPUE
A	8	0.21	0.50
U	5	0.14	0.40
M	62	0.43	0.82
F	292	0.27	0.37
All areas	367	0.28	0.45

3.6.2.4 Catch/Angler Day, 1971

Methods

Catch per angler day was calculated for the river and lake anglers and overall. The original data were derived from sheets completed by anglers and returned by hand or by mail. The responses were completely voluntary and there was no possibility of assessing the reliability of data provided. The sheet provided check spaces for months and days of fishing, number in field party, number of fish caught and location of fishing. A copy of the sheet, originally intended primarily for the recovery of tags from anglers, is shown in Figure 3.6-2.

Total number of angler days was calculated by multiplying the number of anglers in the party by the total number of days fished. Total angler days divided into total number of fish caught yielded a value for catch/angler day. Since it could not be determined from the original forms how the effort was distributed between the various days, the assumption was made that the effort was expended equally and could be assigned to any of the calendar dates recorded. Consequently, there could be several different effort values for the same calendar day from different anglers. The effort for each species and combined catch for each calendar day was averaged.

Results

The overall mean catch-per-angler day data are shown by date in Figure 3.6-3. The catch-per-angler day data for the lake, stream and other are shown by date in Appendices 42, 43, and 44 respectively. In all cases, the plot of catch/day against time through the season shows no distinct increasing or decreasing trends and appears to remain level.

The results of the catch/angler day calculations by fishing locality are shown in Table 3.6-16.

FIGURE 3.6-2

ANGLER HAND-OUT FORM

SKAGIT · ROSS FISHERY RESEARCH

A research project is being conducted on the fish populations of Ross Lake, its U.S. tributaries and the Skagit River in British Columbia. Fish have been tagged to provide information on their abundance, movements, spawning areas, and to evaluate angling results.

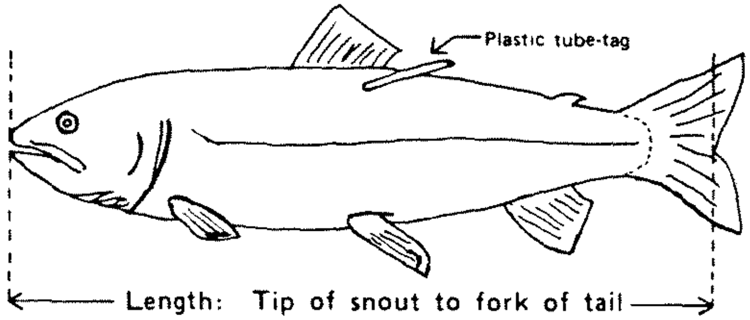
The Washington Department of Game and the Fisheries Research Institute of the University of Washington are cooperating in this research on the biology of these fish populations and their contribution to the fishery. These studies extend into the Skagit River where fishery biologists from the B.C. Fish and Wildlife Branch and the F. F. Slaney & Co., Ltd., are cooperating.

Your cooperation in reporting angling efforts and catches and the recovery of any tagged fish will assist these studies.

Please record the information requested on the form at the bottom of this sheet. Deposit the completed forms in boxes at Ross Dam and Hozomeen access areas, with Washington Department of Game Wildlife Agents, at Dameron's Ross Lake Resort, the Diablo Lake boat operator, or any of the fishery research or creel census teams you may meet. If you leave the watershed without depositing the form, please mail it to either of these addresses:

Washington Department of Game
Environmental Management Division
600 North Capitol Way
Olympia, Washington 98501

British Columbia Department of
Recreation and Conservation
Fish and Wildlife Branch
4529 Canada Way
Burnaby, 2, British Columbia



Please circle the month and dates of fishing days - -

Month	Days
6 7 8 9 10	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Number of anglers in party:____________

Total number of fish caught:
Rainbows____________
Dolly Varden__________

INFORMATION ON TAGGED FISH CAPTURED

PUNCH SMALL HOLE WITH PENCIL & INSERT TAG	COLOR OF TAG | SERIAL NO. (Delete if tag returned)	FORK LENGTH	LOCATION OF CAPTURE (See map on back)
o			
o			
o			

FIGURE 3.6-2

ANGLER HAND-OUT FORM (Continued)

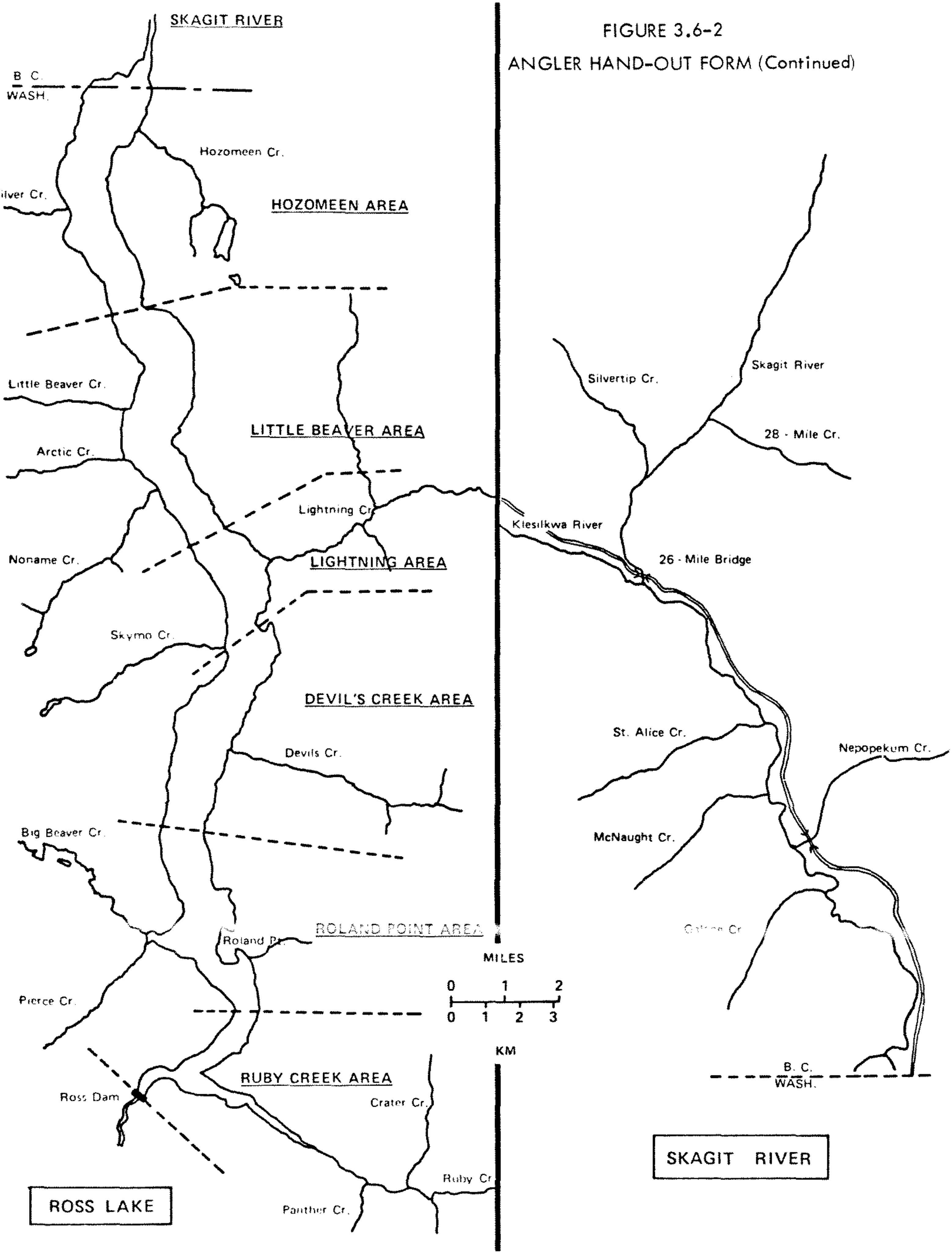
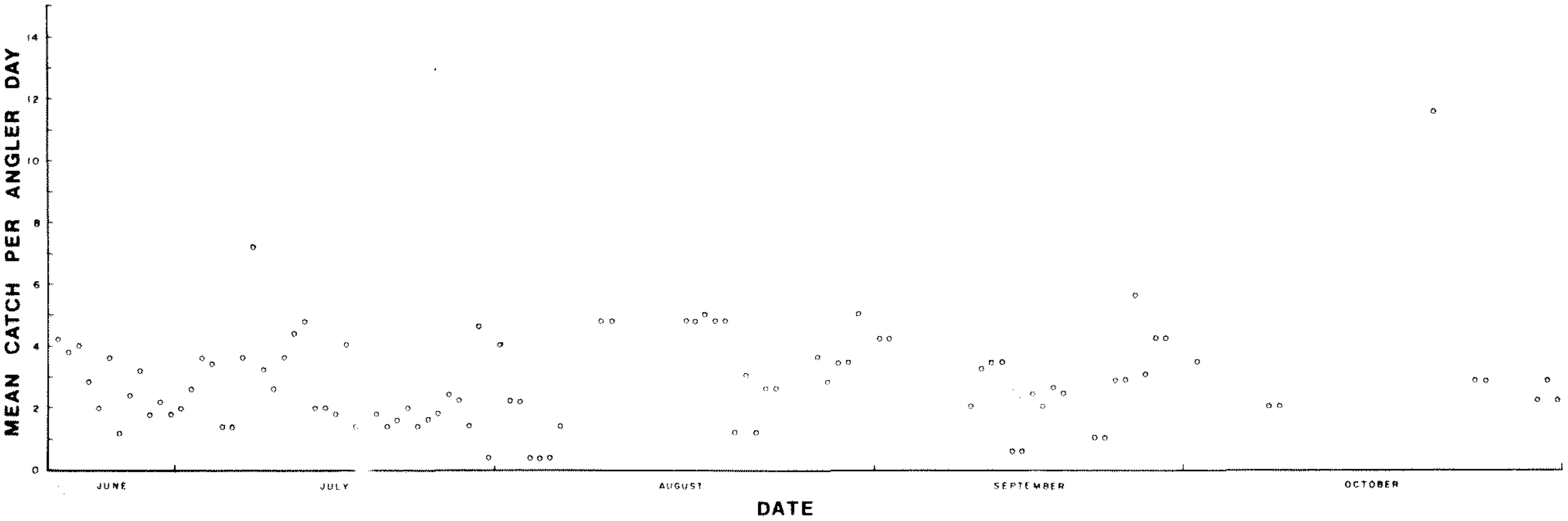


FIGURE 3.6-3

CATCH PER ANGLER DAY

All Areas

1971



5/8-C6 #3

TABLE 3.6-16

CATCH/ANGLER DAY BY FISHING LOCATION, 1971

Region	No. of Anglers	Angler Days	Catch	Catch/Day
Overall	655	1358	3942	2.90
River	73	139	504	3.62
Lake	209	372	1140	3.06
"Other"	16	47	98	2.08

Since most fishermen did not indicate locality of fishing, the data were combined for an overall analysis. River, lake and other catches are also tabulated as the information was provided.

3.6.2.5 Total Estimated Angler Catch, 1971

South End of Ross Lake

(by Fisheries Research Institute)

The catch of anglers entering from the south end of Ross Lake was determined from creel census data obtained by the Washington Department of Game.

For days on which a creel census was conducted, it was assumed that all anglers were interviewed, thus the complete daily catch was determined. For non-creel census days, indirect means were employed to determine daily catch. From the south end creel census, the following seasonal averages were determined:

1. The average fishing day length was 5.2 hours. This value does not include June 19, 1971 (opening day) which was an exceptionally long fishing day (9.9 hours).

2. The average catch per unit of effort (CPUE) was 0.47.
3. The average number of fishermen per boat was 2.59.

In addition, a direct measure of fishing effort is required to determine daily catch on non-creel census days. For the south end of Ross Lake, Dameron's resort is the only source of boats available to south end anglers. Thus the number of boats fishing out of Dameron's resort provides the best daily estimate of fishing effort. The number of boats not used for fishing is assumed to be negligible in the estimate. By multiplying the daily effort (number of boats out of Dameron's resort) by the above seasonal values, the daily angler catch can be estimated. These daily catch estimates were then summed with the catches on census days to provide a seasonal catch of 7789 fish for the south end of Ross Lake.

North End of Ross Lake

(by Fisheries Research Institute and F.F. Slaney and Co.)

The estimate of the season total catch by anglers entering at Hozomeen (north end of Ross Lake) could not be made as directly because it was not possible to census all anglers on creel census days. Therefore, the fishing effort must be computed indirectly from boat count information. Data on catch per hour, length of fishing day and number of anglers per boat were obtained from creel census or completed trip forms. Catch per angler hour changed little over the season and the seasonal averages for the fishing day length and number of anglers per boat also appear to be adequate.

Counts of number of boats entering the Hozomeen area were kept on most weekends and holidays at a road check point. Adjustments were made to approximate the number of boats fishing each day on weekends and holidays. Generally no counts were available for week days except Fridays. To estimate north end boats out on weekdays, the ratio of week day to weekend boats out at the south end was applied to the north end. The details of the estimation procedures are given in Appendices 46 and 47.

The estimated season catch by anglers entering the lake at Hozomeen is 28,763 legal-size fish. While this estimate involves a number of approximations, it is believed to be a reasonable estimate, since boat distribution counts on the lake on opening weekend, July 1-5 and October 10-11, indicate that effort by anglers entering at Hozomeen was approximately 3-1/2 to 4 times that of anglers entering at Ross Dam.

Skagit River

(by F.F. Slaney and Company)

The calculation of catch is based on the assumption that a random sample of angler effort and catch is available and raising this value by an appropriate fraction will relate the sample size to the total.

The Skagit River was divided into four sections, A, U, M and F. The sections were split up into units approximately 1/2 mile in length so as to facilitate sampling (see Map 3).

The region was sampled randomly throughout the fishing season. The random sample was based both on day and area. Due to the nature of censusing, the selection of daily sample areas for sections A and U were combined as was M and F. Consequently, the estimates derived are legitimate only for either of these two sections combined or for the total. Individual values for A, U, M and F can only be estimated as the determination of numbers from these separate sections would be subject to sample bias.

Data collected in the course of the census included the number of sections actually surveyed, number of fishermen observed, their catch and information as to the time spent on fishing. It should be emphasized that this latter figure was measured from the time fishing started to the time of interview and was not the length of the fishing day.

An independent volunteer census provided information of fish catch, number of anglers and associated data that gave an estimate of catch per unit of effort per day. These data were collected on the angler hand-out forms (see Figure 3.6-2). The catch per unit of effort per day data from the two methods made it possible to accurately determine the number of hours actually spent fishing.

The calculations were performed as follows: the fraction of the sections surveyed was obtained by dividing the total number of survey sections by the number of sections actually surveyed. The number of sampled fishermen was obtained from the creel census. The estimated number of fishermen is determined by multiplying the sampled fishermen by the survey fraction. The catch per unit of effort until time of interview is obtained from the creel census. The catch per unit of effort multiplied by the estimated number of fishermen provides total catch per hour. As previously noted the number of hours in a fishing day can be determined from the independent estimates of CPUE. The catch for a given day is obtained by multiplying the catch per hour by the number of hours in a fishing day.

Because of possible different degrees of fishing on weekends as opposed to week days it is advisable to stratify the data according to these categories. Thus, the total number of weekend days in the fishing season less selected days, divided by the number of weekend days sampled multiplied by the sum of catch for censused days provides the total catch for weekend days. Similarly, the catch for week days can be determined.

These two sums give the grand total of catch for the season.

In addition to random samples some censused data were obtained on selected days. These were usually chosen to take account of holiday effort or other such special occasions. These selected days were not included in the aforementioned ratio calculations but the catch obtained on these days was added to the totals.

Using the procedure as described two estimates of catch are available - overall and by paired sections. The catch estimates are as follows. The overall catch for the season based on a mean eight hour fishing day was 4026 fish taken by an estimated 2066 fishermen. The paired sections estimates were:

Area	A + U	M + F	Totals
catch	222	2373	2595
fishermen	154	1228	1382

Estimates of the number of fish taken from each of the four sections have not been attempted from the basic data. It will be clear from the distribution of fishing effort, however, that the vast majority are in the sections M and F. Within these regions an attempt was made to determine fishermen by section. It must be recognized that these estimates may be biased. The estimates are:

Area	Fishermen
A	67
U	58
M	213
F	988

Some empirical adjustment is possible and working values for the four sections might be 85, 70, 225 and 1000 fishermen respectively. The mean catch per unit of effort for the river can be applied to these values to give biased catch estimates as follows:

Area	Catch
A	190
U	157
M	504
F	2240
	3091

On the assumption that the environmental assessments are to consider the "worst possible" case, the extreme value for catch, i.e. 4026 fish and 2066 fishermen, should be used.

3.6.2.6 Ross Lake, 1972

Methods

In 1972 the Ross Lake creel census included the complete fishing season from opening day on 17 June through the close of the season on 31 October. For the 1972 creel census two approaches were used. One included on-lake boat and angler counts plus brief angler interviews to assess fishing effort and catch per unit of effort on the lake. The sampling effort was randomized by day of the week throughout the season, time period during the day, and lake section.

The second method was essentially similar to that carried out in 1971 and described in section 3.6.2.2. By this approach, lake entry point sampling was carried out and anglers were questioned as to their personal characteristics, preferences, catch, and effort upon returning to sampling stations on the shore of the Lake. For these angler interviews the format was the same as utilized in 1970 and 1971 and described in section 3.6.2.1 (Methods) and Appendix 40.

On-lake sampling took place on 49 days chosen randomly by day of the week throughout the season, plus 3 additional days (opening day, Dominion Day, Labour Day). Sampling days were divided into 7, 2-hour time periods from 0600 to 2000. The lake was divided into the 7 sections (L1 through L7) described previously. Sampling days, time periods and locations were selected at random and pre-determined before the field season commenced. Sampling effort was distributed evenly across the days of the week, time periods and lake sections.

Field samplers arrived at the specified location during the specified time period. Once there, they counted anglers and numbers of boats in that section and noted the time of the count. Up to 10 anglers within the lake section were questioned on the lake about the length of time they had been fishing and the number of fish they had taken. This abbreviated angler interview was an attempt to minimize interference with anglers' fishing and still provide accurate effort and catch data by lake section. The only exception to this procedure was on the three additional days when attempts were made to count boats and anglers in each lake section during each time period. When more than 10 anglers were found in the given section a randomized procedure for sub-sampling within the section was available. By this procedure the lake section was mentally divided into 15 sub-sections which were sampled in a predetermined, random order until 10 anglers had been interviewed.

In proceeding to or from the selected lake section counts of anglers and boats were made by section and the time of these counts noted. In most cases it was possible, therefore, to get counts of all sections of the lake within the chosen 2-hour time period. Angler interviews were carried out only within the selected section, however.

The Ross Lake sampling schedule for 1972 showing dates, time periods and locations of sampling is reproduced in Appendix 45. Also found in Appendix 45 is the series of sequences of random numbers utilized to sub-sample anglers within lake sections.

The Sample

A total of 434 interviews of lake anglers from the lake entry point sampling only is the basis for the analysis in this section.

Anglers

Male fishermen made up 78.8% (342) of the lake anglers interviewed in 1972; females were 21.2% (92) of the sample. The age distribution of the anglers in the sample is shown in Table 3.6-17.

TABLE 3.6-17

AGE DISTRIBUTION OF LAKE ANGLERS, 1972 SAMPLE

AGE	NUMBER	PERCENT
Children	49	11.3
Teenagers	25	5.8
20 - 29	25	5.8
30 - 39	83	19.1
40 - 49	135	31.1
50 +	117	27.0

The duration of whose visit was noted, 301(91.5%) were overnight campers in tne area while the remainder were day fishermen only.

Of the lake anglers answering the question, 13(7.9%) preferred stream fishing, 116 (70.3%) preferred lake fishing and 96 (21.8%) had no preference. Of the lake anglers reporting on their success, 21 (11.5%) considered their success excellent, while 56 (30.6%) reported good success; 106 (57.9%) reported their success as poor.

Distribution of Anglers and Fishing Methods

The distribution of the anglers across the seven lake sections in the sample is shown in Table 3.6-18.

TABLE 3.6-18

DISTRIBUTION OF LAKE ANGLERS, 1972 SAMPLE

AREA	NUMBER	PERCENT
L-1	76	17.5
L-2	52	12.0
L-3	31	7.1
L-4	32	7.4
L-5	67	15.4
L-6	157	36.2
L-7	19	4.4

Fishing techniques used by fishermen in the 1972 sample are shown in Table 3.6-19. The "combination" was primarily bait (e.g. worms) and lures ("pop gear") that were trolled behind the boat, as in previous years. Total fishing effort in the 1972 sample was 1805.8 hours. Average fishing period of anglers in the sample was 4.16 hours.

TABLE 3.6-19

FISHING TECHNIQUES USED BY LAKE ANGLERS, 1972 SAMPLE

METHOD	NUMBER	PERCENT
Flies	5	1.2
Lures	23	5.3
Bait	66	15.2
Combination	340	78.3

Fishing time started anywhere between 4 A.M. and 8 P.M. but 75.3% of the fishing began between 6 A.M. and 12 noon.

Catch

The total catch by anglers in the 1972 sample was 1027 fish, 1022 of which were of legal size (6" in U.S., 8" in B.C.) and are utilized in the following analysis. Species composition of the legal catch was 961 (94.0%) rainbow trout, 37 (3.6%) Dolly Varden char, 3 (.3%) brook trout, 1 (.1%) cutthroat trout and 20 (2.0%) others.

Total legal catch, overall CPUE and mean CPUE are shown in Table 3.6-20.

TABLE 3.6-20

CATCH, OVERALL AND MEAN CPUE BY LAKE AREA, 1972 SAMPLE

AREA	CATCH	OVERALL CPUE	MEAN CPUE
L-1	196	0.57	0.70
L-2	221	0.80	0.98
L-3	101	0.72	0.72
L-4	95	0.43	0.42
L-5	129	0.52	0.62
L-6	257	0.46	0.52
L-7	23	0.53	0.48
All areas	1022	0.56	0.63

3.6.2.7 Skagit River System, 1972

(by F.F. Slaney & Company)

Methods

The creel census sampling in 1972 on the Skagit River system was carried out on the same days as the sampling on Ross Lake (see section 3.6.2.6 above). Thus, sampling was carried out on 49 days selected at random throughout the season, plus 3 additional days when attempts were made to sample all sections.

Sampling sections (see Map 3) within the four areas (F, M, U, and A) of the Skagit River system were predetermined and selected at random. Time periods were also chosen randomly. Sampling effort over the season was proportional to the size of the area.

Field workers sampled the specific section noted at the given time. Sampling was also done within the entire area as time and density of anglers permitted. Due to the small numbers of anglers encountered, however, the sampling was still limited.

The angler interview format was the same as described previously in section 3.6.2.1 (Methods) and shown in Appendix 40. The detailed sampling schedule for the Skagit River system 1972 creel census, showing date, time period and location of sampling is reproduced in Appendix 41.

The Sample

The 1972 Skagit River creel census analysis is based on interviews with 22 river anglers.

Anglers

Of the river fishermen in 1972, 77.3% (17) were male while 22.7% (5) were female in the sample. Age distribution of this sample is given in Table 3.6-21.

TABLE 3.6-21

AGE DISTRIBUTION OF RIVER ANGLERS, 1972 SAMPLE

AGE	NUMBER	PERCENT
Children	0	0
Teenagers	4	18.2
20 - 29	4	18.2
30 - 39	0	0
40 - 49	9	40.9
50 +	5	22.7

All of the anglers in the sample were residents of British Columbia. Seventeen of the total (77.3%) were camping in the area, while the remainder were day fishermen.

Of the anglers responding to the question, 11 (57.9%) preferred stream fishing, 4 (21.1%) preferred lake fishing, and the remaining 4 (21.1%) had no preference. Of the 15 anglers responding, 2 (13.3%) felt their angling success was excellent; 8 (53.3%) felt their success was good, while 5 (33.3%) said their fishing success was poor.

Distribution of Anglers and Fishing Methods

Anglers in the sample were distributed between the four major areas of the Skagit River system as shown in Table 3.6-22.

TABLE 3.6-22

DISTRIBUTION OF RIVER ANGLERS, 1972 SAMPLE

AREA	NUMBER	PERCENT
A	0	0
U	0	0
M	7	31.8
F	15	68.2

Techniques used by anglers in fishing in the Skagit River system are shown in Table 3.6-23.

TABLE 3.6-23

FISHING TECHNIQUES USED BY RIVER ANGLERS, 1972 SAMPLE

METHOD	NUMBER	PERCENT
Flies	1	4.5
Lures	1	4.5
Bait	17	77.3
Combination	3	13.6

The total fishing effort in the sample was 63.2 hours. Average fishing period of anglers in the sample was 2.87 hours.

Fishing began between 6 A.M. and 4 P.M. but 81.8% of the anglers in the sample began fishing between 6 A.M. and 11 A.M.

Catch

Total catch of fish by river anglers in the 1972 sample was 24 fish. Of these, 23 (95.8%) were legal size and are considered in the following analysis. Species composition of the legal catch was 22 (95.7%) rainbow trout and 1 (4.3%) brook trout.

Total legal catch, overall CPUE and mean CPUE are shown for the river sample in Table 3.6-24.

TABLE 3.6-24

CATCH, OVERALL AND MEAN CPUE BY AREA, 1972 SAMPLE

AREA			
A	0	0	0
U	0	0	0
M	5	.14	.13
F	18	.61	.60

3.6.2.8 Total estimated angler catch, 1972

Ross Lake and Canadian Skagit River
(by Fisheries Research Institute)

The catch of anglers in Ross Lake in 1972 was calculated on the basis of fishing effort and CPUE information obtained from on-lake boat interviews and angler counts as described in Section 3.6,2.6 A total of 161 anglers was interviewed. From the data obtained the following seasonal averages were calculated:

1. The 161 angler sample effort was 521 hours; the catch was 270 fish giving a CPUE of 0.52.

2. The average number of angler hours of effort per week day was 274.4 (excludes holidays).

3. The average number of angler hours of effort per weekend day was 995.4 (excludes holidays and opening day).

The above effort averages when multiplied by CPUE (0.52) and number of week days (95) and weekend day (40) respectively in the fishing season provided a catch estimate of 34,259. The catches for June 17, July 3 holiday, and Labor Day holiday were determined separately using the method described above and were 2,175, 706, and 240 fish respectively, providing a total estimated catch of 37,380 fish in the lake.

Data collected in 1972 were inadequate to estimate the Canadian Skagit River catch. If the percentage of the total Ross-Skagit catch taken in the River was comparible to that of 1971 (9.8 percent), 4,061 fish were captured by anglers in the Canadian Skagit River in 1972.

The total sport catch estimate for the Ross-Skagit system from June 17 to October 31, 1972 is 41,441 fish. The 1972 total catch estimate is very similar to the 1971 catch estimate (40,578).

Additional information on visitor-use of the Skagit-Ross area as determined from counts made at the Hozomeen entrance at the northend of the lake shows that recreational use of the area in both years was nearly the same and thus gives further support to the accuracy of the catch estimate. The visitor use data, provided by the U.S. National Park Service, follows:

	1971	1972
Vehicle count (traffic counter)	6,886	6,662
Estimated visitors in vehicles	25,377*	18,498
Campers using recreational vehicles	7,651	6,666
Campers using tents	3,079	3,665
Total campers (camper days) **	10,730	10,331

* This figure may be high and is not as accurate as the 1972 figure.

** A camper day represents one person camping overnight.

3.6.2.9 Discussion

(by F.F. Slaney & Company Limited)

Ross Lake vs Skagit River System, 1971

Anglers

More of the anglers on the Skagit River system in 1971 were male (88.3%) than on Ross Lake (75.2%). As a rule, the lake fishermen were older than river fishermen. This is illustrated strikingly by the fact that 55.8% of the Ross Lake anglers were over 40 years of age, while 66.1% of the river anglers were less than 40 years of age. Lake fishermen were predominately residents of Washington (91.8 percent) while river fishing was dominated by British Columbia residents (91.1 percent). Only 2.5 percent of lake fishermen came for the day while 32.1 percent of the river anglers were fishing for the day only.

Of those responding to the optional questions on fishing preference, about equal proportions of anglers fishing on the lake (13.9 percent) and in the river (15.0 percent) preferred neither lake nor stream fishing to the other. A greater proportion of anglers fishing on the lake preferred lake fishing (74.9 percent) than stream anglers preferred stream fishing (61.2 percent). Conversely, 11.2 percent of those fishing on the lake preferred to fish in streams while 13.8 percent of those fishing on the river preferred to fish in lakes.

On the second optional question of fishing success, 58.3 percent of lake fishermen who responded rated their success excellent or good. Of the river fishermen, 30.1 percent rated their success either excellent or good.

Bait (12.0 percenf) and combination techniques (82.2 percent) (usually worms and "pop gear") were used primarily in lake fishing. On the river bait (70.0 percent) and combination techniques (15.8 percent) were again predominant. Fly fishing was employed by 9.9 percent of the sample.

Catch

In both lake (97.9 percent) and stream (89.6 percent) fishing the predominant species taken is rainbow trout.

Legal catch per hour of fishing in the lake is very close to 0.50 by both measures (overall and mean CPUE). This indicates an average legal catch of one fish every two hours. This rate of fishing success is approached on the river (in terms of overall CPUE) only in Area M. The average overall CPUE for the river is 0.28 or one fish every 3.6 hours. Mean CPUE's are higher than overall CPUE's on the river, although sample sizes are small in some cases. The data used for angler day calculations were angler-provided and indicated catch/angler day varies from 2.08 to 3.62 fish in different areas. They indicate larger average daily catches in the river (3.62) than on the lake (3.06). There were no increasing or decreasing trends in catch/angler day through the 1971 season.

Total estimated catch of legal-sized fish from the Ross Lake-Skagit River system during 1971 was 40,578 fish. Of the total, an estimated 7789 (19.2 percent) were taken by anglers who entered Ross Lake from the south end. Catch by anglers entering the lake from the north end is estimated at 28,763 fish (71.0 percent of the total). Skagit River total catch for the season is estimated at 4026 fish which represents 9.8 percent of the total catch from the system.

Although the methods utilized for collecting and analyzing creel census data in 1971 differed in detail from those of previous years, a general comparison of results is useful.

An examination of past catch per angler day data from Ross Lake (Table 3.6-2) shows considerable fluctuation from year to year with a downward trend in numbers of fish caught over the years (Figure 3.6-1). The 1971 data (catch per angler day = 3.1) are consistent with the general trend.

Table 3.6-3 shows overall catch per angler hour (CPUE) for the Skagit River above 1602.5 feet elevation over the years 1962 through 1967. There is no apparent trend in river fishing success during this time. The overall CPUE for all areas sampled on the Skagit River in 1971 was 0.28 (Table 3.6-7) and falls within the range observed in the past.

3.7 POPULATION SIZE, MOVEMENTS AND MORTALITY

3.7.1 Introduction

Population size of the fish as well as their movements are important factors in studying the fish and the fishery of the Ross Lake-Skagit River system. These data, combined with a knowledge of the growth and mortality rates of the fish, provide a basis for estimating the effects of a changed environment on the population dynamics of the species.

3.7.2 Distribution and Movements

(by Fisheries Research Institute)

3.7.2.1 Lake

Information on the movements of fish in Ross Lake was provided by tag recoveries from angler and investigator catches and by sonic surveys.

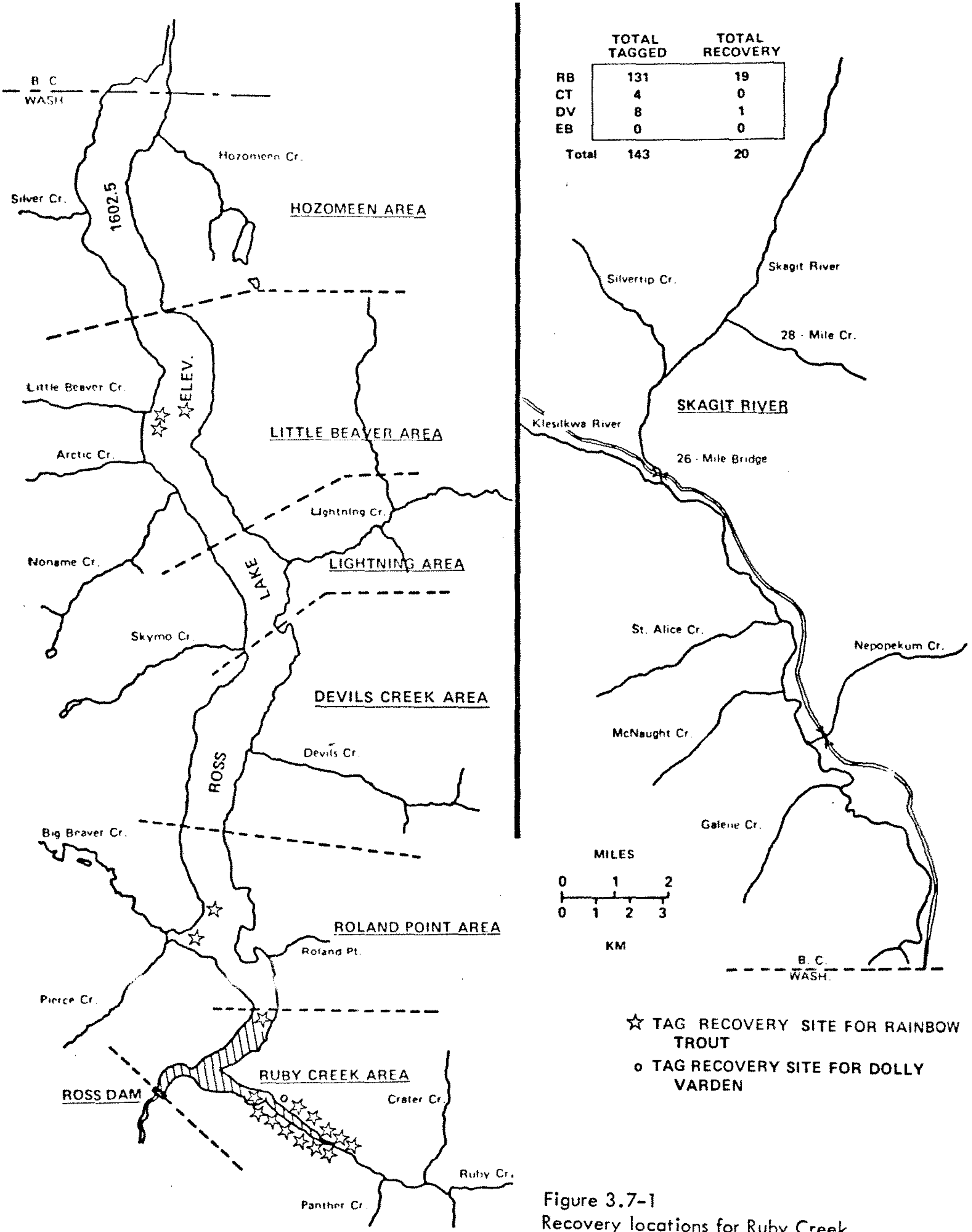
Results from Tagging 1971

A total of 514 rainbow trout, 21 cutthroat trout, 33 Dolly Varden, one brook trout was tagged and released in Ross Lake and the Canadian Skagit River in 1971. Recoveries of tagged fish were made by anglers and by research personnel. Large signs describing the program of studies were placed at five locations in the Ross Lake vicinity to acquaint anglers with the research efforts. A box, provided with each sign, contained information sheets with a map of Ross Lake and the Canadian Skagit River (Figure 3.6-2). The posted directions requested the anglers to provide information on their tag recoveries and to return it to the deposit boxes, research personnel in the area, or by mail. Anglers fishing on Ross Lake and the Canadian Skagit River were censused by representatives of the Washington Department of Game and F.F. Slaney & Company Limited of Vancouver, B.C. For the 1971 fishing season, the angling public made

84 percent of the tag recoveries.

Distribution of tag recoveries by tagging area and species is given in Figures 3.7-1 through 3.7-7. Appendix 49 presents the location and date of tagging and recoveries for recovered tagged fish. The duration in time from tagging to recovery for each tag recovery is also calculated. Table 3.7-1 presents the number of tags released and recovered by species for each tagging area. Appendix 50 gives the full data taken at time of tagging for each recovered tagged fish as well as data taken at time of recovery.

The pattern of tag recoveries shows considerable movement of rainbow trout in the lake and some movement into the Skagit River during the period of tagging and recovery (April through October, 1971). Figure 3.7-8 is a schematic diagram of the 1971 tag release and recovery locations. Fish tagged in the Lightning Creek area showed the greatest variation in the pattern of movement. Fish tagged in this area were recovered in every tagging area although more were recovered north of the Lightning Creek area than south of the area. This undoubtedly reflects in part, the greater fishing effort toward the north end of the lake. Ten rainbow trout tagged in the lake were recovered in the Canadian Skagit River. Only one of these came from the three tagging areas to the south of the Lightning Creek area, although more than half of the tagged fish were released in these areas. Due to the small number of tags recovered from cutthroat trout and Dolly Varden char in 1971, little can be said about their movements within the lake. Most of the cutthroat trout tagged in the lake were captured around the mouth of Big Beaver Creek and five out of the six cutthroat tag recoveries were made here. One Dolly Varden tagged at Lightning Creek mouth was recovered in the Canadian Skagit River.

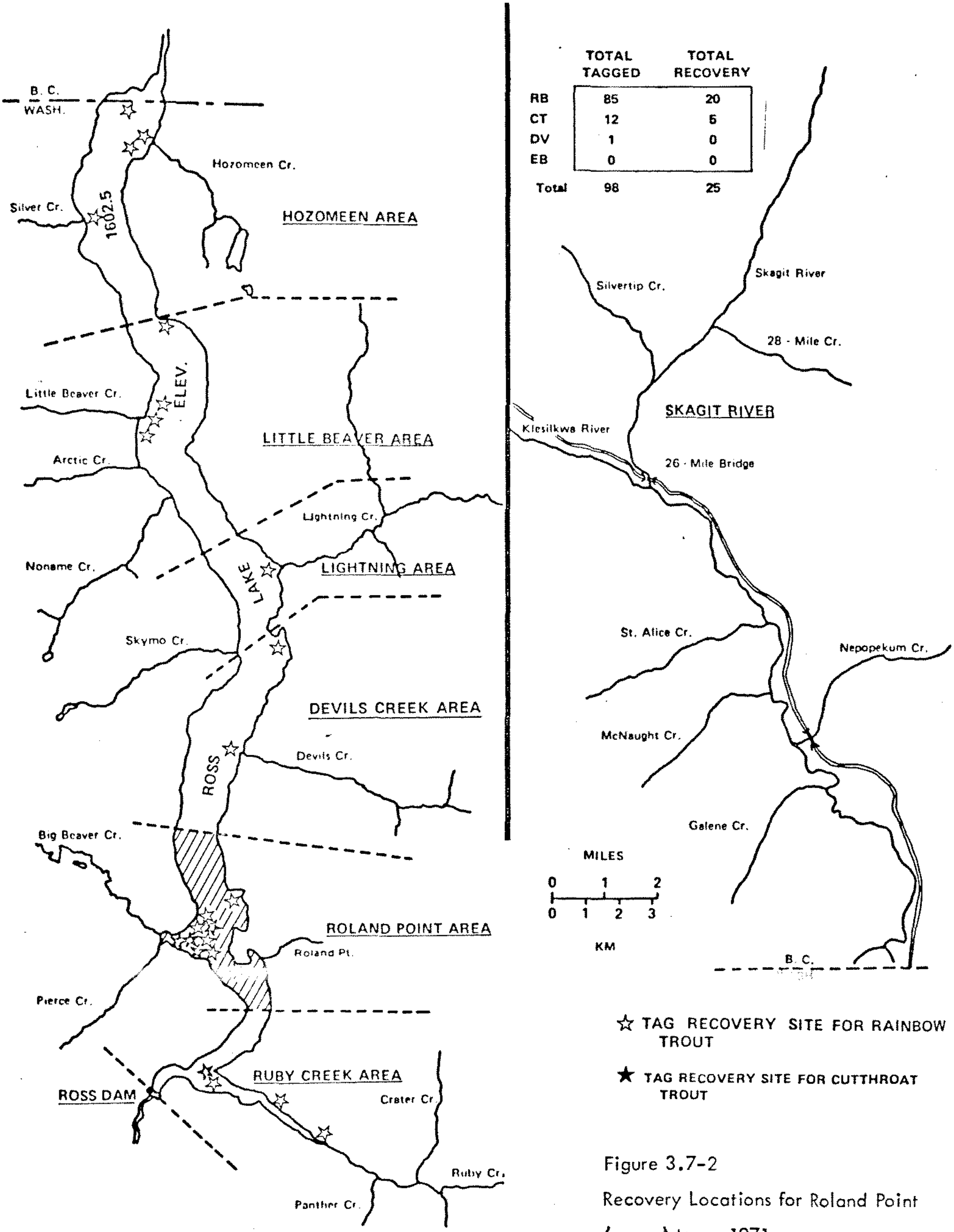


	TOTAL TAGGED	TOTAL RECOVERY
RB	131	19
CT	4	0
DV	8	1
EB	0	0
Total	143	20

☆ TAG RECOVERY SITE FOR RAINBOW TROUT

o TAG RECOVERY SITE FOR DOLLY VARDEN

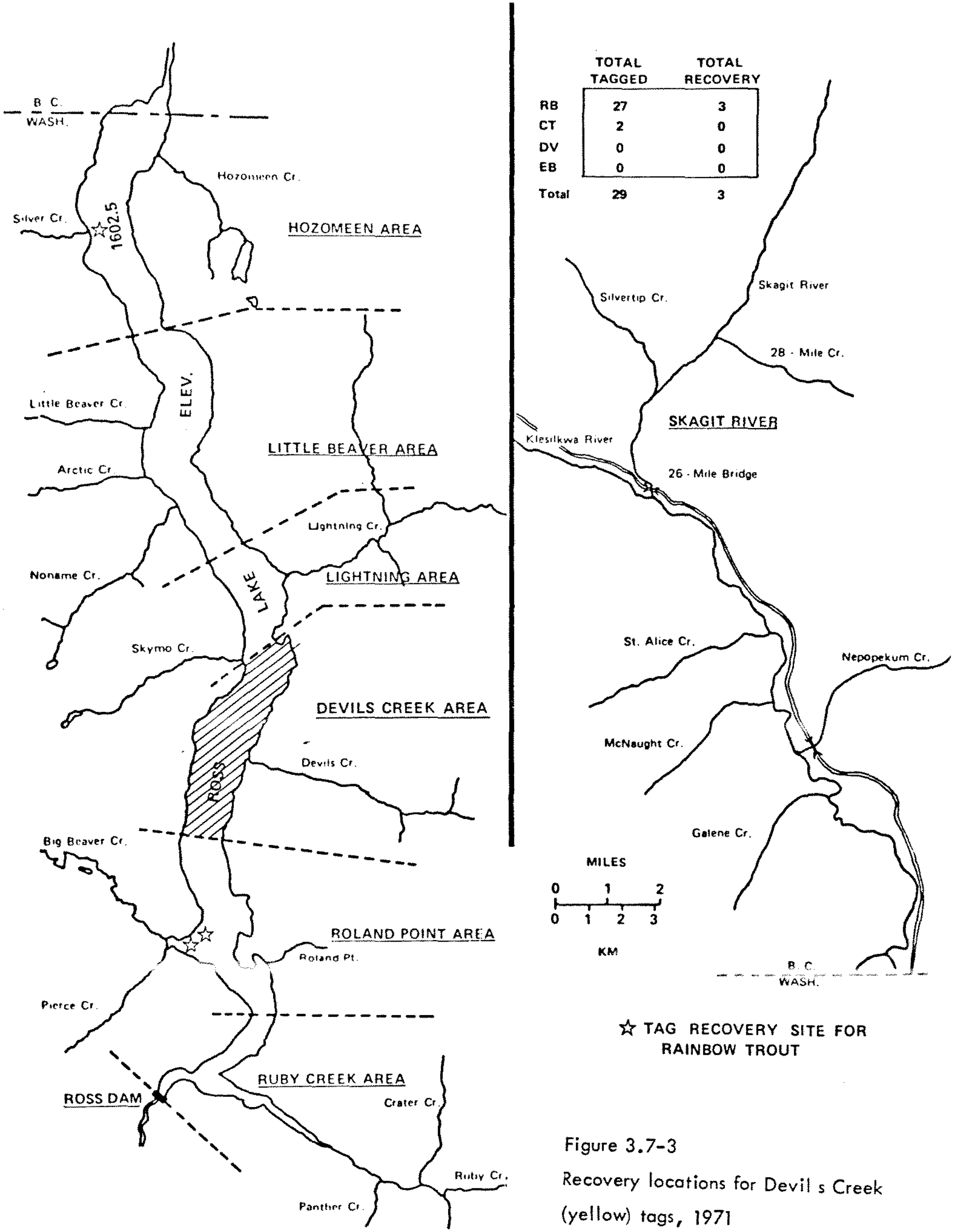
Figure 3.7-1
Recovery locations for Ruby Creek (blue\ tags,1971. The exact location of recovery for blue tag No. 26 in the Skagit River is unknown.



	TOTAL TAGGED	TOTAL RECOVERY
RB	85	20
CT	12	5
DV	1	0
EB	0	0
Total	98	25

Figure 3.7-2

Recovery Locations for Roland Point (green) tags, 1971

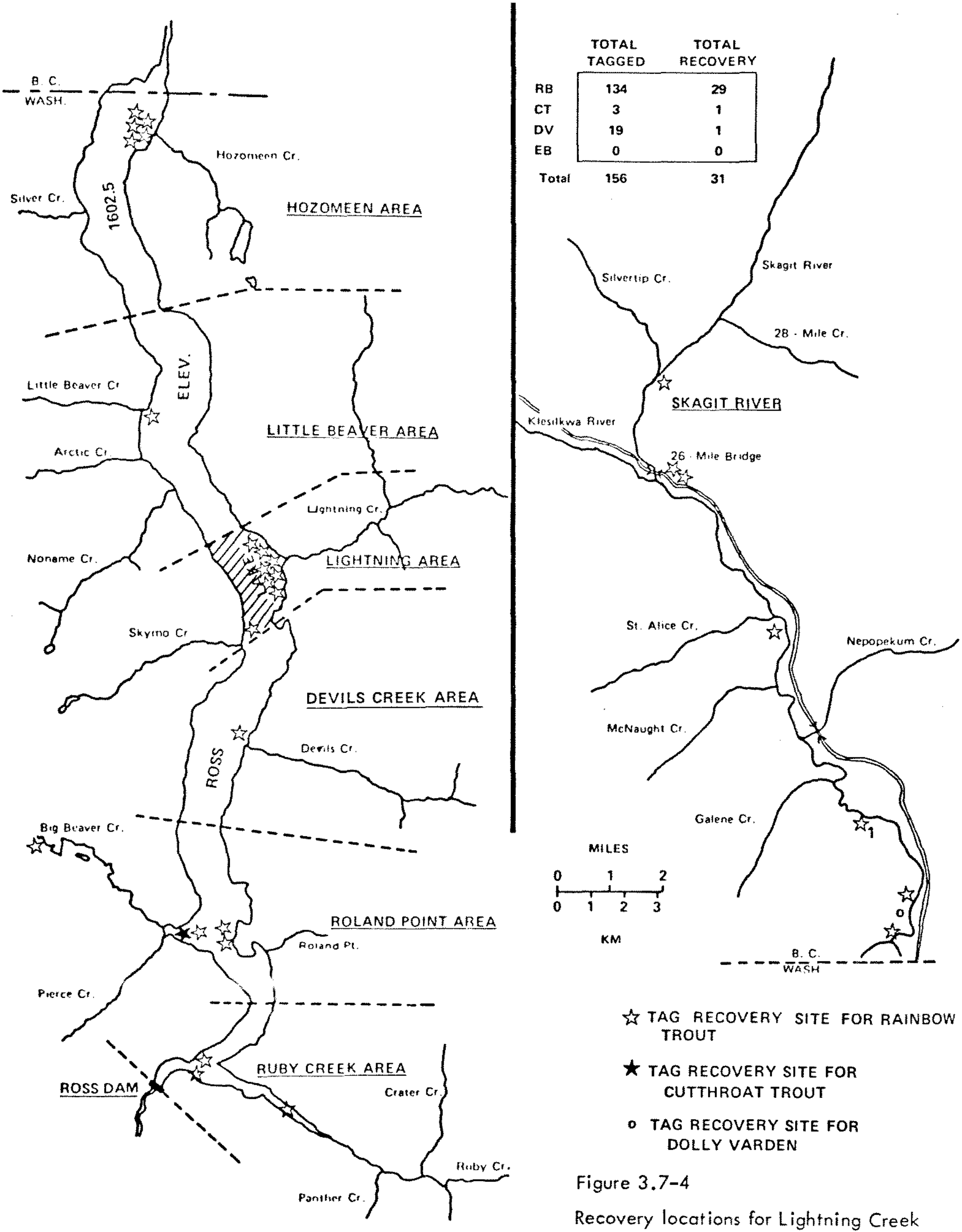


	TOTAL TAGGED	TOTAL RECOVERY
RB	27	3
CT	2	0
DV	0	0
EB	0	0
Total	29	3

☆ TAG RECOVERY SITE FOR RAINBOW TROUT

Figure 3.7-3

Recovery locations for Devil s Creek (yellow) tags, 1971



	TOTAL TAGGED	TOTAL RECOVERY
RB	134	29
CT	3	1
DV	19	1
EB	0	0
Total	156	31

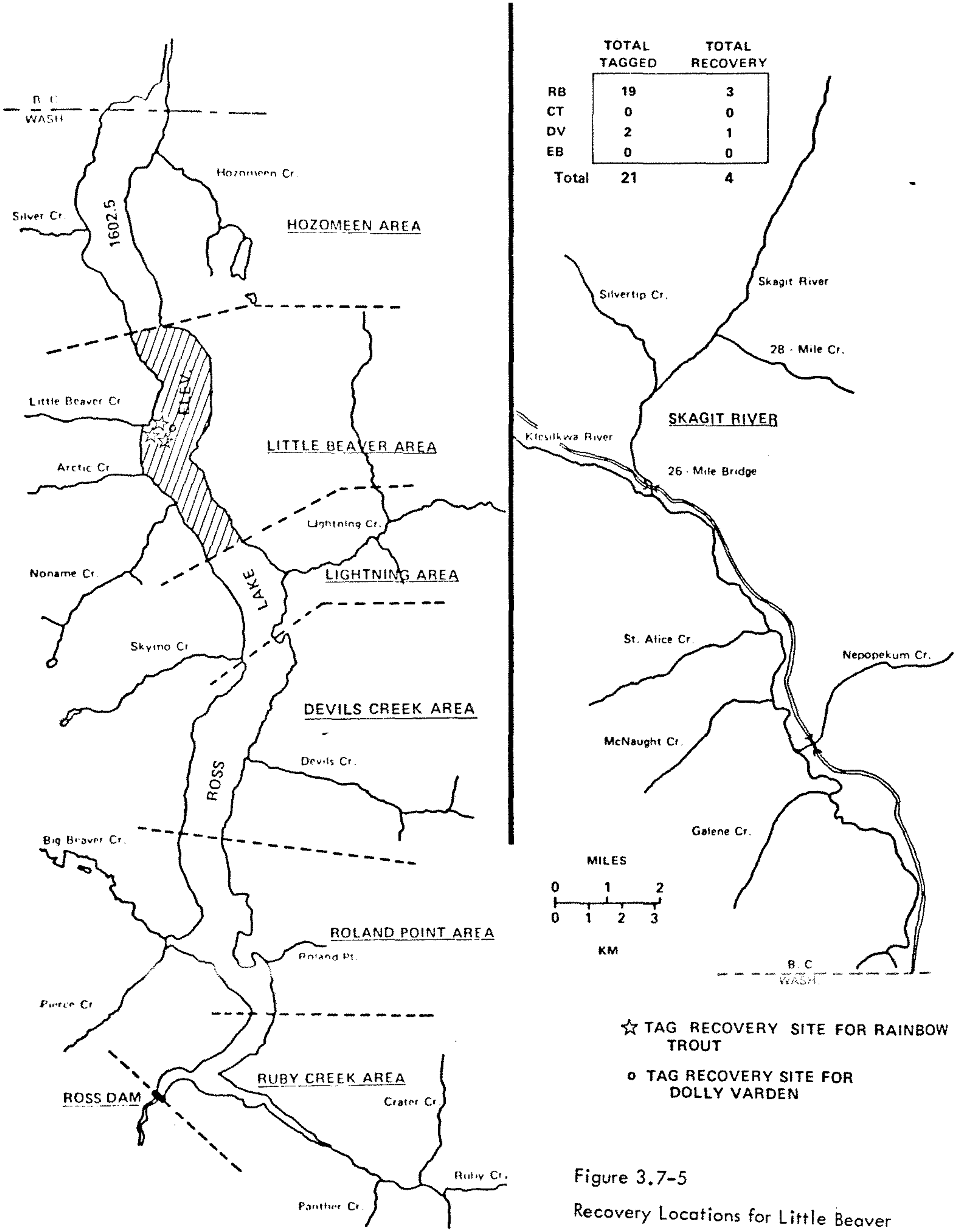
☆ TAG RECOVERY SITE FOR RAINBOW TROUT

★ TAG RECOVERY SITE FOR CUTTHROAT TROUT

o TAG RECOVERY SITE FOR DOLLY VARDEN

Figure 3.7-4

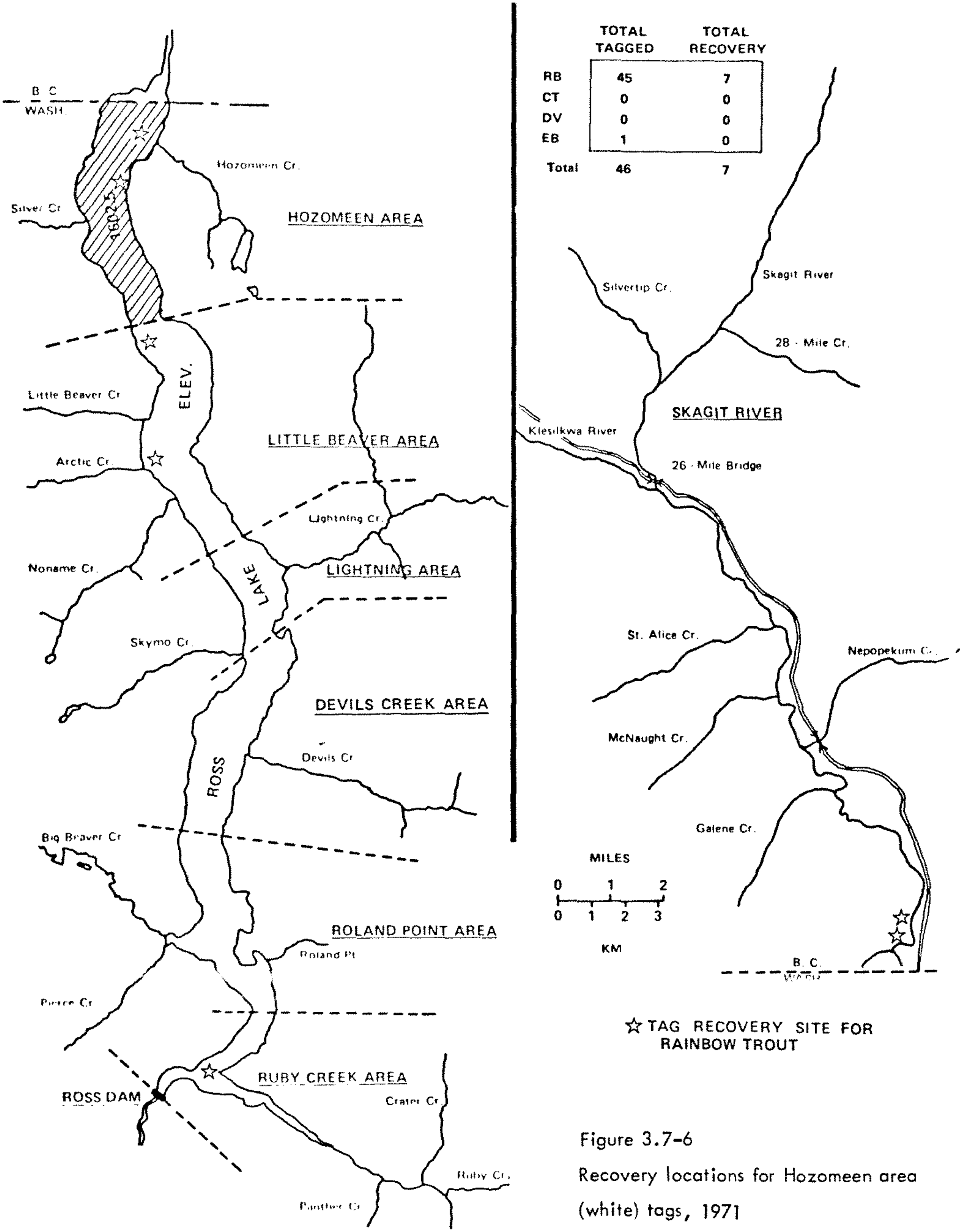
Recovery locations for Lightning Creek (orange) tags, 1971. The exact location of recovery for orange tag No. 28 in the Skagit River is unknown.



	TOTAL TAGGED	TOTAL RECOVERY
RB	19	3
CT	0	0
DV	2	1
EB	0	0
Total	21	4

Figure 3.7-5

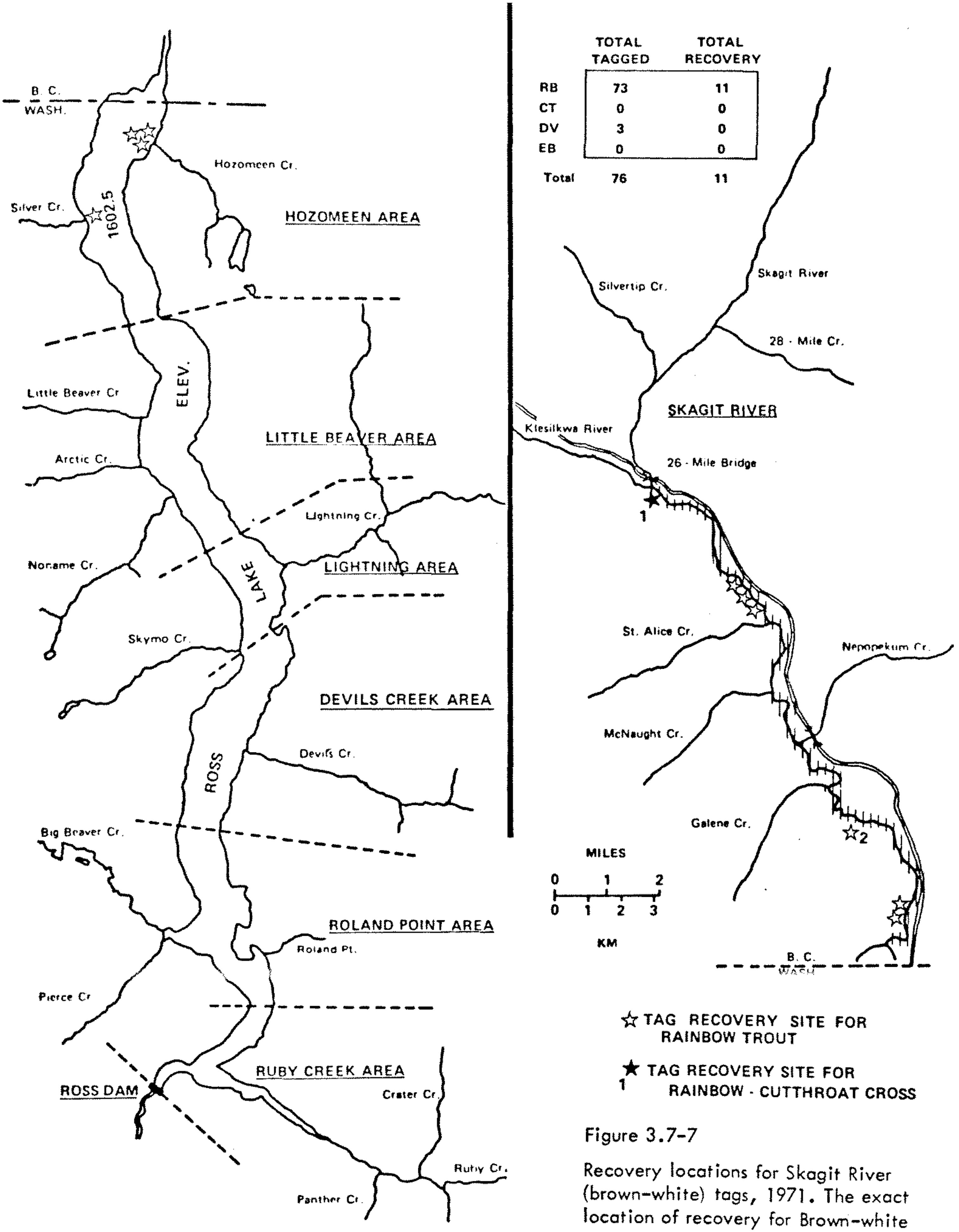
Recovery Locations for Little Beaver Creek (red) tags, 1971



	TOTAL TAGGED	TOTAL RECOVERY
RB	45	7
CT	0	0
DV	0	0
EB	1	0
Total	46	7

Figure 3.7-6

Recovery locations for Hozomeen area (white) tags, 1971



	TOTAL TAGGED	TOTAL RECOVERY
RB	73	11
CT	0	0
DV	3	0
EB	0	0
Total	76	11

Figure 3.7-7

Recovery locations for Skagit River (brown-white) tags, 1971. The exact location of recovery for Brown-white tag No. 34 in the Skagit River is unknown

TABLE 3.7-1

TOTAL TAGS RELEASED (2 APRIL-21 SEPTEMBER, 1971) AND RECOVERED FOR EACH SPECIES BY MAJOR TAGGING AREA, ROSS LAKE, 1971.

Tag recovery values represent all recoveries of a given color or area by species in all areas combined.

Major tagging area	Rainbow Trout		Cutthroat Trout		Dolly Varden		Brook Trout		Total		
	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Percent
Ruby Creek	131	19	4	0	8	1	0	0	143	20	14.0
Roland Point	85	20	12	5	1	0	0	0	98	25	25.5
Devil s Creek	27	3	2	0	0	0	0	0	29	3	10.3
Lightning Creek	134	29*	3	1	19	1	0	0	156	31	19.9
Little Beaver Creek	19	3	0	0	2	1	0	0	21	4	19.0
Hozomeen	45	7	0	0	0	0	1	0	46	7	15.2
Canadian Skagit River	73	11**	0	0	3	0	0	0	76	11	14.5
Total	514	92	21	6	33	3	1	0	569	101	17.75

*Value includes second recovery of Orange Tag No. 37.

**Value includes one rainbow-cutthroat cross.

FIGURE 3.7-8

DISTRIBUTION OF TAG RECOVERIES BY LAKE AREAS

IN 1971

LOCATION RECOVERED
South → North

LOCATION TAGGED
South → North

	Ruby Creek Area	Roland Point Area	Devils Creek Area	Lightning Creek Area	Little Beaver Cr Area	Hozomeen Area	Canadian Skagit Area
Canadian Skagit River						4 4	7 76 7 14.5%
Hozomeen Area	1 1				1 1	4 46 4 15.2%	1 1
Little Beaver Cr. Area					3 21 3 19.0%	1 1	
Lightning Creek Area	3 3	3 5 2	1 1	3 156 8 19.9% 5	1 1	5 5	6 8 2
Devils Creek Area		2 2	29 10.3%			1 1	
Roland Point Area	3 4 1	7 98 10 25.5% 3	2 2	1 1	4 4	4 4	
Ruby Creek Area	9 143 14 14.0% 5	2 2			3 3		1 1

LEGEND

9	Number of tags recovered by anglers
143	Number of tags released
14	Number of tags recovered
5	Number of tags recovered by research personnel
14.0%	Percentage of tags recovered in all areas

Fish tagging extended over a six month period with tag recovery lasting for four and one-half months. Considerable overlap existed between these two periods. The tag duration in the fishery extended from one to 205 days. The movements of the fish following tagging are unknown until the tag is recovered. The overall movement could be gradual but constant, initially rapid, or considerably delayed.

Results from Tagging, 1972

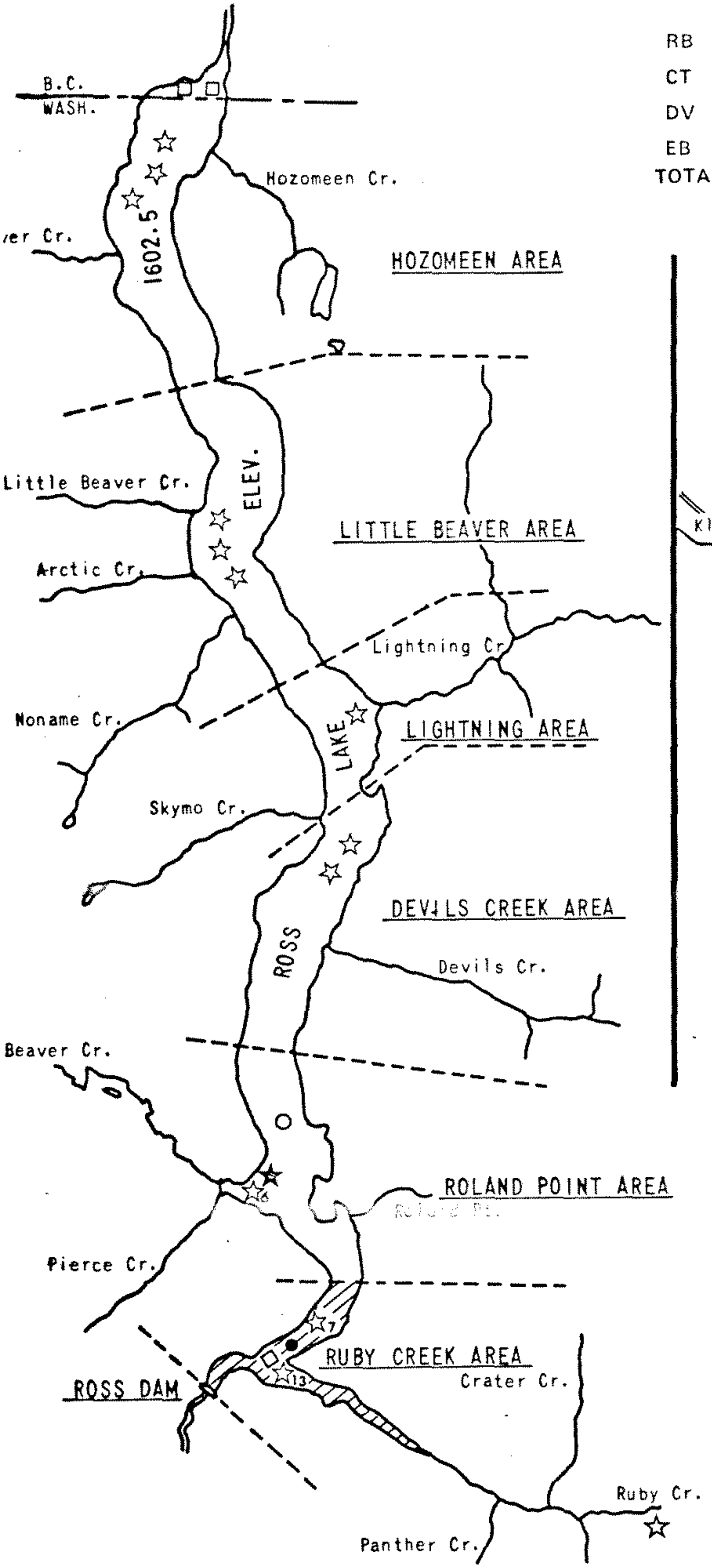
A total of 837 rainbow trout, 36 cutthroat trout, 77 Dolly Varden, and 4 brook trout were tagged and released in Ross Lake and the Canadian Skagit River in 1972. Recoveries of tagged fish were made by anglers and by research personnel. The same informational signs, sheets, and deposit boxes were used in 1972 as in 1971. Representatives of the Washington Department of Game, F.F. Slaney & Company Limited and the Fisheries Research Institute cenused the anglers fishing on Ross Lake and the Canadian Skagit River. During the 1972 fishing season, the angling public made 98 percent of the tag recoveries.

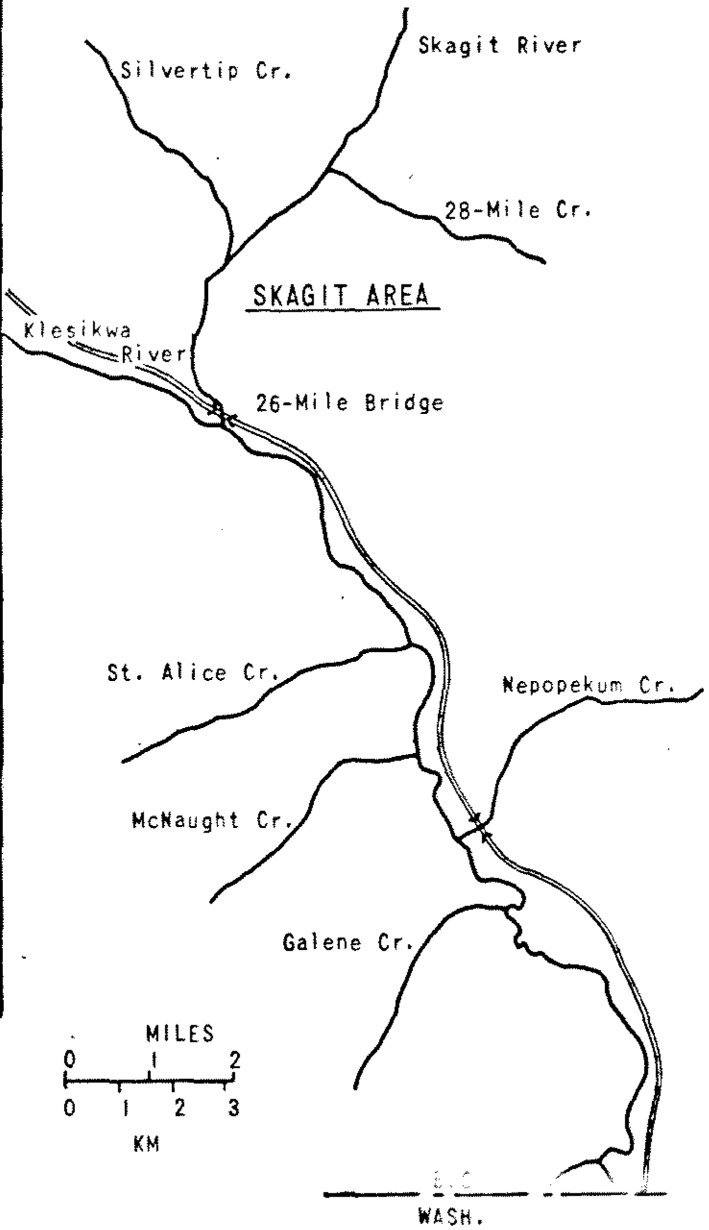
Distribution of tag recoveries by tagging area and species is presented in Figures 3.7-9 through 3.7-15. Appendix 49 presents the location and date of tagging and recovery for recovered tagged fish. The duration in time from tagging is also presented. Table 3.7-2 presents the number of tags released and recovered by species for each tagging area. All data taken at time of tagging and recovery of tagged fish are presented in Appendix 50.

The pattern of tag recoveries is shown in Fig. 3.7-16, which is the schematic diagram of the 1972 tag release and recovery location. Fish

	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS 1971	1972
RB	172	4*	36
CT	3	0	1
DV	14	1	1
EB	0	0	0
TOTAL	189	5*	38

*1 1971 RB RECOVERED IN GORGE LAKE





☆ RECOVERY SITE FOR RAINBOW TROUT TAGGED IN 1972

□ RECOVERY SITE FOR RAINBOW TROUT TAGGED IN 1971

★ RECOVERY SITE FOR CUTTHROAT TROUT TAGGED IN 1972

○ RECOVERY SITE FOR DOLLY VARDEN TAGGED IN 1972

● RECOVERY SITE FOR DOLLY VARDEN TAGGED IN 1971

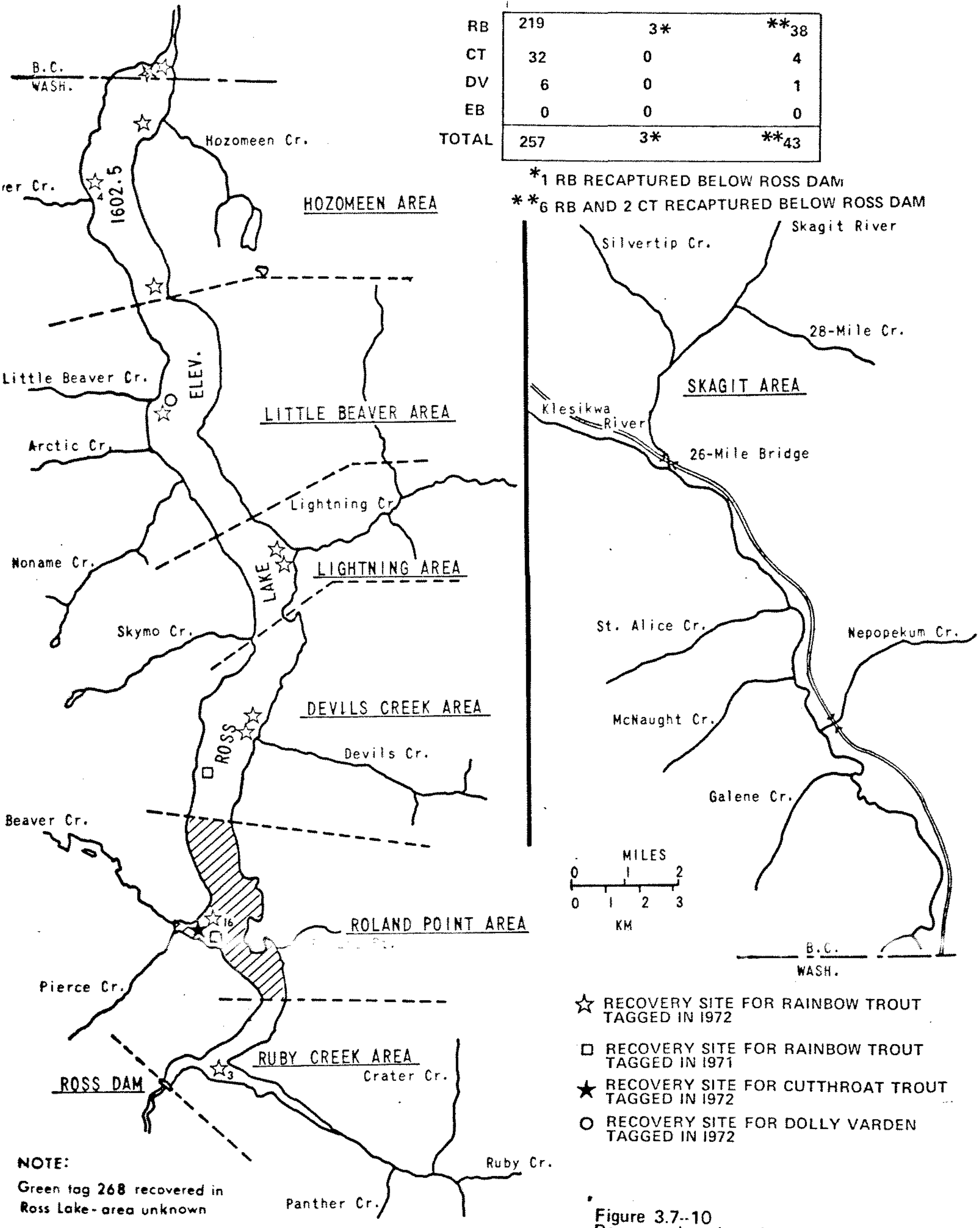
Figure 3.7-9

Recovery locations for Ruby Creek (blue tags) 1972.

	FISH TAGGED	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS	
	1972	1971	1972
RB	219	3*	**38
CT	32	0	4
DV	6	0	1
EB	0	0	0
TOTAL	257	3*	**43

*1 RB RECAPTURED BELOW ROSS DAM

**6 RB AND 2 CT RECAPTURED BELOW ROSS DAM



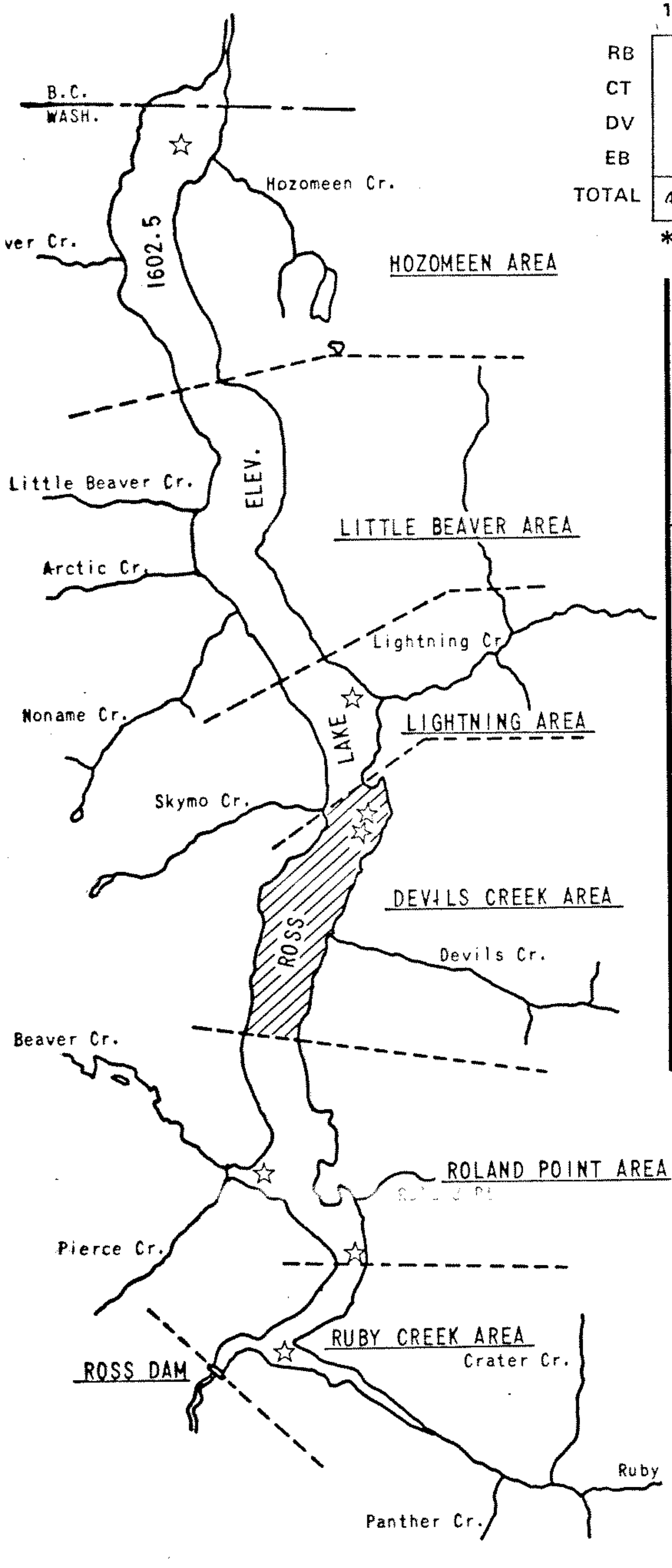
NOTE:

Green tag 268 recovered in Ross Lake-area unknown

Figure 3.7-10
Recovery locations for Roland Point (green) tags, 1972.

	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS 1971	1972
RB	42	0	*9
CT	0	0	0
DV	5	0	0
EB	1	0	0
TOTAL	48	0	9 *

* 1 RB RECAPTURED BELOW ROSS DAM



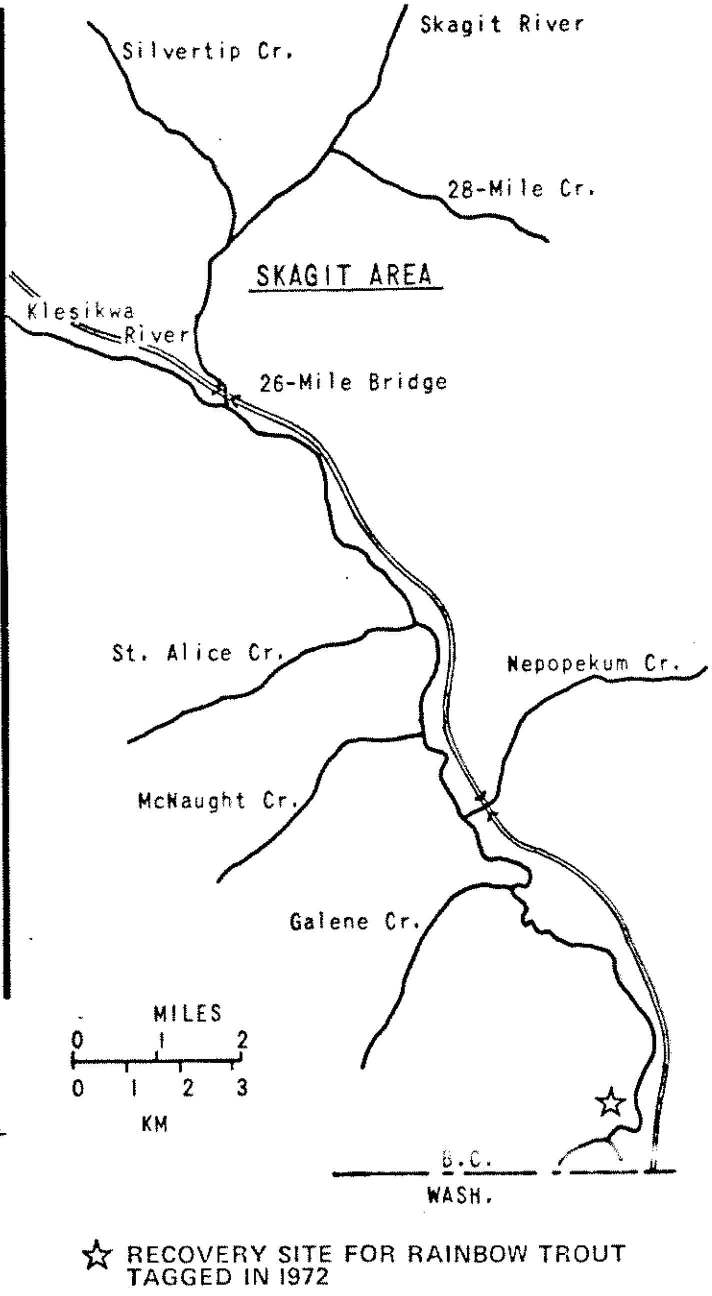
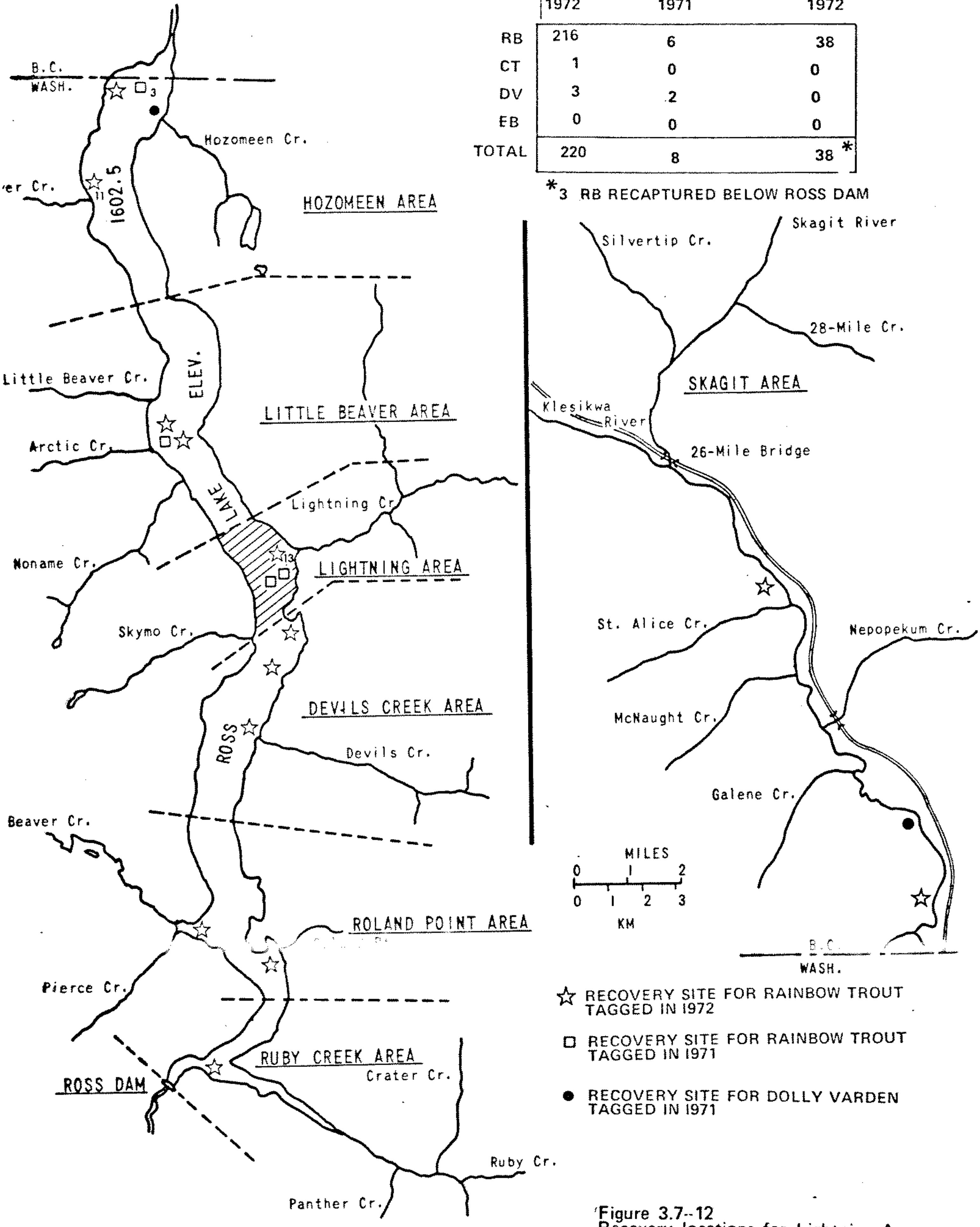


Figure 3.7-11
Recovery locations for Devils Creek (yellow) tags, 1972.

	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS 1971	1972
RB	216	6	38
CT	1	0	0
DV	3	2	0
EB	0	0	0
TOTAL	220	8	38 *

*3 RB RECAPTURED BELOW ROSS DAM



☆ RECOVERY SITE FOR RAINBOW TROUT TAGGED IN 1972

☐ RECOVERY SITE FOR RAINBOW TROUT TAGGED IN 1971

● RECOVERY SITE FOR DOLLY VARDEN TAGGED IN 1971

Figure 3.7-12
Recovery locations for Lightning Area (orange) tags, 1972.

	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS	
		1971	1972
RB	25	1	2
CT	0	0	0
DV	1	0	0
EB	0	0	0
TOTAL	26	1	2

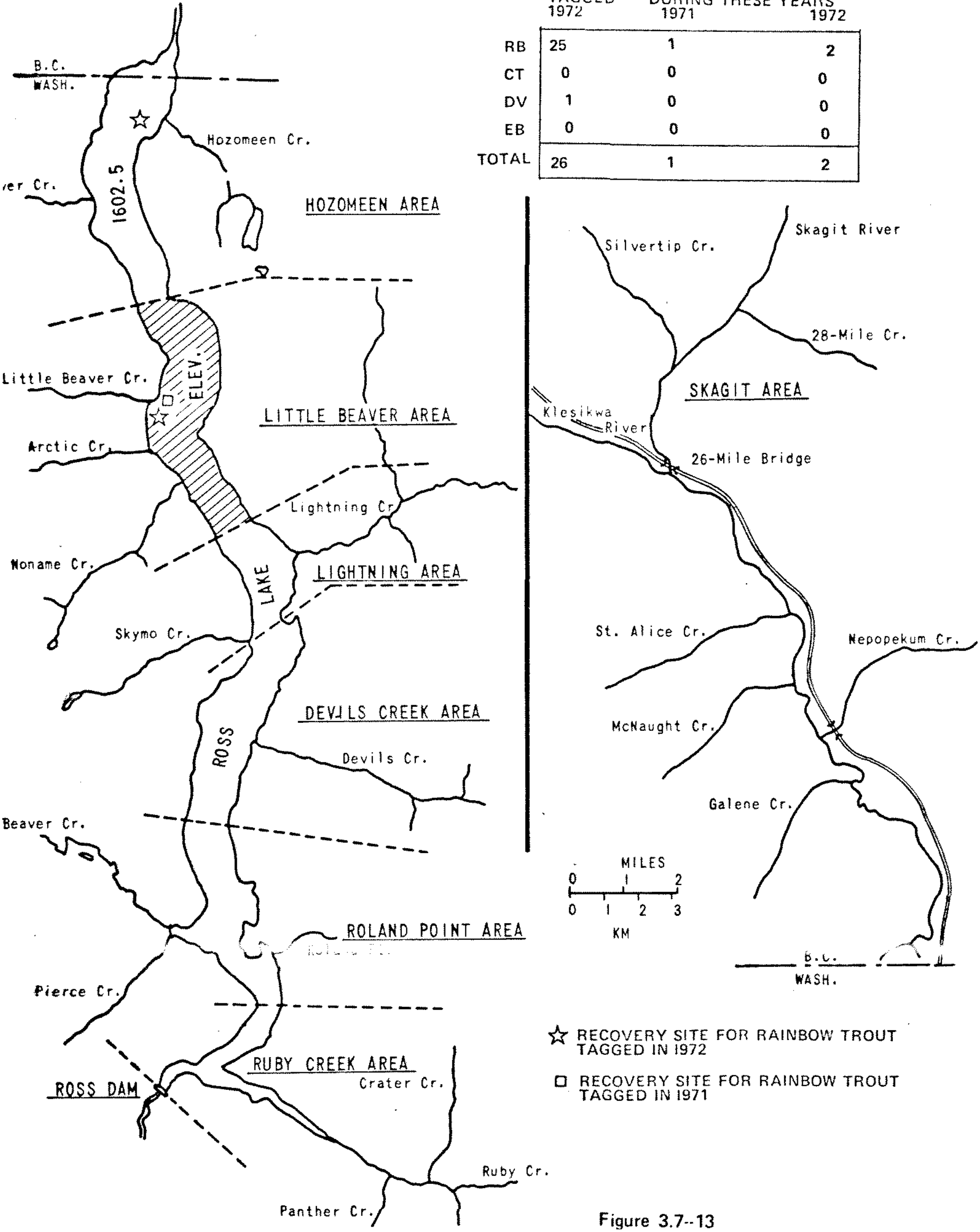
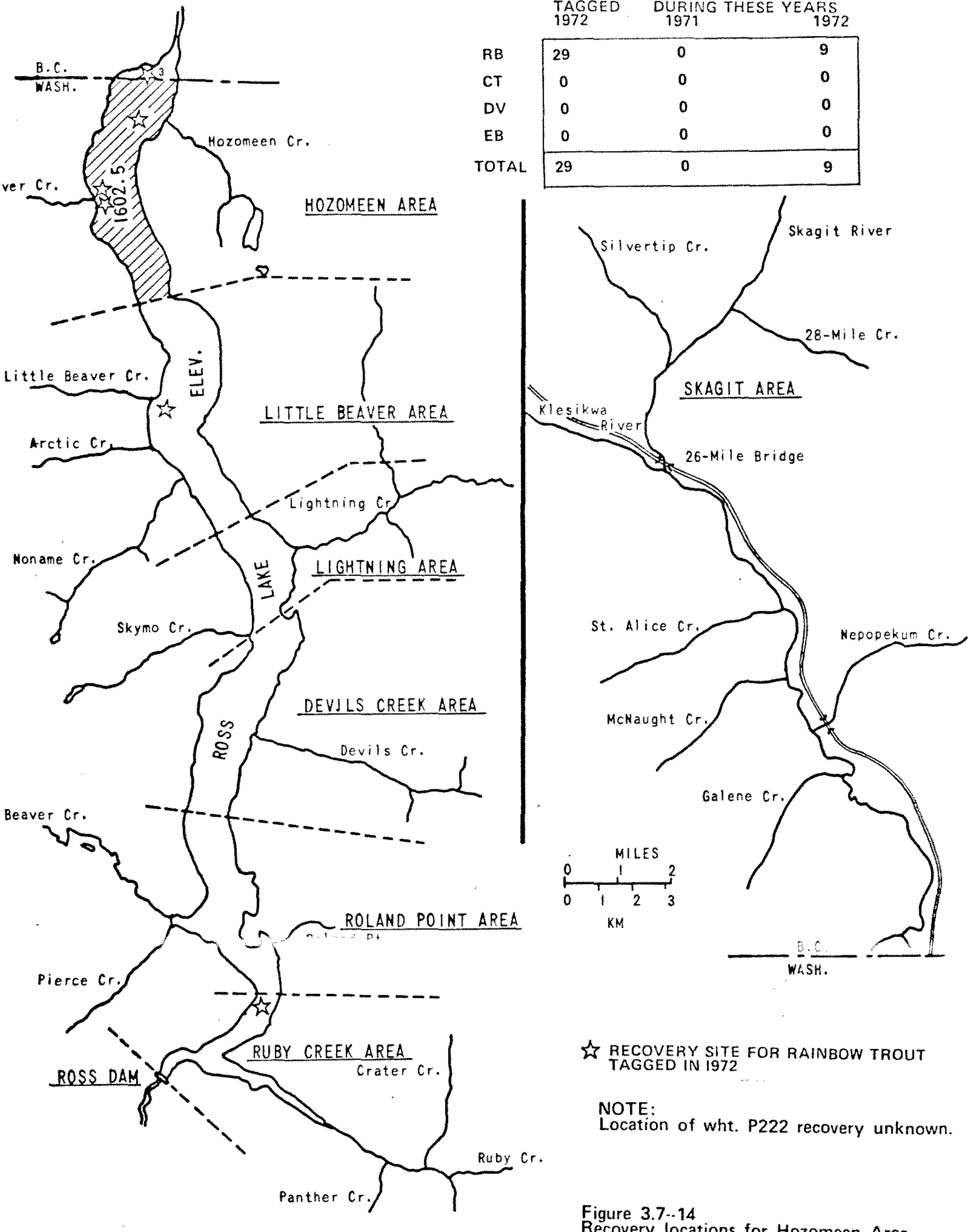


Figure 3.7--13
Recovery area for Little Beaver Area (red) tags, 1972.

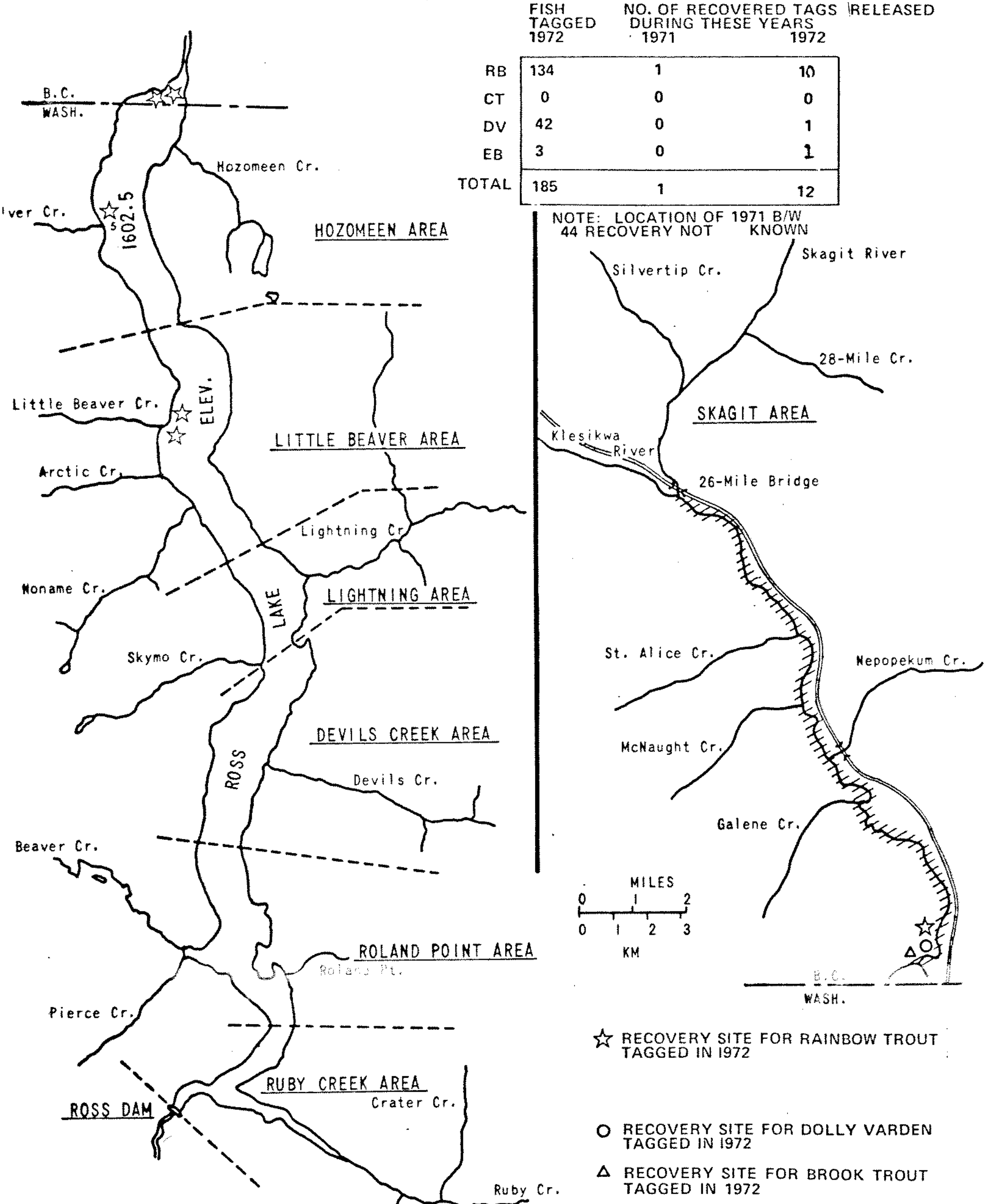
	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS 1971	1972
RB	29	0	9
CT	0	0	0
DV	0	0	0
EB	0	0	0
TOTAL	29	0	9



☆ RECOVERY SITE FOR RAINBOW TROUT TAGGED IN 1972

NOTE:
Location of wht. P222 recovery unknown.

Figure 3.7-14
Recovery locations for Hozomeen Area (white) tags, 1972.



	FISH TAGGED 1972	NO. OF RECOVERED TAGS RELEASED DURING THESE YEARS 1971	1972
RB	134	1	10
CT	0	0	0
DV	42	0	1
EB	3	0	1
TOTAL	185	1	12

Figure 3.7-15
Recovery locations for Skagit River (brown/white) tags, 1972.

TABLE 3.7-2

Total tags released (April 25 - August 28, 1972) and recovered for each species by major tagging area, Ross Lake, 1972.
Tag recovery values represent all recoveries of a given color or area by species in all areas combined.

Major tagging area	Rainbow trout		Cutthroat trout		Dolly Varden		Brook trout		Total		
	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Tags released	Tags recovered	Percent
Ruby Creek	172	36	3	1	14	1	0	0	189	38	20.11
Roland Point	219	32	32	2	6	1	0	0	257	35	13.62
Devils Creek	42	8	0	0	5	0	1	0	48	8	16.67
Lightning Creek	216	35	1	0	3	0	0	0	220	35	15.91
Little Beaver Creek	25	2	0	0	1	0	0	0	26	2	7.69
Hozomeen	29	9	0	0	0	0	0	0	29	9	31.03
Canadian Skagit River	134	10	0	0	48	1	3	1	185	12	6.49
Total	837	132	36	3	77	3	4	1	954	139	14.57

FIGURE 3.7-16

DISTRIBUTION OF TAG RECOVERIES BY LAKE AREAS IN 1972

Recoveries to the right of the heavy boxes indicate uplake fish movement. Recoveries to the left of the heavy boxes indicate downlake fish movement. Recoveries in the heavy boxes indicate no fish movement to other lake areas. Values represent all species. Tagged fish recovered below Ross Dam are not included.

LOCATION RECOVERED

South → North

LOCATION TAGGED

South → North

	Ruby Creek Area	Roland Point Area	Devils Creek Area	Lightning Creek Area	Little Beaver Cr. Area	Hozomeen Area	Canadian Skagit Area	
Canadian Skagit River					2 2	7 7	3 185 3 6.5%	
Hozomeen Area	1 1				1 1	6 29 6 27.6%		1 recovery Site Unknown
Little Beaver Area					1 26 1 7.7%	1 1		
Lightning Creek Area	1 1	2 2	2 3 1	13 220 13 16.4%	2 2	12 12	2 2	
Devils Creek Area	1 1	2 2	2 48 2 16.7%	1 1		1 1	1 1	
Roland Point Area	3 3	16 257 17 13.6% 1	2 2	2 2	2 2	8 8		1 recovery Site Unknown
Ruby Creek Area	20 189 21 20.1% 1	8 8	2 2	1 1	3 3	3 3		

LEGEND

20 — Number of tags recovered by anglers

189 — Number of tags released

21 — Number of tags recovered

1 — Number of tags recovered by research personnel

20.1% — Percentage of tags recovered in all areas tagged in the Lightning and Devils areas showed the greatest range in pattern of movement. Fish tagged in the Lightning area were recovered in greater numbers north of the area of tagging than south of the area. This is explained by the greater fishing effort at the north end of the lake. Only 3 fish were recovered in the Canadian Skagit River of those tagged in the lake. Of the 185 fish tagged in the Canadian Skagit River, 12 (6.5 percent) were recovered and 9 of these were taken in the north end of the lake. Recoveries of fish tagged in the Ruby and Roland Point areas were made in all areas of the lake but not in the Skagit River above the lake. Cutthroat trout, Dolly Varden char, and brook trout were recovered in such small numbers in 1972 that little can be concluded concerning movements of these species. Two of the 3 cutthroat trout recoveries in Ross Lake were made at the mouth of Big Beaver Creek. One of these had been tagged in the Ruby area, the other in the Roland Point area. The third cutthroat (tagged in the Roland Point area) was recovered at the mouth of the Canadian Skagit River in the north end of the lake and 2 cutthroat tagged in the Roland Point area were recovered in Diablo Lake below Ross Lake. Only 3 Dolly Varden were recovered in 1972, one in the Skagit River (tagged in the Skagit River) and 2 in Ross Lake (tagged in Ross Lake). One brook trout, tagged in the Canadian Skagit River, was recovered there.

Tagging of fish extended through a 4 month period from April 25 to August 28, 1972. Tag recoveries were made over a 5 month period from mid-June to mid-November, 1972. The tag duration in the fishery extended from 0 to 185 days. Eight fish were recaptured less than 5 days after tagging.

Comparison of 1971 and 1972

The results of tag recovery distribution within Ross Lake and the Canadian Skagit River in 1971 and 1972 show strong similarity between the two years with minor exceptions. Fish tagged in the Lightning area showed the greatest range of movement in both years. The major difference in the recovery distribution pattern in 1972 was with the recovery of 14 fish below Ross Dam, 4 in Gorge Lake or its tributaries and 10 in Diablo Lake. Two of the fish had been tagged in 1971, one of which was recaptured in Gorge Lake and the other in Diablo Lake. No tagged fish were recovered below Ross Dam in 1971. The passage of fish from Ross Lake past the dam is attributed to the heavy continuous spill over Ross Dam lasting from May 22 to July 20 (60 days) in 1972. Average spill during this time period was 8280 cfs. Spill averaged approximately 14,000 cfs continuously for 14 days and reached a one-day maximum average of 16,800 cfs in this time period. In 1971 the longest period of spill over Ross Dam was from June 23 to August 2 (41 days). Average spill during this time period was 4463 cfs with a 7 day average of 8000 cfs and a one-day maximum of 9400 cfs within this time period.

Results from Sonic Surveys 1971

Sonic surveys were conducted on transects designed so that the odd-numbered transects ended in the major creeks, beginning with Ruby Creek, and the even-numbered transects were positioned approximately midway between. Ten transects were run during the day and ten at night with transect ten just north of Little Beaver Creek (Figure 3.7-17). Seven surveys were conducted from September 1970 to August 1971.

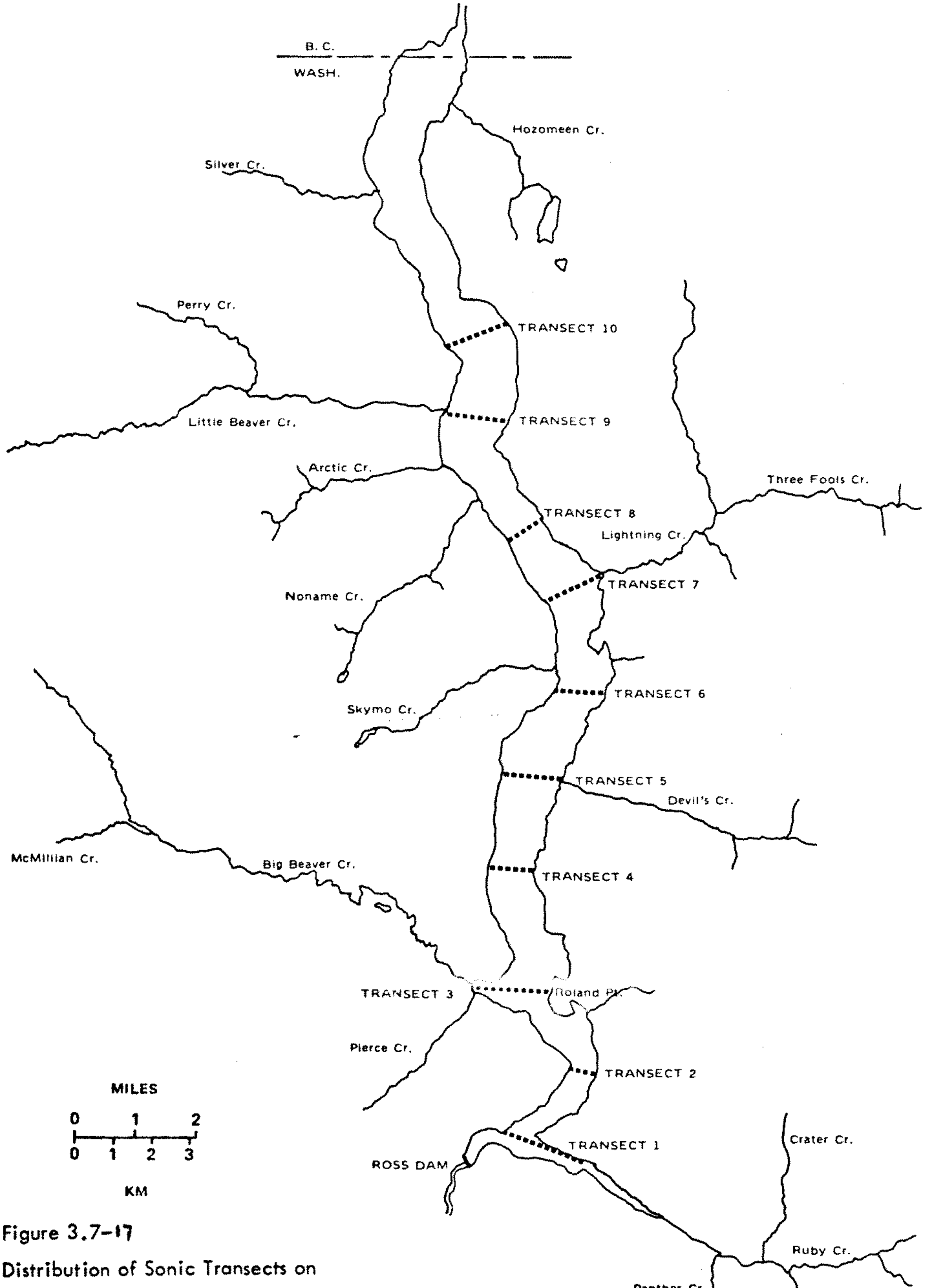


Figure 3.7-17

Distribution of Sonic Transects on Ross Lake, 1971

The echo sounder was a Ross 20 Fineline, 100 kHz, 115 volts AC power supply operating off 12 volt batteries with an inverter. A 10 degree circular transducer was used, towed facing downward just below the lake surface.

The distribution of targets observed at night in Ross Lake from October 1970 to August 1971 is shown in Table 3.7-3. The same information for daylight surveys is given in Table 3.7-4. There were consistently large differences in the number of targets observed between day and night. Apparently the fish move into shallow water and around stream mouths during the day. If the fish are close to bottom or in shallow water inshore, they would not be detected by the method used.

During June and August the sum of fish targets seen at night in the four northernmost transects was considerably larger than the sum of targets in the six transects in the southern half of the lake, which suggests a greater concentration of fish in the north half of the lake.

3.7.2.2 Skagit River Float Downs

(by F.F. Slaney & Company)

Methods

Underwater counting of fish by wet-suited divers was carried out on four dates between mid-August and mid-October, 1971. The techniques approximated those of Northcote and Wilkie (1963) where two to four divers counted only fish they passed within pre-arranged counting strips along the river bed. Only in the October count was it possible to distinguish Dolly Varden and brook trout from rainbow trout. All of the river from M-7 to F-2 was censused at least once. Between F-15 and F-8 was done twice; three counts were made

TABLE 3.7-3

ROSS LAKE ACOUSTIC SURVEY DATA SUMMARY
DISTRIBUTION OF TARGETS AT NIGHT

Transects	1	2	3	4	5	6	7	8	9	10
Location	Ruby		Big Beaver		Devil s		Lightning		Little Beaver	
Series										
October 70	-	-	7	-	-	-	9	-	-	-
December 70	0	-	0	1	2	-	7	3	16	-
March 71	1	0	3	1	-	2	5	8	4	-
May 71	1	1	1	23	2	3	7	1	5	10
June 71	4	4	14	2	1	2	13	13	13	8
August 71	3	0	4	2	3	2	9	8	5	3

TABLE 3.7-4

ROSS LAKE ACOUSTIC SURVEY DATA SUMMARY
DISTRIBUTION OF TARGETS DURING DAY

Transects	1	2	3	4	5	6	7	8	9	10
Location	Ruby		Big Beaver		Devil s		Lightning		Little Beaver	
Series										
October 70	0	0	3	0	0	1	7	1	1	0
December 70	-	-	0	0	0	-	0	6	4	-
March 71	3	0	0	0	0	0	1	2	4	11
May 71	-	-	-	-	-	-	-	-	-	-
June 71	-	1	4	1	1	1	-	-	-	-
August 71	-	-	-	-	-	-	-	-	-	-

from M-4 to F-15. Taking part in each dive were two F.F. Slaney & Company employees, and one (Dive 4) or two divers from the Fisheries Research Institute. All had experience in underwater counting. The results of a B.C. Fish and Wildlife Branch dive in October, 1970 are included for comparison.

Results

The numbers of fish observed per section on the various dates are shown in Appendix 51.

An approximation of the number of fish between Twenty-six Mile Bridge (M-4) and Ross Lake (F-1) can be obtained by applying the density (number of fish per mile) from each section sampled for each date to the total river length below Twenty-six Mile Bridge (see Table 3.7-5). This is intended only as a basis for comparison of relative numbers of fish between counting dates. Table 3.7-5 also shows the densities of fish observed on the various dates.

TABLE 3.7-5

DENSITIES OF FISH OBSERVED,
SKAGIT RIVER FLOAT DOWNS

Dive No.	Date of Dive	Miles Sampled	No. Fish Per Mile	No. Fish (M-4 to F-1)
A	15,16 Oct. 1970	12	4.6	55
1	12 Aug. 1971	7	17.9	approx. 205
2	19,20 Aug. 1971	8	67.1	" 772
3	1 Sept. 1971	3	59.0	" 678
4	16,17 Oct. 1971	8.5	2.6	" 30

The fish observed during Dive 1 were quite evenly distributed over the length of river censused. In Dive 2 a small school of brook trout was seen in F-7, and large schools, mostly rainbow, were found holding in or near log jams in F-3. These schools disappeared within four or five days, as verified by observations from shore with a diver's mask.

During Dive 3, separate counts were made of fish in log jams and fish holding in the main stream. Of the 177 fish seen, 106 (59.9 percent) were in or near log jams, and 71 (40.1 percent) were in the main river current. As in Dives 1 and 2 most of the fish seen in Dive 3 were rainbow, but a few (less than 10) Dolly Varden and brook trout of spawning size were seen.

In Dive 4 it was possible to make separate counts of rainbow and char. Of the 22 fish seen, eight were rainbow, 11 were Dolly Varden, and three were char of uncertain identity. All of the char except two small Dolly Varden were large, probably about 10 pounds.

An additional count was made in the Klesilkwa River on 2 October, 1971, in which 240 fish were seen over 2.5 miles. In the two miles directly above the confluence with the Skagit in M-3, 230 fish were seen, of which 38 were brook trout and Dolly Varden, holding in mixed schools with rainbow.

3.7.3 Population Size Estimates, 1971

(by Fisheries Research Institute)

3.7.3.1 Sonic Survey Estimates, 1970-1971

Use of sonic transects across the lake to detect fish was reported in Section 3.7.2.1. The average number of targets per transect day and night and corresponding population estimates based on night series are presented in Table 3.7-6. Previous to the May 1971 series, targets were counted from the echogram. Part of the May series and the June and August series were analyzed with an oscilloscope. Direct measurement of the magnitudes of targets and measurement of the sampling volume of the sounder was possible with this procedure.

The sampling volume of the sounder was calculated during the June survey from the duration of time the targets at different depths were within the beam as the boat passed over the targets at a known speed. The average of the targets for which this parameter was measured was 2.6 pulses at a rate of two pulses per second, or 1.3 seconds duration. Boat speed was measured to be 1.7 meters/second, so the average chord path-length across the sounder beam was 1.3 x 1.7, or 2.21 meters. This chord length corresponds to a circle diameter of $\frac{2.21}{0.8} = 2.76$ meters. A total of 74 targets was counted during the night series. Assuming the linear distance of the lake represented by the transects is 26,000 meters the population estimate for the entire sampling area in June, 1971, for example, is $\frac{74}{10} \left(\frac{26,000}{2.76}\right)$ = approximately 70,000 fish. The sampling area included the lake southward from the point north of Little Beaver Creek. Population estimates for other surveys were determined by comparison of the number of targets per transect with those in the June survey.

TABLE 3.7-6

AVERAGE NUMBER OF TARGETS PER TRANSECT AND TOTAL FISH, ROSS LAKE, 1970 - 1971

Series	Day	Night	Population Estimate
Sept. 70 20-22	1.7	-	-
Oct. 70 29-30	1.3	-	-
Dec. 70 17	1.7	4.1	38,500
Mar. 71 9-10	2.1	3.0	28,000
May 71 17-18	-	5.4	51,000
June 71 14-15	1.6	7.4	70,000
Aug. 71 31	-	3.9	37,000

The difference in magnitude of estimates could arise from several factors. In December, March, and May the lake was drawndown and it was more difficult to run transects as close to shore. Also, at drawdown levels the fish were more apt to be in areas of standing submerged trees, making it more difficult to distinguish targets with certainty. In August during full pool as in June the estimate may have been lower than in June because of several possible factors including the following: (1) more fish near shore or bottom and therefore not detected, (2) more fish in streams or stream mouths and not detected, (3) fish removed by capture and not replaced by recruits during June-August period. The June estimate is therefore considered to more closely approximate the population in the sampling area at the beginning of the fishing season.

Confidence intervals on the June estimate were determined by grouping transects into high and low density strata and calculating the associated variances of the mean numbers of targets per transect. This procedure resulted in 95 percent confidence intervals of 56,000 - 84,000 fish. This range does not include possible bias due to the fact that half of the transects terminate in front of stream mouths. The population estimate based only on the five transects which did not terminate at stream mouths was 54,000 fish. The estimates include all fish in midwater. It was not possible to accurately determine the size of the fish, thus the estimate may represent a greater population than that associated with the sport fishery.

An additional 9,000 meters of lake at the north end of the lake was not included in the sampling area. If it is assumed fish density was uniform from Lightning Creek northward, the June estimate is increased by 40,000 fish to a total of 110,000. The estimate of course only includes fish in the lake.

3.7.3.2 Tagging and Recapture Estimates

The methods of fish capture, tagging and release for fish movement and population estimate studies for 1971 were described in Section 3.2.2.

It was expected that in spite of careful handling and processing that some fish mortality would occur following tagging and release. It was necessary to account for such mortality to reduce error in the population estimates based on tag recoveries. Therefore holding pens were constructed for use in determining short term post-tagging mortality of fish caught by angling. Each pen consisted of a 4 x 4 foot floating frame constructed of four inch diameter pvc pipe with a net enclosure (1/2 inch mesh, stretched measure) hung from the frame and a hinged cover bolted to the frame top to prevent fish from jumping out of the enclosure. The pens were placed in the lake at the inlets of Lightning and Ruby Creeks. Fish captured by angling were placed in the pens and held for one to four days after the normal processing and tagging procedure. The pens were checked periodically and mortalities recorded. The results are given in Table 3.7-7 and Appendix 52. A post-tagging mortality of 9.38 percent was estimated for fish captured by angling gear. This percentage and the differential recovery rates of fish captured by the different types of gear, tagged, and then released provide data to approximate the number of live tagged fish remaining in the population after initial tagging mortality had occurred (Table 3.7-7).

It was assumed that only short term mortalities from capture and tagging occurred.

Other assumptions which were made in estimating population size from the angler catch and tag recoveries are (1) tagged fish do not lose their identifying marks throughout the period of study; (2) fishing effort is proportional to the density of the fish population throughout the lake; (3) tagged and untagged fish are equally susceptible to capture; (4) recruitment to the fish population does not occur during the recovery program; and (5) losses through natural mortality after short term tagging mortality or emigration are the same for tagged as for untagged fish, and (6) all tags recaptured were reported.

TABLE 3.7-7

MORTALITY ESTIMATES OF FISH CAPTURED, TAGGED, AND RELEASED BY METHOD OF CAPTURE, ROSS LAKE, 1971

	Method of capture					
	Angling	Gill net	Trap	Shocker	Fyke net	Total
A. Number Tagged	385	112	33	38	1	569
B. Number of tagged fish recovered by anglers	63	5	6	6	0	80
C. Tag recovery rate (percent)	16.36 (18.18)**	4.46	18.18	15.79	-	14.06
D. Tagging (Sampling) mortality - percent (calculated)	9.38*	75.45	0	13.16	-	
E. No. of tagged fish remaining after sampling mortality	346.5	27.5	33.0	33.0	-	

Method:

1. Assume 18.18 percent tag recovery rate after subtracting sampling mortality for each method of capture.
2. Calculate number of tagged fish after sampling mortality for each method of capture.

$$(.1818)\ (E) = B \text{ or } E = \frac{B}{.1818}$$

3. Calculate percent sampling mortality for each method of capture. $D = (1 - \frac{E}{A})\ (100)$

---

* Mortality calculated from holding pen experiment results.

** Recovery rate of tagged fish after sampling mortality.

Fish which were recovered by research personnel were inspected for tag loss. Fins were clipped during the tagging procedure so that any fish which had lost its tag could be identified if recaptured. None were observed, however. Tags on recaptured fish appeared to be well anchored as long as 6 months following tagging. Tag wounds appeared to be well healed. For these reasons tag loss following tagging was assumed to be negligible.

Movements of the tagged fish throughout the lake are indicated by the location of tag recoveries. Probably, all tagged fish in the population were available to anglers. Angler effort may tend to concentrate on lake areas which yield the most fish; therefore effort was probably roughly proportional to fish population density.

Recruitment to the fishery during the tag recovery program would increase the ratio of untagged to tagged fish thus increasing the apparent population size. However, the population estimates based on tag recapture throughout the fishing season (Table 3.7-8) did not greatly fluctuate. Probably, recruitment to the fishery during the fishing season did not occur at a rate which would greatly affect the accuracy of the population estimates.

It is not known what proportion, if any, of all tag recoveries were unreported but if this factor is present it would bias the population estimate upward.

To what degree natural mortality differed between tagged and untagged fish is not known. If natural mortality was higher for tagged fish the population size estimate would be biased upward. The estimate would be biased downward if natural mortality of tagged fish was lower. It is suspected that the former

TABLE 3.7-8

ESTIMATION OF THE LEGAL-SIZED FISH POPULATION FROM TAGGING AND ANGLER RECOVERIES

ROSS LAKE-SKAGIT RIVER SYSTEM, 1971

Period	Periodic Catch C_t	ΣC_t	Tag recoveries R_t	$\Sigma R'_t$	No. of tags available at start of period M_t	$C_t M_t$	$\Sigma C_t M_t$	$\hat{N}$ *	95 Percent Confidence Interval
19-28 June	12,986	12,986	23	23	289	3,752,954	3,752,954	163,172	115,150-299,900
29 June-8 July	5,426	18,412	8	31	269	1,459,594	5,212,548	168,147	123,709-262,405
9-18 July	2,887	21,299	10	41	269	776,603	5,989,151	146,077	111,310-212,427
19-28 July	1,933	23,232	0	41	290	560,570	6,549,721	159,749	121,729-232,310
29 July-7 Aug.	1,867	25,099	4	45	315	588,105	7,137,826	158,618	122,188-225,993
8-17 August	2,414	27,513	4	49	325	784,550	7,922,376	161,681	125,753-226,352
18-27 August	2,232	29,745	5	54	330	736,560	8,658,936	160,351	114,313-186,801
28 Aug.-6 Sept.	2,657	32,402	10	64	355	943,235	9,602,171	150,034	120,026-200,044
7-16 September	1,178	33,580	7	71	357	420,546	10,022,717	141,165	114,086-185,099
17-26 September	2,209	35,789	5	76	350	773,150	10,795,867	142,051	115,544-184,342
27 Sept.-6 Oct.	1,080	36,869	5	81	348	375,840	11,171,707	137,922	112,845-177,327
7-16 October	1,713	38,582	3	84	343	587,559	11,759,266	139,991	114,915-179,867
17-26 October	1,114	39,696	0	84	341	379,874	12,139,140	144,514	118,628-184,853
27-31 October	882	40,578	1	85	341	300,762	12,439,902	146,352	120,263-186,898

$$* \hat{N} = \frac{\Sigma C_t M_t}{\Sigma R_t}$$

is true to a slight extent because many tagged fish were sexually mature at time of tagging; however, these fish were recovered by anglers at a higher rate (23%) than immature and unsexed fish at time of tagging (13%). The June-September mean length of tagged fish at large was 33 mm longer than that of fish in the sport catch but the tagged fish recovered by anglers were those from the large side of the length distribution at time of tagging.

The above suggest that larger and sexually mature fish are more vulnerable to angling gear than smaller, immature fish. Thus, if the larger, mature fish suffer greater natural mortality and a proportion of tag recoveries are unreported the resulting upward bias of the population estimate would tend to be balanced out.

A restriction on the population estimate based on tagging and recovery is that it applies only to fish above 200 mm in length (total length) because virtually all tagged fish were above this size as were all but about five percent of the sampled catch. The population estimates include Ross Lake and Skagit River fish.

The Petersen equation (Lagler, 1961) was used to estimate the fish population size on the opening day of fishing season (June 19, 1971). The formula is:

$$\hat{N} = mc/r$$

where m = 289 = total number of tagged fish in the population (number of tagged fish released - tagging mortality estimate) on June 19, 1971 (opening day of fishing season).

c = 40,578 = number of fish in the catch during fishing season (includes untagged and any tagged fish).

r = 65 = number of tagged fish in the season catch from fish tagged before June 19 (recoveries).

$\hat{N}$ = 180,416 = population estimate as of June 19, 1971 based on Ross Lake and Skagit River catch and tag recovery.

95% C.I. = 180,416 ± 39,372

A variation of the Petersen method, a multiple sample-tag recovery experiment, (Ricker, 1958) was used to estimate the population at the beginning of the fishing season. This allowed fish tagged during the fishing season to be included in the equation whereas the simple Petersen method described in the previous paragraph did not. The fishing season was arbitrarily divided into ten-day time periods beginning on June 19, 1971 and ending with a five-day period on October 31, 1971.

The equation used is :

$$\hat{N} = \frac{\Sigma C_t M_t}{\Sigma R_t}$$

where C_t = catch during the given time period

M_t = number of tagged fish in the population at the beginning of the time period (includes all tagged fish previously in population less angler removal plus newly tagged fish less tagging mortality)

R_t = number of tags recovered during the time period

$\hat{N}$ = population estimate at beginning of the fishing season.

Summation of the values as shown in the equation accumulates all information up to the time period at which the estimate is made; thus after the last time period all tagged fish, recoveries and catch for the entire fishing season are used in the population estimate. This provides an estimate of 146,352 fish with a 95 percent confidence interval of 120,263 to 186,898. Results of this method based on Ross Lake and Skagit River catch and tag recovery for each time period are presented in Table 3.7-8.

3.7.4 Population Size Estimates, 1972

3.7.4.1 Sonic Survey Estimates

Acoustic surveys of fish populations in Ross Lake were conducted in 1972 as in 1971, except only during the months of June and September. The equipment was basically the same as that used during 1971 surveys. Transects were made off the tug Skagit over the same general design as used previously (Fig. 3.7-18). Ten transects were run during the night in June and one during the day. Eleven transects were run twice during the night and at least once during day for the September series.

Data processing consisted of measuring with an oscilloscope the maximum amplitude, depth and length of time in the sounding cone of each target above threshold amplitude. The threshold was established to separate fish targets from echoes of lesser magnitude associated with debris and compared with the expected target amplitude of a fish target of approximately 100 mm. Targets between 3.75 and 37.5 m only were counted. The sampling volume of the echo sounder was determined from the average length of time in the sounding cone.

Results

The June 7 - 8 survey was conducted during a period of extremely high runoff. Extreme interference was encountered due to reflections from debris and bubbles. Consequently it was not possible to accurately separate fish targets from background interference, and further analysis was not attempted.

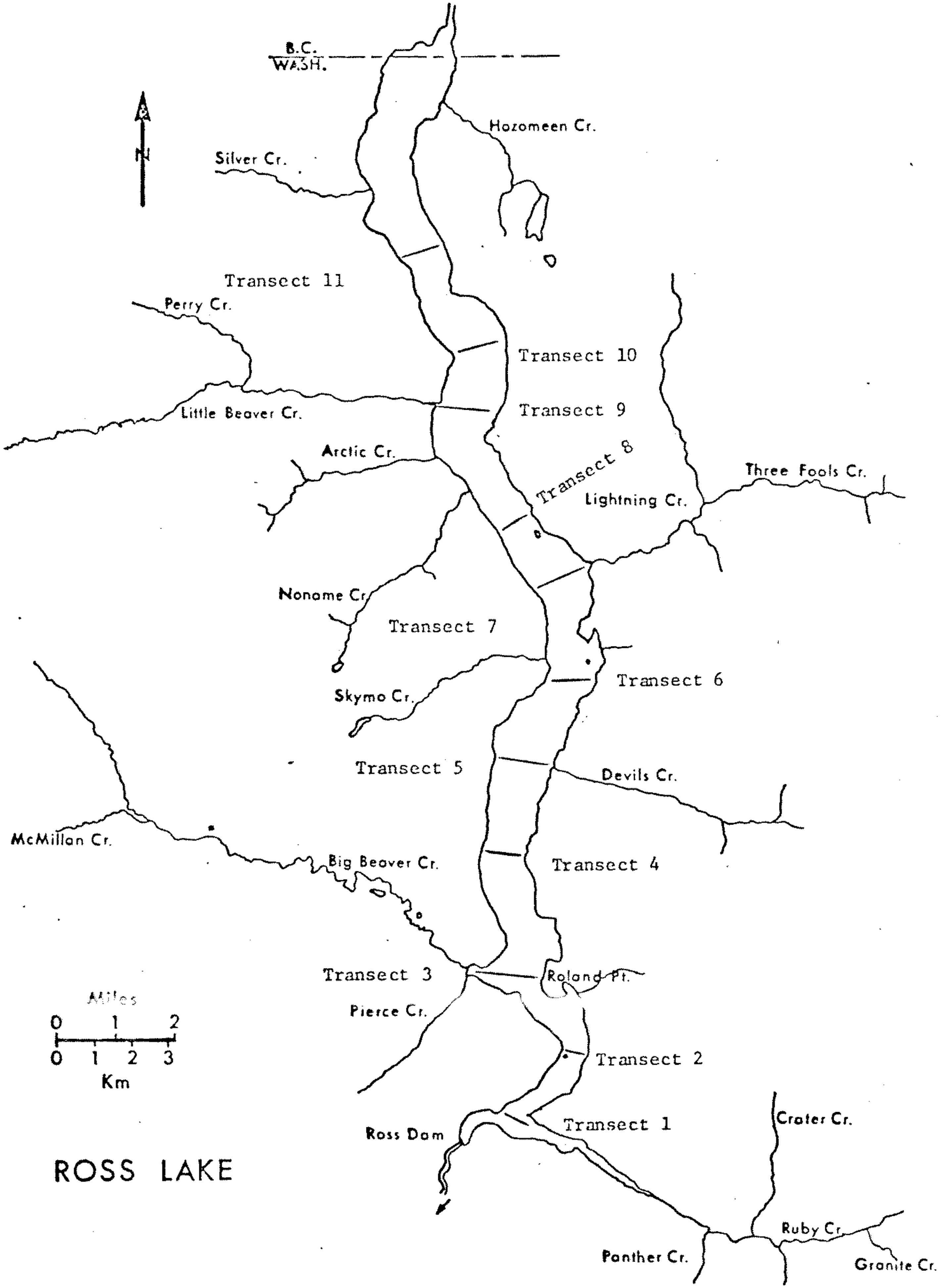


Figure 3.7-18 Distribution of sonic transects on Ross Lake, 1972.

The distribution of targets over the various transects for each series September 20 - 21 is given in Table 3.7-9. A total of 61 fish targets were encountered with average duration in the sounder beam of 2.5 pulses, corresponding to a beam diameter of 3.0 m at the average fish depth, and a cross-sectional area of 7.1m^2. Assuming the surface area of Ross Lake to be 4.73 x 10^7 m^2, the estimate of the abundance in the limnetic zone below 4 m in depth is

$$\frac{2.5 \text{ echoes/targets} \times 61 \text{ targets} \times 4.73 \times 10^7 \text{ m}^2}{47,246 \text{ pulses} \times 7.1 \text{ m}^2\text{/pulse}} = 21,601$$

Since fish are typically more accessible to acoustic gear at night, the calculation was redone using only data from the night series, resulting in an estimate of 25,900.

Discussion and Between Year Comparison

The September 1972 estimate is less than comparable series in 1971. Since sampling volume measurements were similar, trends of the population can be examined by comparison of average number of targets per transect (Table 3.7-10). The average for the night series in September 1972 was about 1/2 that of the August 31, 1971 night series. The September 1972 estimate does not agree with the 1972 tag and recovery estimate. The differences in the population estimate may represent a difference in the portion of the population occupying the limnetic zone. It has been shown in Section 3.4.6.1 that the trout feed mainly on limnetic plankton in the spring and on littoral gastropods in large numbers in late summer and fall.

TABLE 3.7-9

DISTRIBUTION OF TARGETS DURING DAY AND NIGHT TRANSECT SERIES ON ROSS LAKE, SEPTEMBER 20-21, 1972.

Transect	Day Series	Night Series	Night Replicate
1	0	0	0
2	1	0	1
3	2	2	2
4	2	0	0
5	4	2	1
6	2	3	5
7	1 (replicate = 2)	5	15
8	0	0	0
9	1	0	3
10	1	2	0
11	1 (replicate = 0)	2	1
Total	17	16	28
Average	1.3	1.4	2.5

TABLE 3.7-10

AVERAGE NUMBER OF TARGETS PER TRANSECT FOR VARIOUS SERIES ON ROSS LAKE, SEPTEMBER 1970 TO SEPTEMBER 1972

Series	Day	Night
Sept. 20-22, 1970	1.7	--
Oct. 29-30, 1970	1.3	--
Dec. 17, 1970	1.7	4.1
March 9-10, 1971	2.1	3.0
May 17-18, 1971	--	5.4
June 14-15, 1971	1.6	7.4
Aug. 31, 1971	--	3.9
Sept. 20-21, 1972	1.3	2.0

Fish in the littoral and deeper bottom areas of the lake would not be detected by the sonic gear as they would be when in the limnetic areas in the spring.

It is concluded that the results of the sonic estimates show variable nonavailability to the acoustic gear, thus are not reliable for estimation of total fish abundance in the entire reservoir. Seasonal difference in distribution of the fish probably is the major cause.

3.7.4.2 Tagging and Recapture Estimates

The methods of fish capture, tagging, and release for fish movement and population estimate studies for 1972 were described in Section 3.2.2. Since fish handling and tagging procedures were identical in 1971 and 1972 the same assumptions regarding short-term sampling mortality were made (see 3.7.3.2). Assumptions inherent in the mathematical process of estimating population size from angler catch and tag recoveries are also listed in Section 3.7.3.2. All are applicable to the 1972 population estimate. In 1972 as in 1971 it was found that the mature tagged fish were recaptured by anglers in greater proportions (14%) than the immature fish (13%) and that the recovered fish were those from the large side of the length distribution at time of tagging. Again the June-September mean length of tagged fish at large was 15 mm greater than that of the angler catch. These data suggest that, as in 1971, larger and sexually mature fish are more vulnerable to angling gear than smaller immature fish; therefore downward bias due to these factors and upward bias due to higher natural mortality rates in tagged fish and unreported tag recoveries would tend to balance out.

The population estimate based on tagging and recovery is limited only to fish above 200 mm in length because virtually all tagged fish and those in the sport catch were above this size.

The Petersen equation (Lagler, 1961) was used to estimate the fish population size on the opening day of 1972 fishing season (June 17, 1972). The formula and results are:

$\hat{N} = mc/r$

where m = 498 = total number of tagged fish at large in the population (number of tagged fish released - tagging mortality estimate) on June 17, 1972.

c = 41,441 = number of fish in the catch during fishing season (includes untagged and any tagged fish)

r = 96 = number of tagged fish in the season catch from fish tagged before June 17 (recoveries)

$\hat{N}$ = 214,975 = population estimate as of June 17, 1972 based on Ross Lake and Skagit River catch and tag recovery

95% C.I. = 214,975 ± 39,380

The multiple sample-tag recovery experiment, described in Section 3.7.3.2 was also used to estimate the population at the beginning of the fishing season. The fishing season was divided into four week time periods beginning on June 17, 1972-and ending with a three week time period on October 31, 1972. Angler catch within each time period was estimated by dividing the total season catch among time periods weighted by angler effort and CPUE within each time period. The equation used to estimate population size is described in Section 3.7.3.2. The method provides an estimate of 206,185 fish with a 95% confidence interval of 174,353 to 252,237. Results of this method based on Ross Lake and Skagit River catch and tag recovery for each time period are presented in Table 3.7 -11.

In 1972, 11 fish tagged in 1972 were recovered by anglers in Diablo and Gorge Lakes below Ross Dam. No recoveries of tagged Ross Lake fish were made in Diablo or Gorge Lakes in 1971. It is assumed that the fish passed over the spillway (spill was continuous from May 22 to July 20 in 1972). Assuming that the tag recovery rate was the same in Gorge and Diablo Lakes

TABLE 3.7-11

Estimation of the legal-sized fish population from tagging and angler recoveries
Ross Lake - Skagit River System, 1972

Period	Periodic catch C_t	ΣC_t	Tag re-caps R_t	ΣR_t	No. of tags at large at start of time period M_t	$C_t M_t$	$\Sigma C_t M_t$	$\hat{N}$ *	95 percent confidence interval
June 17-July 14	12,207	12,207	28	28	499	6,091,293	6,091,293	217,546	157,876-349,736
July 15-Aug. 11	10,137	22,344	26	54	588	5,960,556	12,051,849	223,182	175,438-306,643
Aug 12-Sept 8	7,395	29,739	27	81	690	5,102,550	17,154,399	211,783	173,278-272,293
Sept 9-Oct 6	7,197	36,936	20	101	771	5,548,887	22,703,286	224,785	187,476-280,632
Oct 7-Oct 31	2,715	39,651	19	120	751	2,038,965	24,742,251	206,185	174,353-252,237

* $\hat{N} = \dfrac{\Sigma C_t M_t}{\Sigma R_t}$

as in Ross Lake (19%), approximately 58 tagged fish (8% of the number at large in Ross Lake) survived the passage from Ross Lake to the two lakes below. On the basis that a similar percentage of the untagged fish population passed over Ross Dam and survived the trip, it is estimated that approximately 16,000 fish from Ross Lake entered the Diablo and Gorge Lakes populations. It is not known what proportion of fish passing over the Ross spillway survived.

PART 4

ENVIRONMENTAL PROJECTIONS

4.1 ENVIRONMENT DURING CONSTRUCTION AND FILL PERIOD

4.1.1 Ross Lake

(by Fisheries Research Institute)

The construction schedule provided by Seattle Department of Lighting calls for drawdowns to elevation 1475 feet in two consecutive years followed by a filling of the reservoir to elevation 1725 feet within the following two years (Figure 4.1-1). The anticipated reservoir elevation changes during construction will first be described briefly and discussed relative to the pattern of annual reservoir fluctuations in past years.

4.1.1.1 Construction Period

Engineering requirements for concrete placement and grouting stipulate maximum allowable elevations during construction, indicated by the solid line in Figure 4.1-1. The expected lower elevation limit based on the lowest water year (1928-1929) hydrological conditions is shown by the dashed line, with qualifying conditions stated on the graph. With better hydrological conditions, the reservoir level would be expected to fall between the two lines (of maximum allowable because of construction and minimum because of hydrological conditions). During the first summer fill, the reservoir would not be filled beyond the 1565 feet elevation (maximum allowable September 1) because late summer inflow is low and the reservoir would normally be stabilized or dropping at this time. Likewise during the second summer of construction, the reservoir would be filled only to approximately 1605 feet elevation even though construction allowances would permit a higher fill. Therefore, for the purposes of discussion, we will disregard the

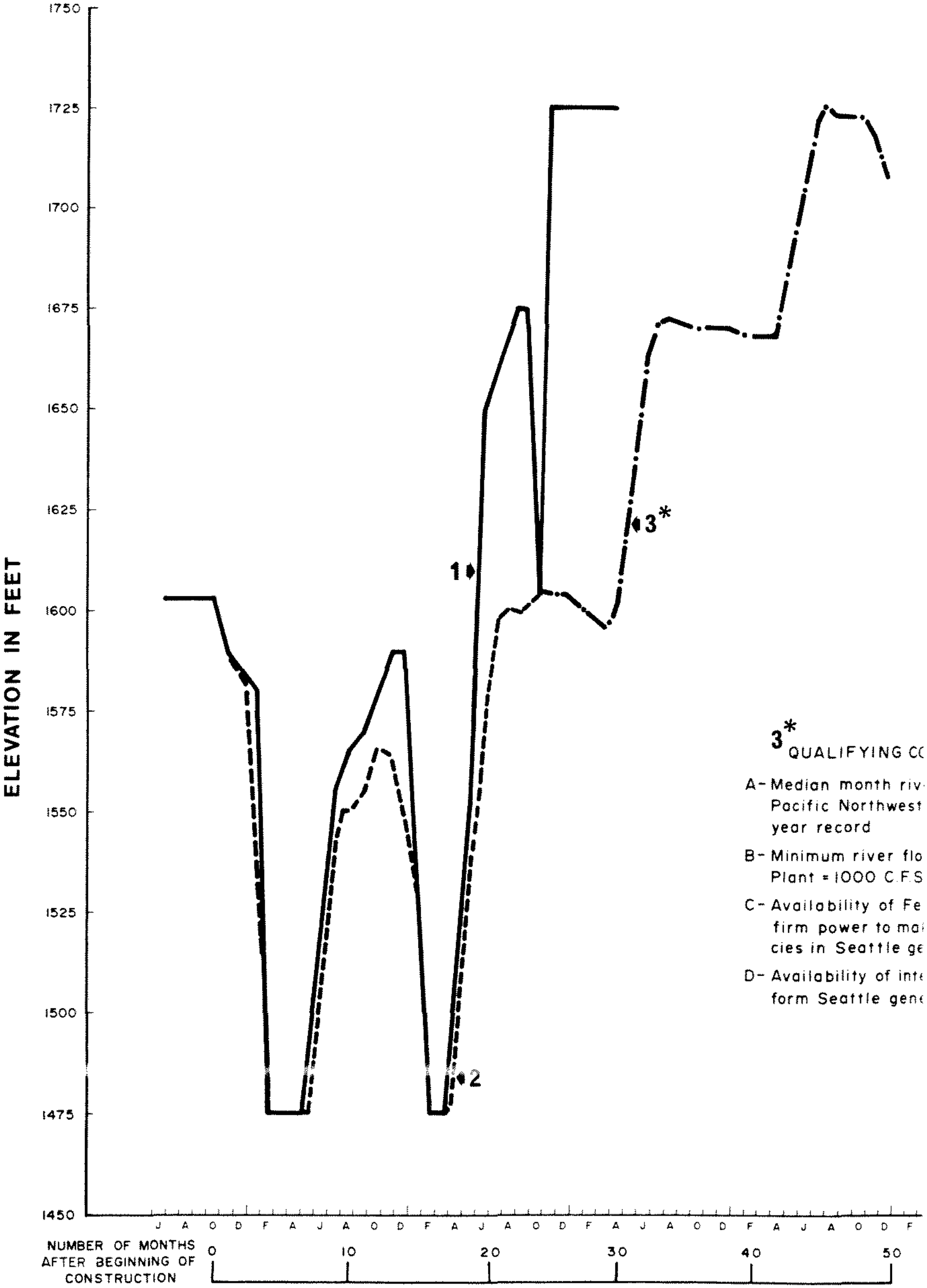

ELEVATION IN FEET
1750
1725
1700
1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
J A O D F A J A O D F A J A O D F A J A O D F A J A O D F
NUMBER OF MONTHS AFTER BEGINNING OF CONSTRUCTION
0
10
20
30
40
50
1
2
3*
3* QUALIFYING CO
A- Median month riv
Pacific Northwest
year record
B- Minimum river flo
Plant = 1000 C.F.S
C- Availability of Fe
firm power to ma
cies in Seattle ge
D- Availability of int
form Seattle gen

FIGURE 4.1-1

ROSS HIGH RESERVOIR PROBABLE SURFACE ELEVATIONS DURING AND AFTER CONSTRUCTION

1 MAXIMUM ALLOWABLE ELEVATIONS BECAUSE OF CONSTRUCTION

2 LOWER ELEVATION LIMIT 1928-1929 HYDRO CONDITIONS REPEATED ANNUALLY

3 FILL LINE WITH UNIFORM REGULATION TO PROVIDE FULL RESERVOIR IN SECOND YEAR AFTER CONSTRUCTION UNDER QUALIFYING CONDITIONS*

ONS

ws in the
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System
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A O D

NOTE:
Based on curves provided by
City of Seattle, Department of Lighting

S14-CG75

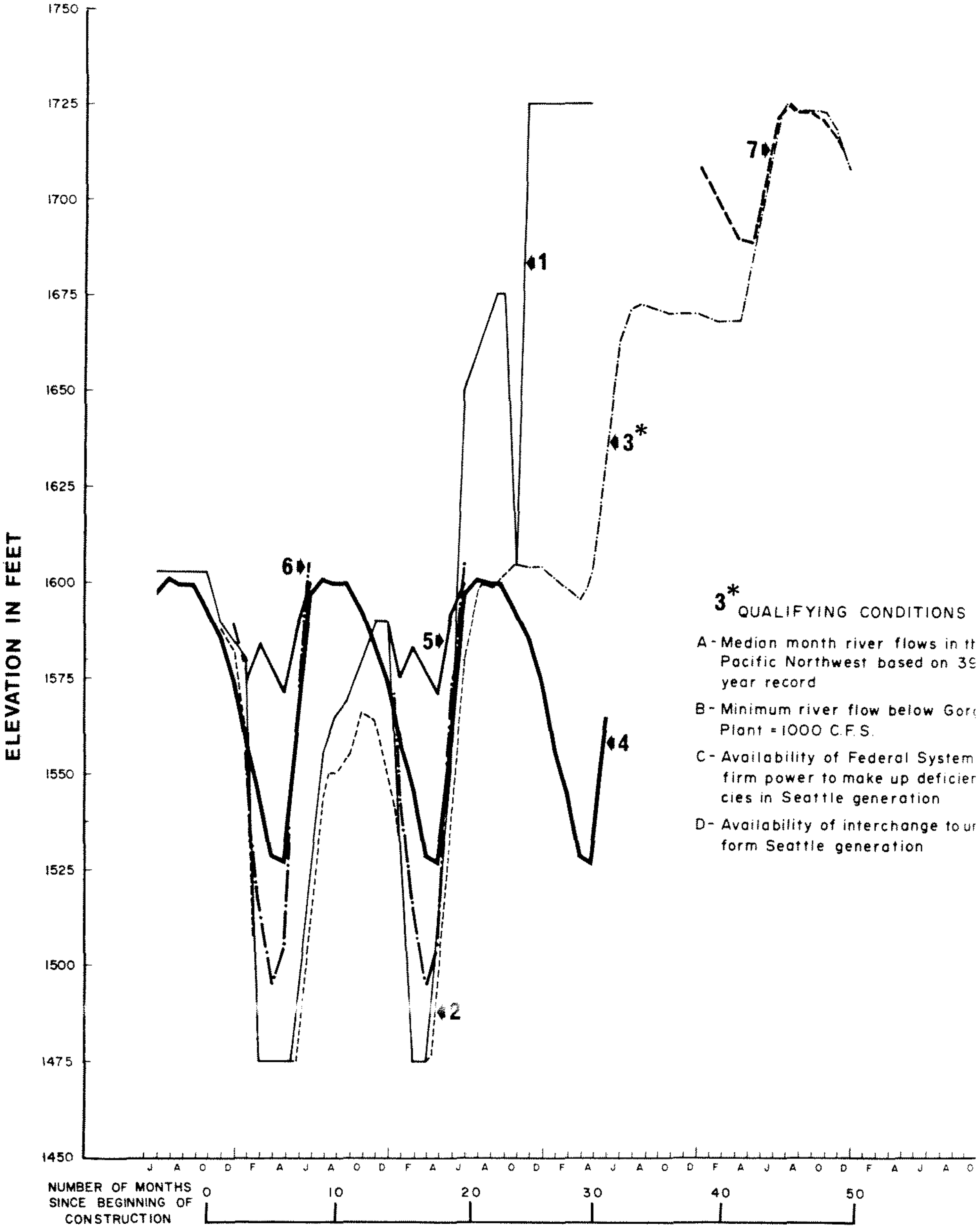
maximum allowable curves for the periods September 1 - December 31 of the first construction year and after June 15 of the second construction year.

Construction is planned to start in the fall. Since reservoir elevations during November-December would apparently not deviate from normal operating levels, this initial period will not be considered further, and discussion will center around the two full calendar years of construction.

Although the planned reservoir level is expected to fall between the two curves as described, discharge capabilities would permit holding the reservoir level constant during any particular period, provided inflow was sufficient to meet downstream minimum flow requirements.

In Figure 4.1-2, curves have been added to show the mean reservoir level fluctuations during the past 19 years of operation and the reservoir levels for the years with the greatest and least drawdowns. The differences between these curves and the construction period curves result from the increased drawdown to 1475 feet elevation, the filling to only 1565 elevation in the first summer of construction, and the difference in timing of fill to summer maximum in the two construction years.

Because elevation changes during trout spawning and incubation of eggs and alevins are of concern, data are presented in Table 4.1-1 to give monthly rates of change during the past 17 years, and the rates of change during construction and filling. The significance of this information will be discussed in Section 5. End of month elevations of Ross Reservoir for the years 1953-1972 are presented in Appendix 41.



3* QUALIFYING CONDITIONS

A - Median month river flows in th Pacific Northwest based on 39 year record

B - Minimum river flow below Gor Plant = 1000 C.F.S.

C - Availability of Federal System firm power to make up deficien cies in Seattle generation

D - Availability of interchange to u form Seattle generation

FIGURE 4.1-2

ROSS HIGH RESERVOIR PROBABLE SURFACE ELEVATIONS DURING AND AFTER CONSTRUCTION

with

Past and Projected Average Elevations

and

Elevations During 1963 and 1969

1 Maximum allowable elevations because of construction

2 Lower elevation limit, 1928 - 1929 hydro conditions repeated annually

3 Fill line with uniform regulation to provide full reservoir in second year after construction under qualifying conditions*

4 Nineteen year (1953-71) average month-end elevation

5 Month-end elevations in 1963

6 Month-end elevations in 1969

7 Probable average month-end elevations with High Ross Reservoir based on water conditions of past nineteen years (1953-71)

NOTE:
Based on curves provided by
City of Seattle, Department of Lighting

S14-CG76

Clearing Specifications

Tentative specifications for clearing High Ross Reservoir in the U.S. portion stipulate that all forest cover is to be removed to elevation 1727 feet. All areas above elevation 1720 feet with slopes less than 30 per cent are to be grubbed of stumps and groomed.

Below elevation 1727 feet, on slopes over 30 per cent, stumps from 6 inches to 12 inches in height may be left depending upon the elevation, except that below elevation 1650 feet tress that do not extend above 1650 feet elevation may be left.

Selected sites are to be grubbed and groomed and the forest cover burned. Forest cover from the balance of the reservoir site is to be floated off to minimize disturbance of the soil.

The floatage would be collected in bag booms and stored for disposal. Merchantable bags are to be salvaged. The final disposition of debris is to be by piling and burning. A crane and grapple would be utilized for this operation and material would be drifted or towed to the Canadian end of the reservoir for disposal. The actual burning site would occupy about one acre of land, preferably on a natural or man made peninsula. A float mounted high temperature burner may be used as an alternative to on-shore piling.

The presence of floatage would be a hazard to recreational boaters for about two years after the reservoir reached full pond. Large masses of floatage from the original clearing operation of the reservoir site was a dominant feature of Ross Lake until about 1960. The original floatage apparently was not detrimental to fish population at that time.

Clearing Specifications

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Selected sites are to be grubbed and groomed and the forest cover burned. Forest cover from the balance of the reservoir site is to be floated off to minimize disturbance of the soil.

The floatage would be collected in bag booms and stored for disposal. Merchantable bags are to be salvaged. The final disposition of debris is to be by piling and burning. A crane and grapple would be utilized for this operation and material would be drifted or towed to the Canadian end of the reservoir for disposal. The actual burning site would occupy about one acre of land, preferably on a natural or man made peninsula. A float mounted high temperature burner may be used as an alternative to on-shore piling.

The presence of floatage would be a hazard to recreational boaters for about two years after the reservoir reached full pond. Large masses of floatage from the original clearing operation of the reservoir site was a dominant feature of Ross Lake until about 1960. The original floatage apparently was not detrimental to fish population at that time.

Flushing Rate

Reservoir mean elevation, volume and flushing rate projected for the first calendar year and the second year of construction through October are presented in Table 4.1-2, based on the 1928-1929 lower elevation limit curve. Data on past reservoir performances are included for comparison. Flushing rate would be considerably higher than average in the first calendar year and somewhat higher in the second year of construction.

Temperature and Dissolved Oxygen

Lake temperature during the winter-early spring months of construction would be close to homeothermous from surface to bottom and, at the lower reservoir level, would not be expected to deviate particularly from the present pattern. During spring-summer warming the hypolimnion volume would be less than at present, but the rate of flushing of the hypolimnion at this time would be less than normal because of the need to store water to meet the rather steep refill curves. It appears that temperature deviations from normal would be inconsequential.

Oxygen replenishment of hypolimnial waters occurs during overturn periods in late fall and early spring and from inflow of colder stream water. Oxygen declines occur in the hypolimnion in late summer and fall. Discharge from the reservoir draws from the hypolimnion. BOD (biochemical oxygen demand) in the hypolimnion would be expected to increase by increased inflow of organic debris as a result of forest removal activities. The net effect may result in lowered oxygen levels near the lake bottom during the late summer-early fall period which may influence the rate of release of bottom nutrients. Exposure of bottom area below the level normally subject to wave action would also result in circulation of nutrients and organic matter during the late winter-early spring drawdown and fill periods. It is not anticipated that these sources of enrichment and BOD would be sufficient to cause serious oxygen depletion problems since the lake is generally oligotrophic.

Turbidity

Both the shoreline clearing activities during construction and the exposure of new bottom area to wave action during extreme drawdown would increase turbidity somewhat. However, the expected primary source of lake turbidity would still be the stream discharge during the April-June period of the year. Some decrease in the depth of the euphotic zone would be expected. Effects on primary production will be discussed in Part 5.

Water Chemistry

For the reasons just described, some buildup of organic and inorganic constituents might be expected in spite of increased flushing rate.

Obstructions

During summer of the first construction year the maximum lake elevation would be some 37 feet below normal full reservoir. Boat travel on the lake would be hazardous, particularly near the lake shoreline, because of trees below the lake surface.

Access

It is probable that access from the south end of the lake would be restricted during construction unless special provisions were made. Access at the north end would be altered by the lower lake level during the first year and by clearing activities in the valley.

TABLE 4.1-1

MONTHLY RESERVOIR ELEVATION CHANGES (IN FEET) FOR PERIOD JANUARY, 1953-MARCH, 1972, AND PROJECTED CHANGES FOR CONSTRUCTION AND FILL YEARS.

	1953-1972		First construction year		Second construction year			
Month	Mean elevation change	Range	Minimum level	Maximum level	Minimum level	Maximum level	First fill year	Second fill year
January	-17.7	(-1.0,-28.8)	-19	-5	-17	-35	-2	-1
February	-11.8	(2.5,-27.4)	-88	-105	-58	-58	-2	-1
March	-15.2	(18.6,-28.1)	0	0	0	0	-2	0
April	- 3.2	(7.8,-20.9)	0	0	22	73	6	8
May	38.4	(66.4, 13.1)	0	15	38	57	27	14
June	31.5	(69.2, 7.8)	38	35	45	N.A.	25	17
July	4.8	(22.0,- 0.1)	30	30	17	N.A.	12	18
August	- 0.9	(0.4,- 5.5)	8	10	1	N.A.	1	-2
September	- 2.7	(1.3,- 6.6)	5	N.A.	3	N.A.	-1	0
October	- 4.9	(1.1,-11.2)	10	N.A.	2	N.A.	-1	-1
November	- 7.4	(-3.9,-13.9)	-2	N.A.	-1	N.A.	0	-4
December	-10.9	(5.6,-20.7)	-14	N.A.	0	N.A.	0	-10

TABLE 4.1-2

PHYSICAL DATA FOR EXISTING RESERVOIR AND PROPOSED RESERVOIR DURING CONSTRUCTION PERIODS

	Reservoir during periods of construction *	Existing reservoir (17-year average)	Ross Lake - 1963 (year of least drawdown)	Ross Lake - 1969 (year of greatest drawdown)
	First Year			
	January - December	January - December	January - December	January - December
Mean elevation (ft msl)	1528.7	1575.0	1588.9	1566.3
Mean area (acres)	7,880	10,280	11,000	9,850
Mean volume (ac/ft)	715,000	1,127,975	1,270,000	1,040,000
Flushing rate (based on mean volume)	3.7019	2.3465	1.8580	2.1586
	Second Year			
	January - October	January - October	January - October	January - October
Mean elevation (ft msl)	1549.8	1571.3	1589.3	1564.3
Mean area (acres)	9,050	10,100	11,050	9,750
Mean volume (ac/ft)	880,000	1,114,208	1,280,000	1,015,000
Flushing rate (based on mean volume)	2.6313	2.0782	1.5241	2.0271

* Based on 1928 - 29 lower elevation limit

early spring drawdown and fill periods. It is not anticipated that these sources of enrichment and BOD would be sufficient to cause serious oxygen depletion problems since the lake is generally oligotrophic.

Turbidity

Both the shoreline clearing activities during construction and the exposure of new bottom area to wave action during extreme drawdown would increase turbidity somewhat. However, the expected primary source of lake turbidity would still be the stream discharge during the April-June period of the year. Some decrease in the depth of the euphotic zone would be expected. Effects on primary production will be discussed in Part 5.

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For the reasons just described, some buildup of organic and inorganic constituents might be expected in spite of increased flushing rate.

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Access

It is probable that access from the south end of the lake would be restricted during construction unless special provisions were made. Access at the north end would be altered by the lower lake level during the first year and by clearing activities in the valley.

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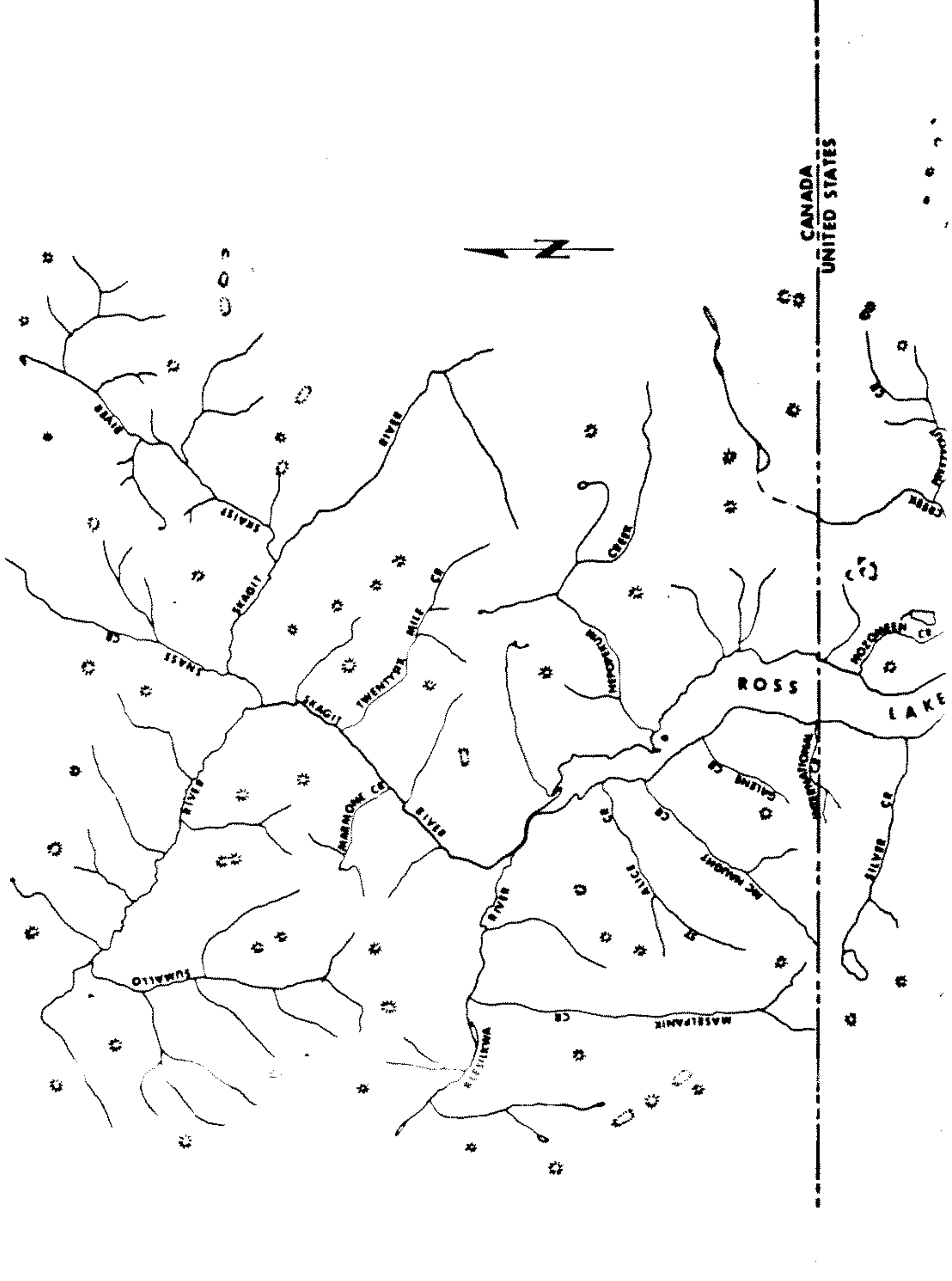

CANADA
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SKAIST
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SNASS CR
TWENTY-SIX MILE CR
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RIVER
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MARMONE CR
RIVER
SUMALLO
KLESILKWA
MASELPANIK CR
ALICE CR
MC NAUGHT CR
GALENE CR
INTERNATIONAL CR
SILVER CR
ROSS
LAKE
HOZOMEEN CR
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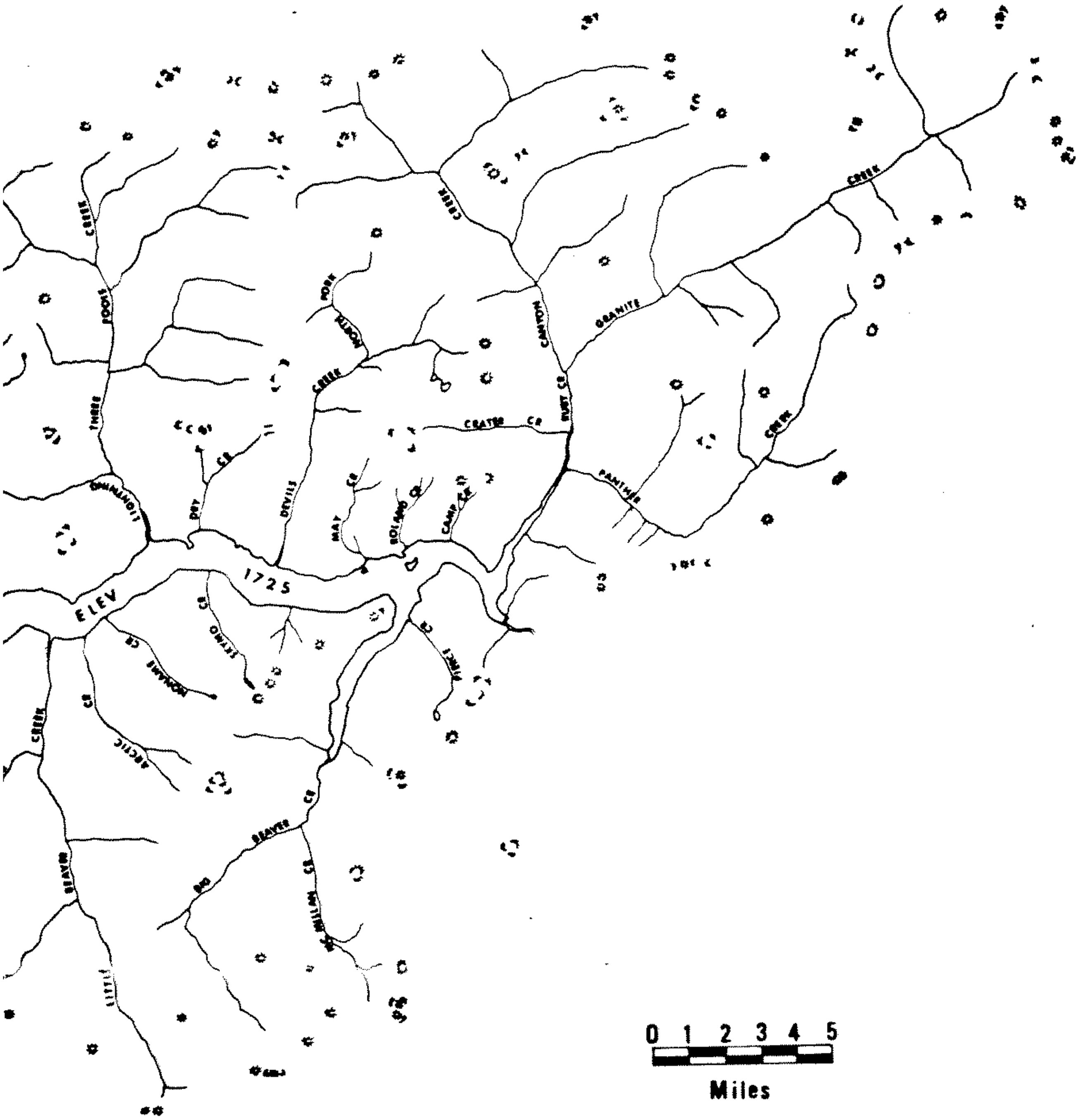
MAP 4

RIVER SYSTEM

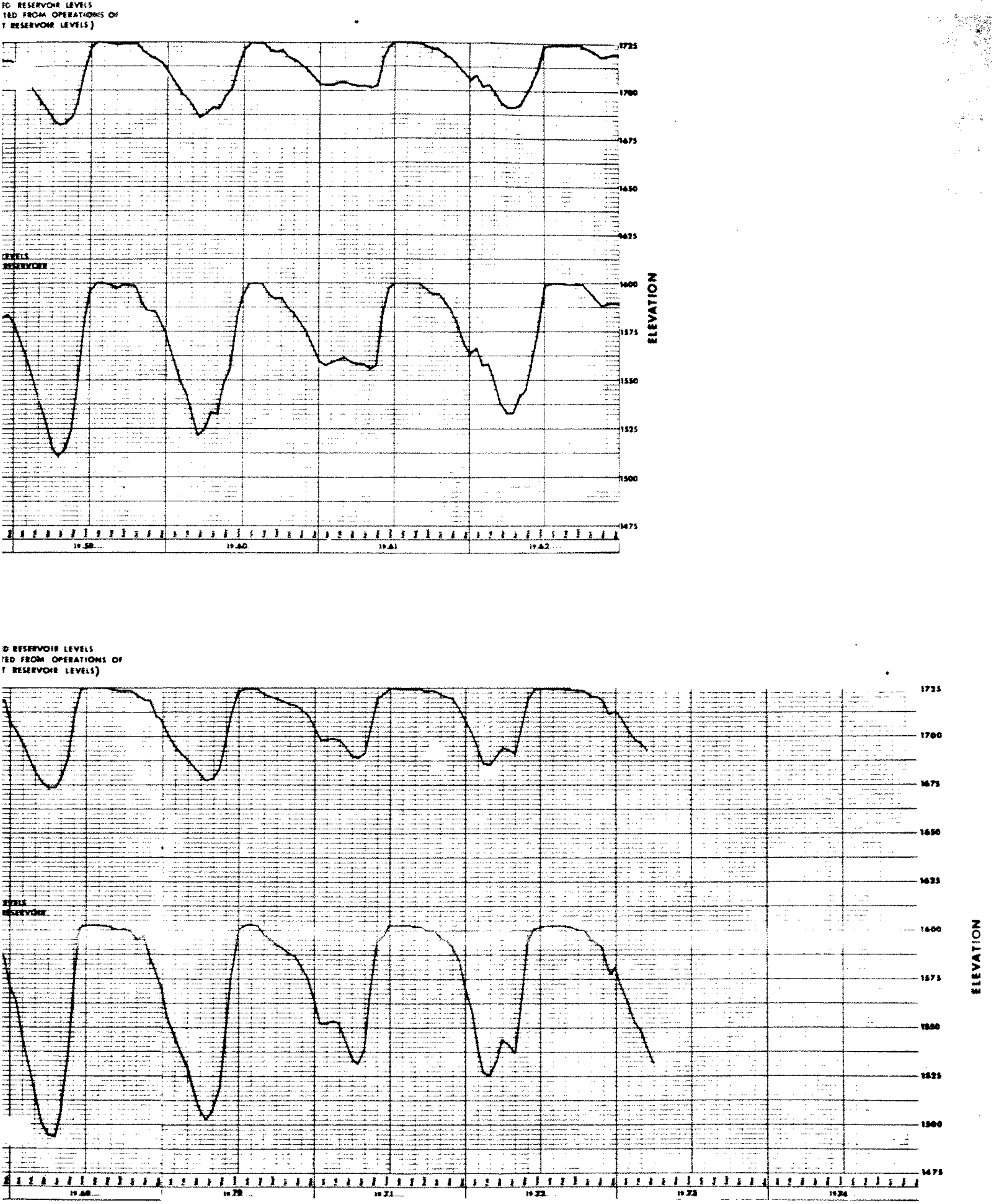
ove Ross Dam

Lake at Elevation 1725 Feet



4.2-1

E ELEVATION FLUCTUATIONS, 1953-1973



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OBSERVED AND PROJECTED ROSS

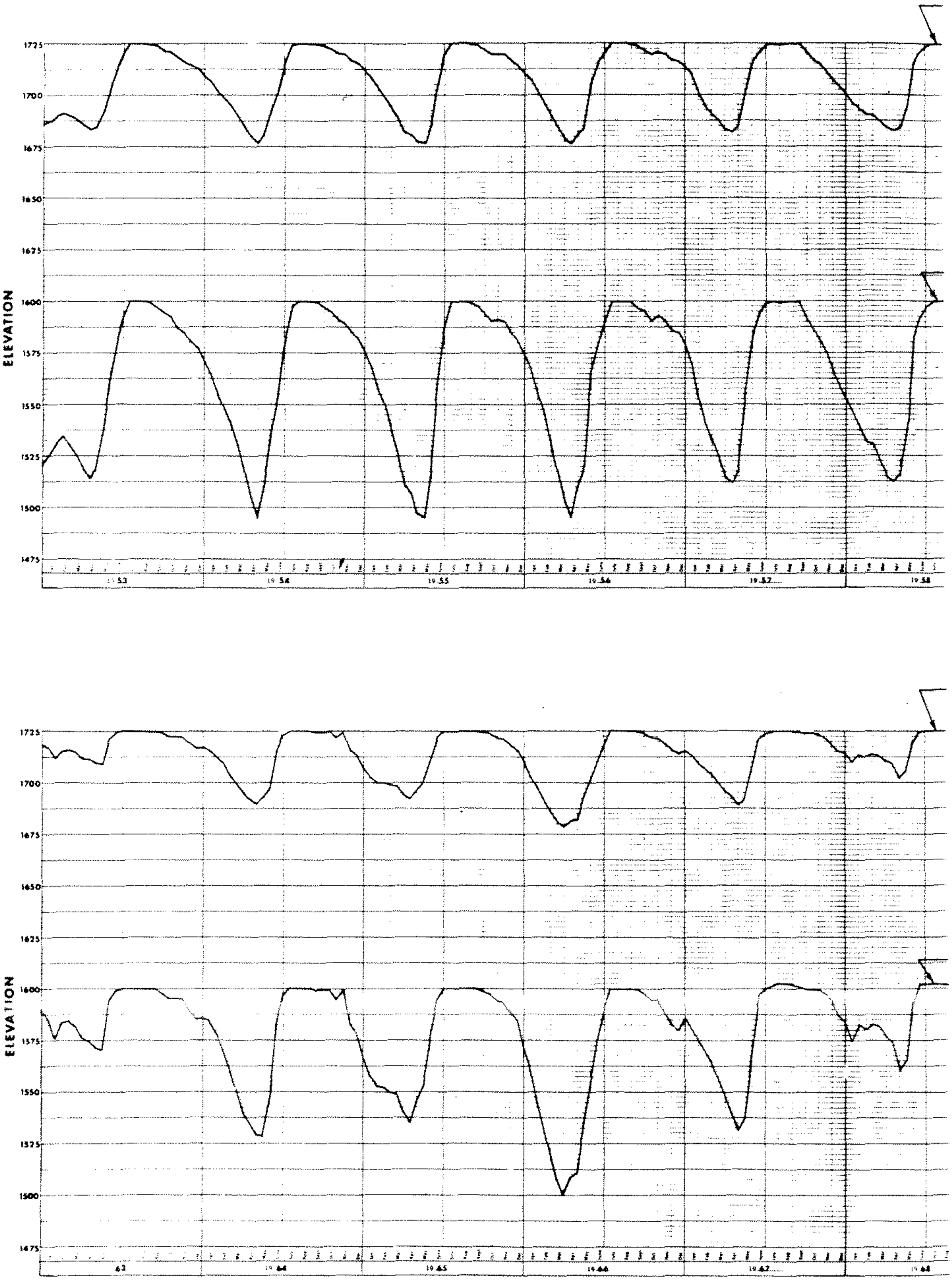

TABLE 4.2-3

MONTHLY FLUSHING RATES FOR HIGH ROSS LAKE BASED ON THE INFLOW IN ACRE-FEET INTO THE RESERVOIR AS A PROPORTION OF THE RESERVOIR VOLUME FOR EACH MONTH. VALUES ARE BASED ON A 17 YEAR EXPERIENCE RECORD[1], 1953-1969

Month	Month end elevation	Reservoir volume (acre feet)	Natural[2] inflow (acre feet)	Outflow (acre feet)	Flushing rate (inflow/ volume)
January	1,702.3	3,006,119	137,577	294,504	.0458
February	1,696.4	2,894,494	120,876	232,501	.0418
March	1,689.0	2,757,876	108,315	244,933	.0393
April	1,687.8	2,736,082	185,490	207,284	.0678
May	1,696.4	2,894,494	486,743	328,331	.1682
June	1,721.9	3,393,048	585,679	87,125	.1726
July	1,725.0	3,456,497	326,422	262,973	.0944
August	1,724.5	3,446,222	134,441	144,715	.0390
September	1,723.0	3,415,492	91,020	121,750	.0266
October	1,720.2	3,358,516	138,990	195,966	.0414
November	1,716.0	3,273,989	167,405	251,932	.0511
December	1,710.4	3,163,046	163,887	274,830	.0518
Year - Total			2,646,845	2,646,845	.8403
Average		3,149,656			

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[1] Experience record is for the existing reservoir with a maximum surface elevation at 1600 feet (1953-1966) and at 1602.5 feet (1967-1969). Inflow records do not include October-December, 1969.

[2] Estimated from discharge and lake volume records, ignoring loss from evaporation.

weather conditions. He further stated that the thermocline would form at about the same time in the spring and its gradient would remain about the same with minor exceptions.

The dissolved oxygen profile has been discussed with respect to the existing reservoir. Oxygen replenishment of the hypolimnion would continue to occur during late fall and early spring overturns of the lake water. With the deeper hypolimnion, the total oxygen available for BOD processes per unit area of water column in the hypolimnion would be greater than in the present reservoir. Inundation of new land and increased amounts of organic detritus would be expected to increase BOD for a few years although the effect on dissolved oxygen concentration would be slight. In Lake Minnewanka--a highly oligotrophic lake in B.C.--construction of a power dam, which raised the lake level 65 feet and increased its area by 40 percent, did not change the temperature structure or reduce hypolimnial oxygen concentration (Rawson, 1958). Because of the decreased annual drawdown anticipated in Ross Lake, more of the particulate matter settling in shallower water would remain there. In the short term, hypolimnial oxygen depletion is expected to be slightly greater; over the long term it is expected to be slightly less than at present.

Turbidity

During the first few years, turbidity will be increased slightly as a result of some erosion of new shoreline, flooding of land, and resultant enrichment of the lake. Eventually, turbidity in High Ross Lake during spring runoff might be expected to be less than in the existing reservoir due to the greatly increased dilution of inflow from turbid streams by the relatively clear lake water. In the fall and winter turbidity of the proposed reservoir would probably be quite similar to that of the existing reservoir.

The lake cleared from its lowest visibility at the end of June to pre-runoff visibility by mid-August in 1972 (see Appendix 1).

Due to heavy runoff in 1972 Ross Reservoir flushing rate in the July-August period was 61 percent of the lake volume. The observed clearing rate, with flushing rate taken into account, indicates that much of the solids contributing to turbidity settles out relatively rapidly in the reservoir. The proposed reservoir would probably take about the same time to clear to pre-runoff visibility as the existing reservoir although average visibility would be greater throughout the runoff and post-runoff (July-August) period.

Water Chemistry

Total dissolved solids (TDS) concentration in Ross Lake is affected by a multiplicity of interacting factors, of which reservoir flushing rate, uptake of dissolved solids by organisms, and accumulation of non-living detritus, which contribute to TDS by decomposition and to uptake of TDS by adsorption, are of importance. Following the addition of new organic and inorganic matter to the lake by initial flooding and subsequent stabilization of TDS levels, input of dissolved solids to the reservoir from the watershed would remain essentially the same as at present. The lower flushing rate of the high lake and the lesser elevation fluctuations would probably allow slightly greater accumulation of dissolved solids and organic detritus in the epilimnion.

Obstructions

The existing reservoir contains many areas where submerged trees present considerable navigation hazards, especially when the lake is below 1550 feet elevation. At the proposed high lake these obstructions would be far below the surface at minimum elevation. All such obstructions in the proposed high lake drawdown area would be removed.

Access

Access to the north end of the lake is by the Silver Skagit Road from Hope, B.C. and across the U.S. border. This access would be modified so road access to the north end of Ross Lake will stop about two miles short of the U.S. border. The south end of Ross Lake is presently accessible by trail or boat from Diablo Lake. Construction of access to the lake by road from the recently completed North Cascades Highway (1972) is under consideration by the U.S. National Park Service.

An extensive trail system exists in the Ross watershed. Plans have been formulated to relocate trails that will be inundated and to relocate and improve lakeside campsites. In general, greater access to the lake is anticipated.

4.2.2 Ross Lake Tributary Streams

(by Fisheries Research Institute)

The lower portions of the major American tributary streams to Ross Lake and of some of the minor American tributaries would be inundated by the proposed lake. Figures 3.3-2 to 3.3-6 show the portions of the major tributaries which will be affected. Characteristics of major and minor tributaries of the Ross Lake watershed at the proposed reservoir level of 1725 feet are presented in Tables 4.2-4 and 4.2-5.

The minor American tributaries would undergo slight or no changes in stream length, gradient and character. The minor streams which empty into the lake would be affected for only a short distance due to their steepness. Of these streams, Silver Creek would be affected most. Its length would be reduced from 6.20 to 5.85 miles (Tables 2.2-2 and 4.2-5). Except for Crater and Panther creeks, which would be affected only slightly, streams tributary to major American streams would not be affected at all by the increase in lake elevation (Tables 2.2-2 and 4.2-5).

The length, gradient, substrate and character of the major American tributaries (Table 4.2-4) would be altered by the increased lake level. Ruby and Big Beaver creeks would be affected substantially. The length of Ruby Creek would be reduced from 3.36 to 1.82 miles. Its over-all gradient would increase slightly from 1.56 to 1.61 per cent. Substrate and character would be essentially

TABLE 4.2-4

CHARACTERISTICS OF MAJOR TRIBUTARIES OF HIGH ROSS LAKE

	TRIBUTARY					
	Ruby Creek	Big Beaver Creek	Devils Creek	Lightning Creek	Little Beaver Creek	Canadian Skagit River
Drainage area (square miles)	132.83	47.66	29.80	140.87	52.97	296.00
Length (miles)	1.82	10.59	9.28	10.49	13.73	10.2
Gradient (percent)	1.61	2.87 (lower 1.09 mi)	4.75 (lower 7.95 mi)	2.81	2.14 (lower 13.08 mi)	0.53
Discharge	will be less - due to loss of Panther Creek and Crater Creek drainages	slightly less - due to loss of drainage area	no significant change from present	no significant change from present	no significant change from present	
Substrate	BO, R, CGR	BO, R-lower 6 miles	variable-BR BO, CGR	BO, R, CGR FGR	BD, BO-lower 1½ miles, BO, R, GR-upper 12 mi	See Section 4.2.3.1
Character	Rapids, deep riffles, a few pools	riffles, rapids - lower 6 mi	variable - falls rapids, pools	rapids, deep and shallow riffles, pools	falls, rapids - lower 1½ miles rapids, riffles meanders upper 12 mi	many log jams; riffle and rapid sections
Accessibility of stream areas above stream mouth to fish from Ross Lake	Accessible	Not accessible	Not accessible	Accessible for 1.85 miles or 6.06 miles with log jams removed	Not accessible	Accessible

TABLE 4.2-5

CHARACTERISTICS OF MINOR TRIBUTARIES OF THE HIGH ROSS LAKE (1725 FT ELEVATION) WATERSHED

	TRIBUTARY						
	Granite Creek	Canyon Creek	Crater Creek	Panther Creek	McMillan Creek	Three Fools Creek	Freezeout Creek
Tributary to:	Ruby Creek	Ruby Creek	Ross Lake	Ross Lake	Big Beaver Creek	Lightning Creek	Lightning Creek
Drainage area (square miles)	-	-	8.20	43.80	-	-	-
Length (mi.)	17.05	16.10	4.88	12.81	5.70	10.30	6.16
Gradient (percent)	3.29	3.95 (lower 13.0 mi)	24.21	4.57 (lower 12.08 mi)	3.48 (lower 4.51 mi)	4.06 (lower 3.17 mi)	10.90 (lower 5.66 mi)
Character	rapids swift flow over bouldery bottom	rapids riffles, pools, BO, R, GR	-	steep rapids and falls, BR, BO	variable - rapids, riffles, pools, BO, R, CGR	rapids falls, swift flow through gorge	-
Accessibility of stream areas above stream mouth to fish from Ross Lake	Accessible for 6.06 miles	Accessible for 9.18 miles	Not accessible	Accessible for .16 mi. or 3.73 mi. if log jam is removed	Not accessible	Accessible for .25 mi.	Not accessible

TABLE 4.2-5 - Page 2

	Perry Creek	North Fork, Canyon Creek	Slate Creek	Mill Creek	Roland Creek	May Creek	Skymo Creek
Tributary to:	Little Beaver Creek	Canyon Creek	Canyon Creek	Canyon Creek	Ross Lake	Ross Lake	Ross Lake
Drainage area (square miles)	-	-	-	-	4.76	3.84	5.16
Length (miles)	5.45	5.59	8.95	6.91	2.49	3.67	3.15
Gradient (percent)	8.90	11.40	8.02	8.99	40.80	25.57	16.99
Character	-	rapids, falls and pools-R, BO and BR substrate, limited GR areas	rapids, falls and pools-BO and BR substrate, limited GR	rapids and falls, few pools-R, BO and BR substrate, little GR	steep falls and rapids	steep falls and rapids	steep falls and rapids
Accessibility of stream areas above stream mouth to fish from Ross Lake	Not accessible	Accessible for 0.62 miles	Accessible for 0.47 miles	Accessible for 1.23 miles	Accessible for .08 miles	Not Accessible	Not Accessible

TABLE 4.2-5 - Page 3

	Noname Creek	Arctic Creek	Dry Creek	Silver Creek	Hozomeen Creek	Pierce Creek
Tributary to:	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake
Drainage area (square miles)	6.75	13.68	6.35	17.00	6.75	3.64
Length (miles)	3.98	5.47	3.61	5.85	4.24	3.20
Gradient (percent)	10.09	13.15	21.59	7.62 (lower 4.76 mi.)	6.32	17.17
Character	steep falls and rapids	steep falls and rapids	steep falls and rapids, pools	rapids and falls	--	steep falls and rapids
Accessibility of stream areas above stream mouth to fish from Ross Lake	Not Accessible	Not Accessible	Accessible for .05 mi or .09 mi, if log jams in North & South forks are removed	Accessible for .11 mi.	Not Accessible	Not Accessible

unchanged. The over-all gradient of Big Beaver Creek between McMillan Creek and the inlet to Ross Lake would be increased substantially from 0.61 to 2.87 percent. The stream character would be greatly changed because the lower 7 miles, which presently is a meandering section with a silt, sand and fine gravel substrate, would be inundated. The remainder of the stream would be characterized by riffles and rapids flowing over a boulder and rubble substrate. A one-quarter mile section of Big Beaver Creek just above the 1725 foot elevation flows through a deep gorge. The stream in this location is precipitous and is characterized by steep rapids and falls. The length and gradient of Devils, Lightning and Little Beaver creeks would be changed only slightly. The falls in Lightning Creek at elevation 1648 feet would be inundated.

4.2.3 Skagit River and Tributaries

(by F.F. Slaney and Company)

4.2.3.1 Skagit River

General Description

The physical characteristics of the Skagit River with Ross Lake at elevation 1725 feet are outlined briefly in Table 4.2-4. The characteristics of other major tributaries to Ross Lake are also presented in the table. Some of the characteristics of the river are considered in greater detail below. The short term changes in the physical characteristics of the Skagit River should not differ appreciably from changes over the long term.

Profile and Gradients

The profile of the Skagit River between elevations 1725 feet and 2011.8 feet is shown on Figure 2.3-2. Figure 2.3-2 also shows the gradients in this portion of the river.

TABLE 4.2-2

CHARACTERISTICS OF THE EXISTING AND PROPOSED RESERVOIR (ROSS LAKE)

Parameter	Existing Reservoir (1602.5 ft msl)	Proposed Reservoir (1725 ft msl)	Difference
Drainage area (mi^2)	999	999	-
Lake elevation (feet)			
Maximum	1,602.5	1,725.0	122.5
Minimum	1,475.0	1,669.0	194.0
Annual Mean	1,575.0	1,710.0	135.0
Surface area (acres)			
Maximum	11,700	20,000	8,300
Minimum	4,400	16,300	11,900
Annual Mean	10,300	19,000	8,700
Volume (acre-feet)			
Maximum	1,435,000	3,456,000	2,021,000
Minimum	412,000	2,420,000	2,008,000
Shoreline development *			
Maximum	4.26	4.79	0.53
Minimum	4.02	4.60	0.58
Annual Flushing Rate **			
Maximum reservoir (1602.5,1725 ft)	1.84	0.77	1.07
Mean reservoir (1575,1710 ft)	2.35	0.84	1.51

* Reid, 1965

** Based on 17-year record for existing reservoir, 1953-1969. Does not include inflow for October - December 1969)

TABLE 4.2-5 - Page 4

	International Creek	Galene Creek	McNaught Creek	Shawatum Creek	St. Alice Creek	Nepopekum Creek
Tributary to:	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake	Ross Lake
Length (miles)	3.1	2.8	6.2	4.3	6.2	11.7
Gradient (percent)	25.0	29.0	12.0	15.0	12.0	4.0

area and elevation are based on the volume changes experienced during the 1953-1969 period.

4.2.1.2 Reservoir Elevation and Size (See Tables 4.2-1 and 4.2-2)

The normal full pool elevation would be 1725 feet msl. Minimum reservoir elevation would be 1669 feet - a maximum drawdown of 56 feet compared to 127.5 feet for the existing reservoir. Annual mean lake elevation would be 1710 feet - 15 feet below full pool. For the existing lake the annual mean is 1575 feet - 27.5 feet below full pool. Mean annual drawdown elevation for the high lake would be 1686 feet (a drawdown of 39 feet) compared to 1530 feet for the existing lake (a drawdown of 72.5 feet).

Surface area of the full reservoir (1725 feet msl) would be 20,000 acres (presently 11,700 acres at 1602.5 feet). The area of the reservoir at maximum drawdown elevation (1669 feet) would be 16,300 acres (presently 4,400 acres at 1475 feet). Mean depth of the proposed reservoir at full pool would be 172.8 feet and at full drawdown, 148.5 feet (existing mean depths are 122.6 and 93.6 feet respectively).

Full reservoir volume would be 3,456,000 acre feet; at maximum drawdown volume would be 2,420,000 acre feet and at the annual mean lake elevation, 3,160,000 acre feet (existing lake volumes are 1,435,000, 412,000 and 720,000 acre feet respectively).

Shoreline length and development at full reservoir (1725 feet) would be 95.0 miles and 4.79 respectively (presently 64.5 miles and 4.26 at 1602.5 feet); at maximum drawdown (1669 feet), 82.3 miles and 4.60 (presently 37.4 miles and 4.01 at 1475 feet); and at mean drawdown (1686 feet) 87.5 miles and 4.73 (presently 51.0 miles and 4.07 at 1530 feet).

Drawdown Schedules and Flushing Rates

Fluctuation of the proposed reservoir levels would vary from year to year depending on weather conditions, snow pack and discharge through the dam. Predicted lake drawdown and filling schedules based on observed conditions in past years are presented in Figure 4.2-1. Also shown for comparison are the drawdown and fill curves for the existing reservoir for the same years.

Average monthly inflow,[1] discharge and projected high reservoir volume data based on records for the 17-year period 1953-1969 were used to calculate annual flushing rate of the proposed reservoir. From July 1 to June 30 the 17-year average flushing rate projected for the high lake, based on full reservoir volume, would be 0.77. Based on average reservoir volume during the year the rate would be 0.84. For the existing lake these values were 1.84 and 2.35 respectively. The existing reservoir would flush approximately 2-1/2 times as rapidly as the proposed reservoir, under identical conditions. Monthly flushing rates based on projected monthly average lake volumes are presented in Table 4.2-3.

Temperature and Dissolved Oxygen

Changes in the temperature regimen of Ross Lake from the existing reservoir to the high reservoir would result from the greater thickness of the hypolimnion at the new height. Burt (1971) indicated that the temperature regimen in the upper 100 feet of High Ross Lake would not change greatly because the geometry of the main lake basin does not change much from the 1500 feet to the 1725 feet elevation and temperature of the upper 100 feet of the lake is controlled by

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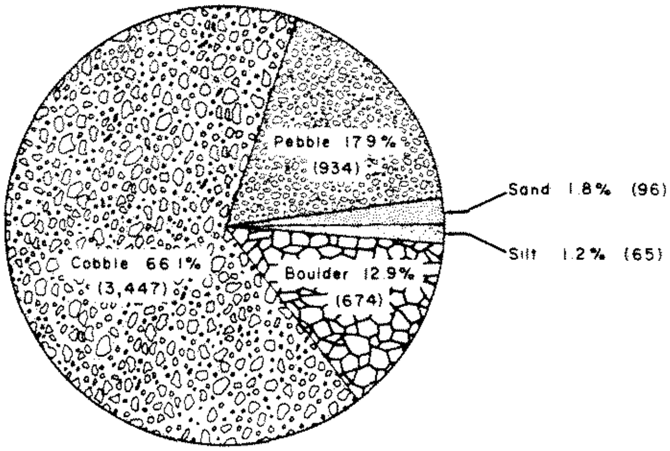
[1] Estimated from discharge and lake volume data, ignoring loss from evaporation.

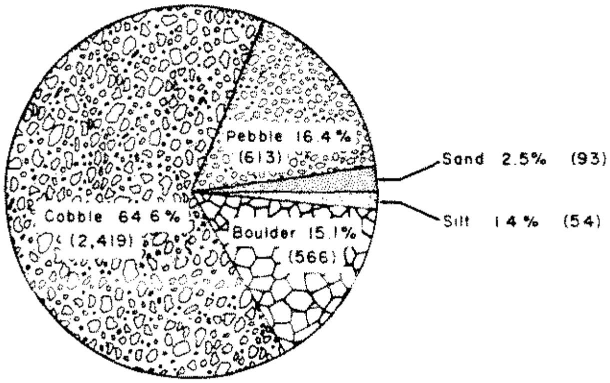
FIGURE 4.2-2

SKAGIT RIVER SUBSTRATE

Elevations 1725 ft. to 2011.8 ft.



High (Spring) Water Levels



LEGEND

( ) Bracketed numbers in thousands of square feet.

Low (Fall, 1970) Water Levels

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PART 5

PROJECTIONS FOR FISHES AND FISHERY

5.1 CONSTRUCTION PERIOD

5.1.1 Spawning Time, Location, and Success

5.1.1.1 American Tributaries

(by Fisheries Research Institute)

The time of rainbow trout spawning was found to occur between mid-May and mid-July as discussed in Section 3.3.2.2. During the construction period, the time of trout spawning should not deviate from normal. The Ross Lake trout should be expected to respond as usual to the increased stream discharge and rising stream temperatures. Likewise, spawning of char (Dolly Varden and brook trout) should occur at the normal time in the fall (approximately Sept. - Oct.).

The areas of potential trout spawning will be altered somewhat due to deviations in lake elevation patterns during construction, especially during the first construction year. As shown in Figure 4.1-1, the normal mid-May to mid-July spawning season will occur when lake elevation is between the possible elevation range of 1475 to about 1530 feet. These elevations are considerably lower than normal. Spawning areas available during the second construction year would more closely approach the normal. The consequence of the lower lake elevations is that generally more stream spawning area will be available. This is described in Section 4.1.2.1. Two possible exceptions are at Big Beaver (if utilized for spawning by Ross Lake trout), and Lightning Creeks. Since the lake elevation during the first construction year will not exceed 1565 feet, the falls on Big Beaver Creek between about 1530 feet and the 1565-foot maximum elevation will block the stream to upstream movements. In Lightning Creek, the migration block at the 1565-foot elevation

4.2.3.3 Drawdown River

The maximum length of the drawdown river with Ross Lake at 1725 feet elevation will be approximately 4.4 miles between elevations 1725 feet and 1669 feet. The gradient of this section is 0.25 percent. The mean drawdown elevation of 1710 feet will expose about one mile of river channel with the same gradient.

Increased amounts of fine particles will be found in the gravels of the drawdown river at certain times of the year with High Ross Lake.

would restrict use of the normal spawning areas upstream unless passage facilities are provided. The locations of spawning in the other Ross Lake tributaries are expected to be expanded due to the increased drawdown exposure of stream channels. The gravels in these areas would be free of fine materials (silt and sand) because of the rapid cleaning by stream flow which has been observed and described in 4.1.2.1. The quality of these areas would thus be adequate for spawning. No other migration blocks are known to exist between the 1475 and 1565 elevations.

The areas of char (Dolly Varden and brook trout) spawning would probably be reduced somewhat during the fall at the end of the first year of construction. Lightning and Big Beaver Creeks would remain inaccessible until the following spring. Char spawning areas would not be significantly affected by the construction schedule in the fall at the end of the second construction year.

Overall, the success of trout spawning in the Ross Lake tributaries during the construction period should not be detrimentally affected by spawning area availability. To date, there is no indication that Big Beaver Creek above elevation 1602.5 is of importance as a spawning area for Ross Lake trout. Provision of temporary passage facilities in Lightning Creek at the 1565-foot elevation would open the stream to elevation 1648 feet. It is assumed in the discussion to follow that this will be accomplished since the cost involved would be minimal. However, the possible effects of differences in fill schedules on redd inundation and egg and alevin survival warrants further discussion. During the two construction years, timing of fill will be delayed so that inundation of stream areas will continue into July and August to a greater degree than normal (Table 4.1-1), particularly in the first construction summer. The degree of inundation of fish redds in the first summer will depend on the behaviour of the fish. If they use the available upper portions of the stream as expected, inundation of redds would be less than normal since the lake elevation would rise only to elevation 1565 feet. In the second construction summer, redd inundation may be greater than normal because of the delayed fill and the slightly higher maximum lake elevation. As indicated in Section 3.3.2.3, some production appears to be occurring in inundated stream inlet or lakeshore areas.

The influence of inundation of redds in stream areas by rising lake level on survival of eggs and alevins was investigated in 1972. Plastic containers, perforated with .078 in. diameter holes spaced .2 in. apart and containing gravel and fertilized eggs of resident trout were buried in bottom gravel near several stream mouths in Ross Lake. Four containers were buried at each of preselected depths to 45 ft. below full pool elevation except in the mouth of Roland Creek where only 2 containers were buried. The experiment was hampered by heavy runoff and loss of controls; thus success of the investigation was limited. Results of the experiment (Table 5.1-1) show that heavy egg mortality occurred at most of the stations--particularly those where heavy silt deposits were found. Because of the limited success of the experiment conclusions are necessarily preliminary; however, as the results in Table 5.1-1 indicate, egg to alevin survival potential exists in inundated bottom gravels off the mouth of Roland Creek to a depth of 31 ft. below full pool elevation. In other bottom areas off Lightning and Ruby Creeks heavy siltation appeared to result in total egg mortality. Results in the bottom area off Pierce Creek were inconclusive. Further studies of egg to alevin survival are planned in 1973.

Overall, spawning success in American tributaries and their inlets will probably not be detrimentally affected during the construction period.

4.1.1.2 Fill Period

Projected reservoir elevations for the two year fill period (see Figure 4.1-1) are based on median river flow conditions. Qualifying conditions are stated on the graph. More rapid filling may be possible with above average runoff, and slower filling with below average runoff. In the first three months of the first filling year the reservoir would be held near 1600 feet elevation. The primary elevation rise would occur during heavy runoff in May-June. Because of the greater volume to fill, this rise would be less than the average in past years for these months. The July rise would be about 10 feet greater than average. The reservoir level would then be held at about 1670 feet over winter, and the final filling would occur in May-July of the second year.

Flushing Rate

The reservoir would increase in year end elevation about 67 feet and in volume about 930,000 acre feet during the first year of fill, resulting in an annual flushing rate of about 0.76 with average runoff. In the second year, elevation and volume increases would be about 38 feet and 750,000 acre feet, respectively, resulting in a flushing rate of about 0.60 relative to mean volume during the year. These flushing rates are much lower than the 1953-1969 year average of 2.35 (Table 2.1-2).

Temperature and Dissolved Oxygen

Because of the increase in elevation of the reservoir with filling the hypolimnion would be increased in depth. This would result in a decrease in summer mean temperatures in the water column. Epilimnial temperatures and temperature stratification would not change greatly.

Oxygen replenishment of hypolimnial waters would occur as usual during late fall and early spring overturn and from stream inflow. With increased hypolimnial volume and lower mean temperature of the hypolimnion, a larger amount of oxygen would be stored in the hypolimnion. Flooding of new land and influx of debris from forest removal would add to the hypolimnial BOD, although more of the particulate matter settling in shallower water would remain there because it would remain relatively undisturbed in the absence of the usual drawdown and accompanying surface wave action as the lake level falls and rises. The increase in BOD to be expected is difficult to assess, but would presumably be less per unit volume of lake than that encountered during initial filling in 1940 and the subsequent elevation rise in 1946-1949. Oxygen depletion is anticipated to be somewhat greater than that at present.

Turbidity

Flooding of new land and shoreline clearing activities will increase lake turbidity. Stream discharge will have less effect because of the greater lake volume. Primary production is expected to increase in the euphotic zone, resulting in increased turbidity. Over-all, some increase in lake turbidity during the fill period is anticipated, with consequent decrease in depth of the euphotic zone.

Water Chemistry

A buildup of organic and inorganic constituents is to be expected with flooding of new land and decreased flushing rate. Some increase in conductivity in the lake should occur during water storage.

Access

Plans for access of the reservoir to fishermen during the fill period have not been finalized.

4.1.2 American Tributary Streams to Ross Lake

(by Fisheries Research Institute)

4.1.2.1 Construction Period

The principal change in American streams during the construction period will be in the areas exposed by drawdown. During drawdown to 1475 feet more stream area will be exposed than usual. Silt and debris accumulated in these areas will undergo removal by stream currents. Because of the later than normal fill of the reservoir in spring, stream area inundation will be delayed. No falls would be exposed in Ruby Creek. Five foot falls in Lightning Creek at elevation 1565 (see Figure 3.3-5) would be exposed during the first construction year and remain exposed until sometime in June during the second construction year. Falls in Big Beaver Creek (see Figure 3.3-3) would be exposed in the first construction year and remain exposed until late July in the second construction year.

Logging and clearing operations would be phased to accommodate projected water levels. The basic concept of the proposed clearing operation is to log and machine clear the relatively flat stable sites and fell and float the forest cover from the steep or unstable sites to minimize disturbance of soils. The protection of streams from unwarranted disturbance and unnecessary exposure to sun would be stipulated in the clearing contracts. Trees protecting stream banks could be left until the spring of the year that the reservoir would refill.

Active participation of fisheries biologists to advise and monitor clearing operations would insure that the fishing is properly protected during the construction period.

4.1.2.2 Fill Period

Flooding of stream areas not previously inundated would occur in May-July of both fill years as the lake elevation rises. The total elevation rise would be about 70 feet (near average) in the first year and about 55-60 feet in the second year. The elevation would be maintained near the summer maximum in the fall and winter following the first summer of fill.

No stream obstructions exist in Ruby Creek. The falls in lower Big Beaver Creek (see Figure 3.3-3) would be flooded during the entire fill period. The falls in Lightning Creek at 1648 feet elevation (see Figure 3.3-5) would be inundated by mid-June of the first year of fill and remain inundated. Some steep rapids and falls in Devils Creek and Little Beaver Creek would be inundated during fill, but other stream obstructions would remain a short distance upstream at all times during fill.

4.1.3 Skagit River and Tributaries

(by F.F. Slaney & Company)

4.1.3.1 Construction Period

The levels of Ross Lake during the construction period have been described in Section 4.1.1.1. As a result of the drawdown to elevation 1475 feet during the two winters of construction the length of the drawdown river in these two years will be increased to between 10 and 12 miles. No falls would be exposed by the increased drawdown. Accumulated silt and debris would be removed from the stream gravels in the newly exposed drawdown. Full scale logging operations within the proposed High Ross Reservoir site in Canada would be initiated by the B.C. Forest Service when the decision to proceed with the High Ross project is reached. The government would probably auction the timber from Lot 1103 to the highest bidder. Supervision of the logging operation would be a Forest Service responsibility.

The terms of the logging contract could be expected to reflect the need to protect stream beds and operations could be designed to leave a protective fringe of forest cover adjacent to the river until the spring prior to flooding.

Clearing operations that followed the logging would be scheduled primarily for dry weather operations. Most of the soils are gravelly and no major erosion problems are anticipated from clearing activity. The desirability of removing stumps from the edge of the existing river bank is questionable from a fisheries aspect. Some adjustments in clearing specifications may be feasible to accommodate specific fishery concerns identified during the study.

Basically the clearing specifications in Canada require that all trees below 1670 feet elevation (the drawdown line) be removed to a stump height of less than 12 inches. Above elevation 1670 feet trees must be cut flush with ground except that on slopes greater than 40 percent stump heights less than 6 inches are permissible.

Woody material is to be disposed of prior to flooding.

4.1.3.2 Fill Period

The effects of rising water levels during the fill period will include the permanent inundation of 5.6 miles of the present river below the 1669 foot elevation level over two years and seasonal inundation to the 1725 foot elevation of up to an additional 4.4 miles of drawdown river. These areas can be expected to accumulate more fine particle size gravels than they presently contain. The habitat in general will change from flowing river to more stable lake conditions.

4.2 ROSS LAKE AT ELEVATION 1725 FEET

4.2.1 Ross Lake

(by Fisheries Research Institute)

4.2.1.1 General Description

The proposed construction of High Ross Dam would raise the maximum level of Ross Lake by 122.5 feet to 1725 feet msl and increase its length by 7 miles to 29 miles. Physical data and a map of the proposed lake are presented in Table 4.2-1 and Map 4 respectively. Changes in physical characteristics which would result from the proposed high lake are summarized in Table 4.2-2. Total inflow and discharge from the watershed would not be expected to change; however, the periodic changes and rates of change in lake elevation would be less due to increased lake volume. Anticipated fluctuations in volume,

TABLE 4.2-1

HIGH ROSS LAKE PHYSICAL DATA

Drainage area	999 square miles
Mean lake elevation	1,710 feet
Mean drawdown elevation	1,686 feet

	Maximum reservoir	Minimum reservoir
Lake elevation	1,725 feet	1,669 feet
Lake volume	3,456,000 acre feet	2,420,000 acre feet
Surface area	20,000 acres	16,300 acres
Shoreline development	4.79	4.60
Mean depth	172.8 feet	148.5 feet

Lake elevation (feet)	Shoreline length (miles)	Area * (acres)	Lake volume* (acre feet)
1,725	95.0	20,000	3,456,000
1,700	92.9	18,350	3,000,000
1,675	83.2	16,700	2,518,000
1,669	82.3	16,300	2,420,000
1,650	79.4	15,200	2,110,000
1,625	70.1	13,450	1,725,000
1,600	64.3	11,600	1,390,000
1,575	58.8	10,280	1,125,000
1,550	53.3	9,040	890,000
1,525	50.3	7,600	680,000
1,500	43.7	5,840	520,000
1,475	37.4	4,400	412,000
1,450	29.1	3,400	285,000
1,425	26.9	2,820	210,000
1,400	24.3	2,300	140,000
1,375	21.2	1,850	90,000
1,350	19.4	1,400	60,000
1,325	16.7	900	25,000
1,300	13.4	420	10,000

* Values taken from Seattle City Light drawing C-6048.

TABLE 5.1-1

EGG SURVIVAL EXPERIMENT, ROSS LAKE, 1972

Location	Date containers buried in gravel	Lake level (ft)	Station depth in ft (below 1602.5)	Number of containers	Date and number of containers recovered	Number of containers with living eggs or fry	Remarks
Roland Bay	6/2	1593.34	10.5	2	7/28 (1)	1	Many living alevins.
			10.5		9/05 (1)	1	Many dead fry - trapped in containers.
	6/2	1593.34	31.0	4	7/28 (1)	0	All eggs dead.
			31.0		9/05 (3)	3	Many dead fry - trapped in containers.
	6/2	1593.34	45.0	4	7/21 (1)	0	All eggs dead.
	6/8	1596.26	10.5	2	9/05 (2)	2	Many dead fry - trapped in containers.
Roland Creek Mouth	6/8	1596.26	2.5	2			Many dead fry - trapped in containers. Containers lost due to extensive gravel movement in stream mouth noted on 7/13, probably due to 7/12 heavy rains.
Pierce Creek Bay	6/13	1600.22	19.0	4	7/31 (1)	1	Some eyed eggs, some alevins alive.
			19.0		9/05 (3)		All eggs dead.
			10.0	4	7/31 (2)	0	All eggs dead.
			10.0		9/05 (2)		All eggs dead.
			3.5	4	7/31 (1)	1	Some eyed eggs alive.
			3.5		9/05 (3)		All eggs dead.
Lightning Arm	6/28	1601	25.5	4	8/01 (1)	0	All eggs dead. Two ft of silt & detritus covering bottom.
	6/28	1601	12.5	4	8/27 (4)	0	All eggs dead, no alevins.
	6/28	1601	3.5	2	8/01 (1)	1	Many eyed eggs alive.
			3.5		8/27 (1)	0	All eggs dead, no alevins.
	6/29		3.5	2	8/27 (2)	0	All eggs dead, no alevins.
Lightning Creek	6/30		Instream (1604 elev.)	4			Containers washed out at a later date.
Ruby Arm	7/11	1602.5	12.0	4	8/27 (4)	0	All eggs dead, no alevins. Some siltation - 1-3 ft.

5.1.1.2 Skagit River

(by F.F. Slaney & Company)

The time of rainbow trout, Dolly Varden, and brook trout spawning in the Skagit River should not be affected during the construction period.

Ross Lake will be drawn down in winter during the construction period to lower levels than the recent average (Figure 4.1-2). The figure also shows that the spring risings of the lake elevation will begin later than average in the first summer. These two factors may result in rainbow spawning activity being located further downstream in the first year of construction than in recent years.

The total increase in lake elevation during May through August of the first summer will be between 76 and 90 feet. This elevation change is greater than the 1953-72 mean elevation change but within the range experienced in recent years (see Table 4.1-1 and Figure 4.1-2 for comparison). The lake elevation will also continue to rise throughout the incubation and hatching period for eggs and larval rainbows during the first summer of construction.

The effects of this total elevation change on egg and larval rainbows should be within the range of recent conditions since the rise in water levels is within the range of those of recent years even though it occurs later in the year.

During the second spawning season after construction commences, water level increase and rates of fill during rainbow spawning and egg incubation times will again be greater than the average condition in recent years but will be essentially the same as in 1969 (see Figure 4.1-2). The rainbow population can be expected to respond as it has in recent years with no adverse effects anticipated.

Spawning success during the construction period could be detrimentally affected by deposition of fine particles in the gravels from clearing operations. However, clearing will be scheduled to accommodate the fish to reduce this possibility.

5.1.2 Feeding Conditions and Fish Growth

(by Fisheries Research Institute)

5.1.2.1 Primary Production, Ross Lake

Primary production in the euphotic zone is expected to be greater per unit surface area of lake during the construction period because of the expected increase in organic and inorganic constituents mentioned in Section 4.1.1.1. The relative importance of the different variables--flushing rate schedule, bottom slope nutrient release by wave action, forest removal activities, stream flow, hypolimnial depth, turbidity--will vary between the two construction years, but the net effect should be an increase in both years in production per unit surface area. In the first construction year total primary production will be influenced by the smaller than average summer lake surface area (85 percent of full reservoir area at 1602.5 elevation), but probably would not be less than at present. In the second construction year, primary production would be expected to be greater than at present.

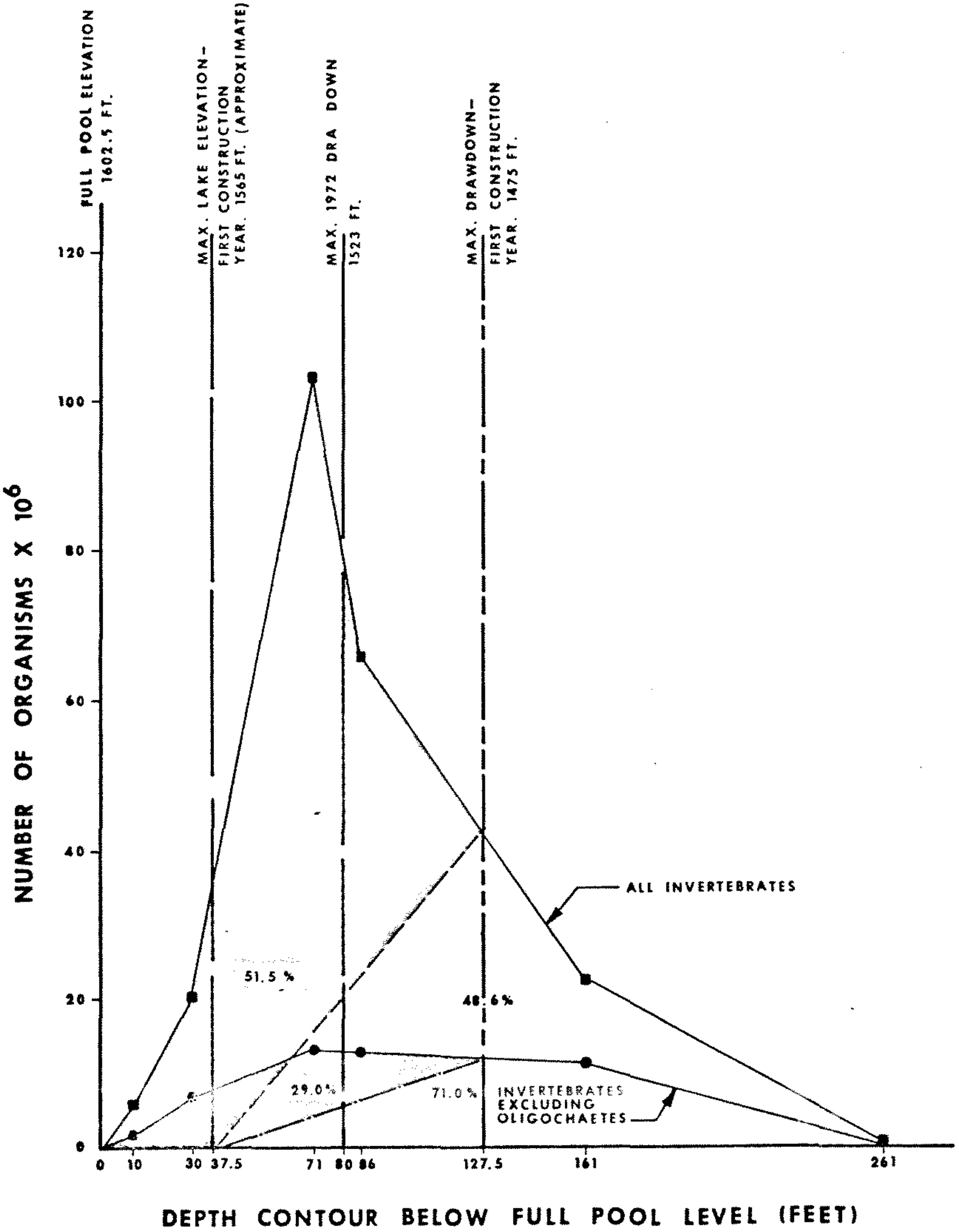
5.1.2.2 Ross Lake Zooplankton

Because total limnetic primary production in the lake is not expected to be less than at present in the first construction year and is expected to be greater in the second construction year, total zooplankton production is expected to follow the same pattern. Although some change in zooplankton species composition may occur, information from literature is inadequate to forecast the trend, which would depend on changes in relative abundance of phytoplankton species, food requirements of zooplankton, and differences in reproduction and mortality rates of zooplankter species. The euphotic zone extends well below the thermocline during summer, and results of zooplankton studies (Section 3.4.3.2) indicate that the zooplankton are more concentrated in the euphotic zone than in the deeper waters of the hypolimnion.

5.1.2.3 Ross Lake Benthos

Benthic invertebrate production would be less during the two construction years because of the greater lake area exposed during winter drawdown. Information described in Section 3 indicates that benthic organisms are drastically reduced in bottom areas exposed during winter and the summer buildup in these areas is gradual. In the first construction year the bottom area at summer maximum level of about 1565 feet will be less than at present full reservoir of 1602.5 feet, providing less area for recolonization of benthic organisms, although this may simply result in greater concentrations in the remaining lake bottom. Based on observed benthic invertebrate abundance in the 1972 mid-lake transect total abundance in the reservoir would be reduced by 51.5 percent (Figure 5.1-1) because benthic invertebrate abundance would be affected down to the first construction year drawdown

FIGURE 5.1.1



NUMBERS OF BENTHIC INVERTEBRATES AT INDICATED DEPTH CONTOURS BASED ON MAY 31, JULY 11, AND AUGUST 31 SAMPLES COMBINED, MID-LAKE TRANSECT, ROSS LAKE, 1972. DEPTH CONTOURS ARE 1 METER WIDE. SHADED AREAS REPRESENT PROJECTED PERCENTAGE DECREASE IN ABUNDANCE IN FIRST CONSTRUCTION YEAR.

elevation of 1475 feet. Subsequently, the lake would be filled only to the 1565-foot elevation. Inspection of Figure 5.1-1 also shows that oligochaetes will be reduced in larger proportion (58.0 percent) than other invertebrates, predominately Tendipedidae (29.0 percent); thus a significant change in benthic species composition during the construction period would be expected. Proportion of benthos in the trout diet is small, oligochaetes are not utilized; therefore effects on the fish diets of reduction of benthic invertebrates other than oligochaetes (15.5 percent) would be minimal.

The observed peak of total benthic invertebrate abundance just above the maximum 1972 drawdown of 1523 feet probably occurred because the lake level remained at 1523 feet for only a short time in February 1972. The sampling station at 71 feet below full pool elevation was exposed for 31 days - from February 10 to March 13, 1972. Recolonization of the bottom area at this depth was rapid. During the first construction year the lake would be held at 1475 feet elevation for approximately three months. Following this period the lake level would rise more rapidly than normal. Recolonization by benthos above 1475 feet elevation would thus be expected to be lower than normal. For this reason, a peak of abundance just above 1475 feet elevation was not included in the projection (Figure 5.1-1). During the three month maximum drawdown to 1475 feet elevation, lake bottom normally in deep water will be in shallow water areas. Benthic invertebrate abundance would be expected to increase in these areas. This effect is not included in the benthic invertebrate abundance projection for the first construction year; therefore, the projected decrease in benthic abundance during the first construction year is considered a maximum possible decrease.

Some enrichment of the lake bottom by organic debris from clearing will occur. This may stimulate benthic production per unit area in the unexposed lake bottom, which could possibly offset to some degree the loss by reduction in area of unexposed bottom during drawdown.

By the second construction year the reservoir would again be drawn down to 1475 feet elevation. The lake level would be held at 1475 feet for one month (March) after which it would be raised to 1602.5 feet by August. Compared to the effects of reservoir drawdown in the first construction year the drawdown the second construction year would have similar detrimental effects on the benthic community in the lake. The greater fill level would allow recolonization in larger areas of lake bottom, however. Thus, standing crop of benthic invertebrates in the epilimnial waters may be higher in the second construction year than in the first, but would still be somewhat below that of the existing reservoir. As in the first construction year some enrichment of the lake bottom by organic debris from clearing operations will occur. This may stimulate benthic production per unit area and thus may offset the loss due to the drawdown.

5.1.2.4 Allochthonous Food

The drift into the lake of allochthonous aquatic insects originating in streams may be reduced in the first construction year but should not be affected materially during the second construction year. In the first summer additional stream area normally inundated will remain exposed because of the lower lake level. The primary area remaining exposed will be approximately 1.75 miles of the Canadian Skagit River. Colonization by drift is expected to be rapid, but the stream insect production would not be expected to reach the level of that in the river above 1602.5 feet elevation. Therefore, the drift of insects into the lake from the exposed area would be less, and drift from the area above 1602.5 feet would tend to settle in the river above the lake level. In the American tributaries, first construction year production of aquatic insects would not be affected materially because of the short distances of normally inundated stream that would be exposed at the lower summer lake fill level.

Availability of terrestrial insects to fish probably would be reduced during the first and second construction summer because of the wider buffer strip of bare shore between the shoreline vegetation and the lake.

5.1.2.5 Stream Food

Availability of stream and terrestrial invertebrates to stream feeding trout would not change above elevation 1725. During the first summer of construction some additional stream area would be available for feeding fish as previously described. Streamside clearing to elevation 1725 will result in some increased siltation in the streams below elevation 1725, although this problem may be minimized by the planned hand logging and floatation removal of material along American tributaries and by delaying streamside clearings until lake filling above elevation 1605 begins.

5.1.2.6 Fish Growth

During the first construction year standing crop of zooplankton probably would not be reduced significantly because density would be greater. If abundance of larger plankton species utilized by the trout remained the same in proportion to the total, abundance of the zooplankton food supply as the primary food source would be relatively unchanged. If the fish population increases during the first construction year because of reduced fishing effort the zooplankton would provide less food per fish. Abundance of benthic insects would be lower, but the change would have little effect on the fish diet because benthic insects presently constitute a very minor part of the summer diet of the trout (Section 3.4.5.2). The possible lower availability of mayfly, stonefly and caddis fly nymphs originating in streams and drifting into the lake, and of terrestrial insects is of more significance because these organisms made up 28 percent of the volume of organisms found in stomachs of fish sampled in the lake in May to October, 1971. Overall, because of these decreases in food availability, growth rate of the trout would probably be reduced during the first construction year.

During the second construction year standing crop of zooplankton would be greater because of higher plankton density and fill of the lake to approximately 1602.5 feet by August. This increase should more than balance out the loss of terrestrial insects and drift. Benthic invertebrate abundance would be lower than at present conditions, but again would have little effect on fish diet. If reduction in fishing effort allows further buildup of the fish population, probably as much plankton food would be available per fish as at present and growth would be similar. Average fish size probably would increase because of an accumulation of larger fish due to reduction in angler effort.

5.1.3 Fish Production

(by Fisheries Research Institute)

The information available to date indicates that overall recruitment to stream and lake areas will not be detrimentally affected during the construction period. The fishable population is expected to increase if the lake is closed to fishing during construction or even if fishing were allowed since access problems would reduce fishing intensity. The 1971 estimated catch in the lake was about 36,000 fish and the 1972 estimate about 37,000 fish. The multiple sample - tag recovery experiments provided point estimates of the trout population of 146,000 in 1971 and 206,000 in 1972. If we assume the Canadian Skagit River catch were to remain at the level of about 4,000 trout per year, a buildup of 10-20 percent in the total fishable trout population is a reasonable expectation over the two year period if fishing is discontinued in the lake. A buildup in the spawning population would likewise occur, and an increase in average age of spawners would be expected.

5.2 DURING AND AFTER THE FILL PERIOD - SHORT TERM

5.2.1 Spawning Time, Location and Success

5.2.1.1 American Tributaries

(by Fisheries Research Institute)

The time of trout spawning in Ross Lake during and after the two-year filling period following construction should remain unchanged. Time of spawning has previously been discussed in Section 3.3.2.2.

Table 5.2-1 compares the accessibility to fish of the Ross Lake tributary streams at both the 1602.5 and 1725-foot elevations. Presently a total of 22.99 miles of stream is considered usable to spawning lake fish. As noted in the table, Big Beaver Creek is not included in the calculations because observations to date indicate virtually no use of the stream by Ross Lake fish for spawning. The unfished rainbow and cutthroat populations in the beaver pond areas of the valley are not considered here. At present their spawning grounds have not been determined. At 1725 feet elevation, 21.88 miles of stream are considered usable. An additional 4.21 miles of Lightning Creek could be made available by minor stream improvement. The loss of total stream area by inundation is balanced by the gain in access to stream area in Lightning Creek

COMPARISON OF ACCESSIBILITY TO FISH OF THE MAJOR ROSS

Lake level (ft.)	Ruby	Panther	Granite	Canyon	N. Fork of Canyon	Slate
1602.5						
First upstream fish migration block						
elevation (ft.)	-	1768	3115	3320	3300	2970
distance upstream (mi.)	-	0.41	6.06	9.18	0.62	0.47
Miles of stream useable by spawning lake fish	3.36	0.41	6.06	9.18	0.62	0.47
1725						
First upstream fish migration block						
elevation (ft.)	-	1768	3115	3320	3300	2970
distance upstream (mi.)	-	0.16	6.06	9.18	0.62	0.47
Miles of stream useable by spawning lake fish	1.82	0.16 3.73**	6.06	9.18	0.62	0.47

* The lower 6.94 mi. of Big Beaver Creek are apparently not utilized for spawnir

** The figures marked by ** indicate miles of stream available to Ross Lake fish af are located a short distance upstream from the confluence of Three Fools Creek (1725 ft elevation in each of the following streams: Roland, Panther, S. Fork Dr log jams which form the blocks, thus making accessible to fish another 8.04 mil This additional stream section has excellent potential for spawning grounds; it is could be made accessible to fish by log jam removal is characterized as riffle an potential is limited. In Dry Creek the additional .08 mile of stream which woul steep rapids, falls and pools flowing over boulder and rubble substrate with limit

E 5.2-1

'RIBUTARY STREAMS AT EXISTING AND PROPOSED RESERVOIR LEVELS

Big Beaver	Roland	Devils	Dry	Lightning	Three Fools	Little Beaver	Silver	Hozomeen	Total
1725	1785	1617	1740	1648	1920	1625	1784	1636	
6.94	0.31	0.08	0.21	0.23	0.24	0.09	0.47	0.05	
*	0.31	0.08	0.21	0.23	0	0.09	0.47	0.05	22.77
1725	1785	1726	1740	1870	1920	1725	1784	1731	
0	0.08	0	0.04	1.85	0.24	0	0.11	0	
0	0.08 0.26**	0	0.04 0.12**	1.85 6.06**	0.24	0	0.11	0	21.86 29.90**

Ross Lake fish.
moval of migration blocks formed by log jams. Three migration blocks in Lightning Creek
rs and Gores, 1971). A migration block is located a short distance upstream from the
I N. Fork Dry Creeks. Each block could easily be made passable to fish by removing the
stream. In Lightning Creek 4.21 miles of stream would be made available to Ross Lake fish.
acterized as a riffle flowing over a gravel substrate. The 3.57 miles of Panther Creek which
ids flowing over a rubble and boulder substrate with occasional gravel areas. Spawning
accessible after log jam removal offers limited spawning potential. It is characterized as
avel areas.

by inundation of the migration block at the 1648-foot elevation. Potentially, Lightning Creek would rise in importance and the main spawning areas in American tributaries would lie in the Ruby and Lightning Creek drainages.

During the first filling year, all of the potential 21.88 miles of spawning area indicated in Table 5.2-1 is expected to be available by mid-June. The last migration block, that at 1648 feet on Lightning Creek, would be inundated by this time. The predicted elevation (Figure 4.1-1) for the first filling year is about 1672 feet. During the second fill year all potential spawning areas will be available when spawning first begins in May. No upstream blocks would be exposed. The 1725 feet maximum elevation is predicted for the end of July.

In the years after the reservoir is filled to the new level, annual reservoir fluctuations would be approximately ½ that at present (see Figures 4.1-2 and 4.2-1), and less stream area would be subject to winter exposure and spring-summer inundation than at present. No migration blocks would exist intermittently during annual fill.

Additional sections of stream, 3.57 miles in Panther Creek, 0.26 miles in Roland Creek and 0.08 miles in Dry Creek could also be made accessible to Ross Lake fish with inexpensive log jam removal. These stream sections offer limited potential for trout spawning. A total of 29.92 miles of American tributary stream would be accessible to Ross Lake fish if the reservoir level were raised to 1725 feet and the aforementioned stream improvements were implemented.

During the fill period, spawning success will depend on the rate of survival of eggs deposited in present spawning locations but inundated as the lake level rises. Success of spawning during the fill and post-fill period will also depend on the adaptability of portions of the trout populations to shift to new or upstream spawning areas and to colonize the greatly increased available area of Lightning Creek. In Little Beaver Creek and Devils Creek the short stretches now possibly supporting a small number of spawning fish would be inundated and not replaced by available area upstream because of the steep creek gradient. Inundated stream areas or lake beaches now apparently utilized to some degree would become unsuitable at the higher reservoir elevation, and new areas would become accessible. Trout now occupying beaver ponds in Big Beaver Valley below elevation 1725 would become part of the reservoir population and would need to find new spawning areas to propagate.

During the first fill year the reservoir level is expected to be at approximately 1637 feet by June 1, with average runoff conditions (see Figure 4.1-2). Observations in 1971 indicate that the bulk of spawning occurs in June and early July. The lake is expected to rise an additional 30-35 feet during June and July, which is about the average elevation change for this two month period at present, but with a higher proportion of the change occurring in July. Redds of trout utilizing stream areas between approximately 1637 and 1670-foot elevations would be inundated to varying depths. In the second fill year the reservoir elevation would rise from 1690 feet to 1725 feet in the June-July period under continued average runoff conditions. In the years following, the average June-July elevation change is estimated at about 18 feet, with most of the rise in June.

The survival in stream redds inundated to varying depths by rising lake level was discussed in Section 5.1.1.1. As indicated in Section 3.3.2.3, some production from inundated areas is occurring.

It is anticipated that adaptation of Ross Lake trout to new spawning conditions will be rapid. Following the initial filling of the reservoir to an elevation of 1380 feet in 1940 there was a period of sequential rises in lake elevations accompanied by seasonal fluctuations as much as 280 feet (see Figure 2.1-3). From 1953 until the present, with the maximum elevation now up around 1600 feet, the seasonal fluctuations have been somewhat reduced, averaging about 70 feet. The former rainbow population was apparently essentially a river population, and adjusted well and rapidly to the formation of Ross Reservoir, the sequence of elevation changes, and changes in available spawning areas. Two examples of adjustment to newly available spawning areas are in Ruby and Lightning Creeks. The diversion dam on Ruby Creek mentioned in Section 3.1.2.1 prevented upstream movement of fish, although resident trout populations existed above and below the dam (1500 feet elevation). Since removal of the dam and formation of Ross Lake the fish in Ross Lake have utilized the spawning areas in Ruby Creek above the existing lake. In Lightning Creek a fall at 1565 feet elevation prevented upstream migration of fish prior to the formation of Ross Lake; however, since 1949 the fall has been inundated during the spawning period and Ross Lake fish now utilize Lightning Creek up to the fall at the 1648 foot elevation. The adaptability of the population is apparent. The future success of spawning thus is assured if quality and quantity of spawning areas are not less. Observations indicate that the upstream areas in the Ruby Creek watershed and the newly accessible areas in Lightning Creek above elevation 1648 are of equal or better quality than areas to be inundated, and that the total available spawning area would not be decreased. If stream inundation by rising lake level does decrease survival of eggs and larvae, the decreased annual fluctuation of lake level at the proposed new level would be advantageous.

5.2.1.2 Skagit River

(by F.F. Slaney & Company)

As the high reservoir fills above present levels in the first spring and summer following completion of construction, the rate and time of filling and total change in lake elevation will be nearly identical to the 19-year (1953-71) average fill curve. The differences will be that this fill will occur upstream of present levels and that more rise will occur during July than average.

In the second year after completion the rate of fill will be slower than the recent average condition. The fill will also occur about one month later than the average predicted fill with High Ross Lake. The total increase in lake elevation will be less than the past average, but greater than the anticipated average with High Ross Dam (see Figure 4.1-2).

In both years it is anticipated that spawning rainbow trout will move upstream in the Skagit River to spawn in the river and its tributaries, including the Klesilkwa River (see also Section 5.2.1.1). This population has been subject to greater rises in water levels and elevation fluctuations in the past. It appears to have adjusted well to those changed circumstances and can be expected to adapt as well with another, more moderate, elevation change. Closely related fish species are also known to utilize newly available spawning areas as they become available, suggesting that these trout will move upstream. Adequate substrate is available upstream (see Section 4.2.3.1) to accommodate the spawning population.

On the basis that the rainbow population will move upstream in the Skagit River to spawn, spawning success can be expected to be at least as good as that in recent years. During both years of the fill period the elevation fluctuations in the lake will be less than recent average conditions. If inundation of stream areas does indeed decrease survival of eggs and larvae then the decrease in elevation fluctuations can be expected to increase the survival of rainbow eggs and larvae. Results of egg survival studies in 1972 indicated reduced survival in some but not all inundated spawning gravels due to siltation. The time of rainbow spawning should not be affected by the filling of the higher reservoir.

5.2.2 Feeding Conditions and Fish Growth

(by Fisheries Research Institute)

5.2.2.1 Primary Production, Ross Lake

As new land is flooded during the fill period, primary production in the lake euphotic zone (5 x Secchi depth according to Verduin, 1956) would increase substantially over present rates per unit surface area because of the enrichment provided by release of nutrients and because the percentage volume increase in the epilimnion would be greater than percentage increase of lake area by 28 percent if the reservoir is raised to 1725 feet. (The mean depth of the euphotic zone in the proposed reservoir would be 106 feet compared to 83 feet in the existing reservoir). In the post-fill years, production rates would decrease gradually as rate of leaching of minerals and organic materials declined in the newly flooded land. This enrichment behavior pattern has been characteristic of other reservoir studies (Kimsey, 1958; Rawson, 1958). Stabilization at a new level of productivity would not be expected until at least three years after fill of the reservoir. The 71 percent increase in lake surface area at new full reservoir would greatly increase the total primary production.

5.2.2.2 Ross Lake Zooplankton

Zooplankton production rates should follow the primary production trend during the fill and stabilization period. Probably, species composition and density of the plankton following lake stabilization will not be significantly different than at present. Studies of Lake Minnewanka, British Columbia, (Cuerrier, 1954) showed that following construction of a power dam in 1941 and subsequent raising of the lake level by 65 feet and maximum drawdown of 35 feet no significant changes in physico-chemical (temperature, oxygen and pH) conditions or in planktonic species composition and density occurred. These conclusions were based on sampling conducted in 1936, 1938, 1941, 1943, and 1952. Because an increase in the trout population is anticipated as discussed in Section 5.1.3, a larger volume, but not necessarily a larger percentage, of the standing crop of zooplankton would be utilized.

5.2.2.3 Ross Lake Benthos

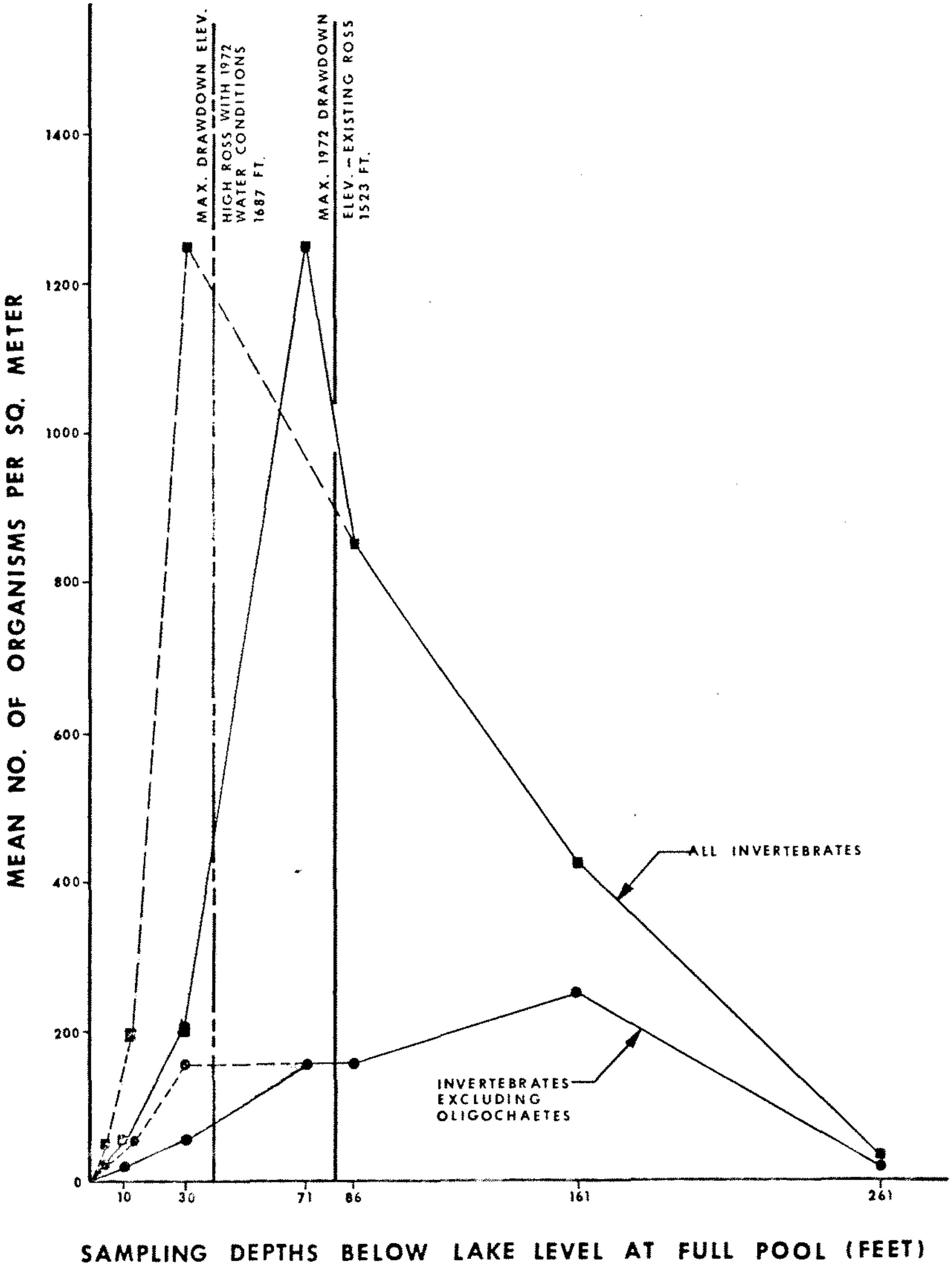
Benthic invertebrate production is expected to increase substantially during the fill and post-fill periods because (1) virtually no drawdown would occur for two winters after the second construction summer, eliminating the drawdown destruction of benthic invertebrates described previously, (2) after fill, less lake bottom area would be exposed during winter drawdown, and the unexposed lake bottom would be over twice the present area, (3) organic and inorganic enrichment during and after the fill period would enhance benthic production, and (4) because of lesser drawdown, more benthic area unexposed in winter would remain in the warmer epilimnial area when the reservoir is full in the summer.

Based on data obtained from sampling along the mid-lake transect in 1972, projections on benthic invertebrate abundance in High Ross Lake can be made. The lesser drawdown would allow benthos to concentrate at shallower depths (Figure 5.2-1) which would have greater area than in the existing reservoir. A 54.4 percent increase in standing crop of benthos would be expected in the bottom areas of the upper 261 feet (Figure 5.2-2) area-depth relationships control benthic invertebrate biomass. The bottom area in the upper 261 feet would increase by 53.9 percent. Due to increase of unproductive bottom areas in deep water (depth greater than 261 feet) in High Ross Lake average density of benthic invertebrates over the entire lake bottom would be slightly less than in the existing lake. The total standing crop in the high reservoir would be about 55 percent greater than in the existing lake under the above assumptions.

Increases of standing crop and density would be favored by three additional factors: 1) lesser drawdown would allow more rapid and complete recolonization of the bottom exposed by drawdown because less vertical distance would be involved, 2) warmer temperatures in shallow water areas would increase benthic productivity per unit of standing crop, and 3) because of less drawdown more of the organic sediments would remain in warmer epilimnial waters and rate of decomposition and release of nutrients from these materials would be more rapid.

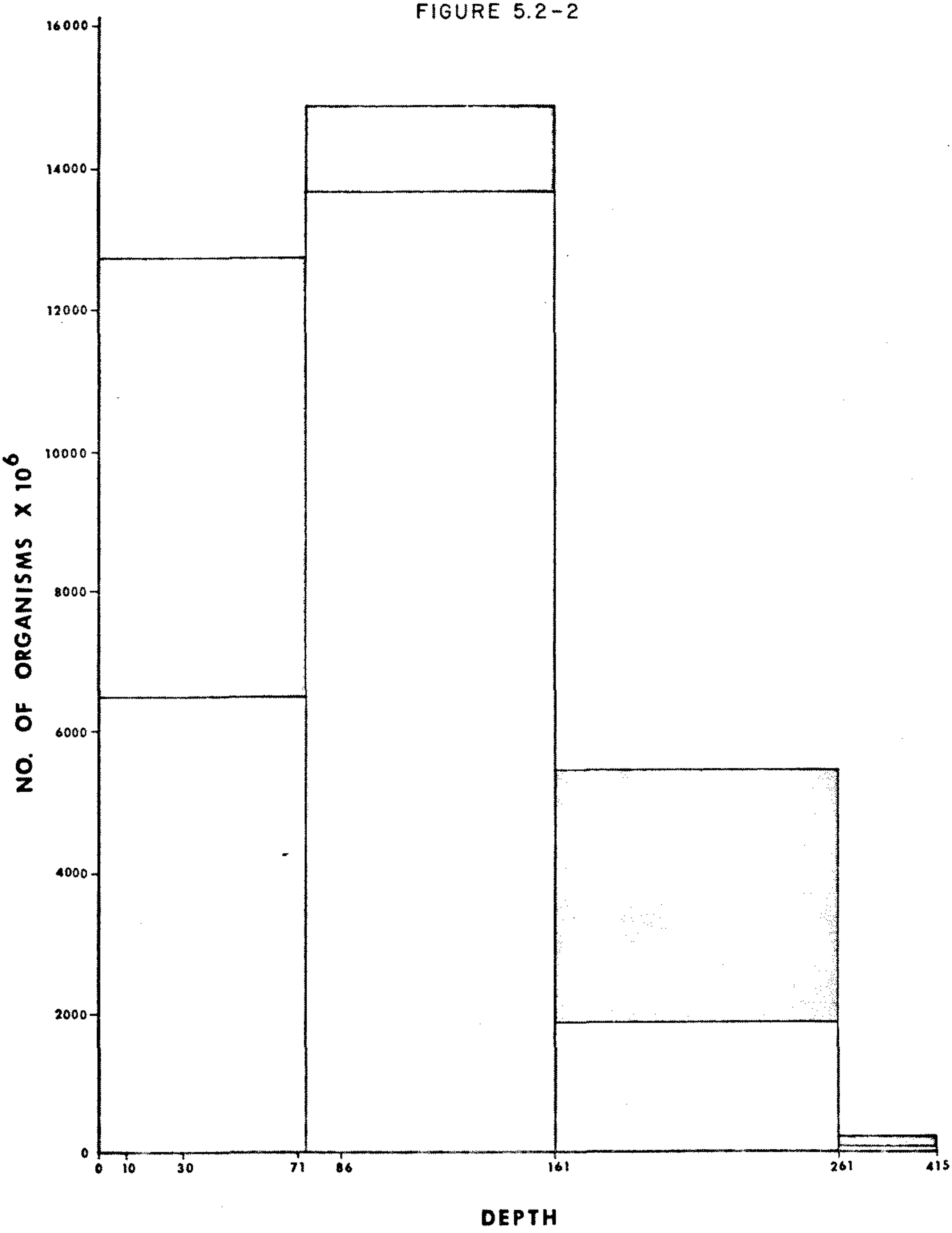
It is difficult to predict how composition of the benthos would be affected because of the obvious change in relative abundance of oligochaetes and tendipedid larvae from 1971 to 1972. However, the data in Figures 5.2-1 and 5.2-2 suggest that elevation changes of the proposed reservoir would

FIGURE 5.2-1



MEAN NUMBERS OF BENTHIC INVERTEBRATES PER SQ. METER, MAY 31, JULY 11, AND AUGUST 31 SAMPLES COMBINED, MID-LAKE TRANSECT, ROSS LAKE, 1972. PROJECTED CURVES FOR HIGH ROSS LAKE ARE INCLUDED FOR COMPARISON AND ARE SHOWN AS DASHED LINES

FIGURE 5.2-2



COMPARISON OF BENTHIC INVERTEBRATE ABUNDANCE IN EXISTING ROSS LAKE AND PROJECTED ABUNDANCE IN HIGH ROSS LAKE BASED ON DATA FROM THE MID-LAKE TRANSECT 1972. UNSHADED HISTOGRAMS ARE OBSERVED DATA FOR EXISTING ROSS LAKE, SHADED HISTROGRAMS REPRESENT PROJECTED INCREASE FOR HIGH ROSS LAKE. TOP OF SHADED HISTOGRAMS REPRESENT TOTAL ABUNDANCE FOR HIGH ROSS LAKE IN RESPECTIVE DEPTH STRATA.

affect oligochaetes and the other invertebrates (mainly Tendipedidae) in the same way, that is to increase their density and abundance in the upper 261 feet of the lake.

5.2.2.4 Allochthonous Food

The drift into the lake of allochthonous aquatic insects originating in streams is expected to equal that at present, since shortened stream length is not a significant factor. Drift from Big Beaver Creek may be greater because the present lower creek is not as favorable a bottom for insect production as that above elevation 1725.

Terrestrial insect contribution to the lake would probably increase somewhat in proportion to increase in shoreline. Shoreline length will be increased by 47 percent at the proposed new full reservoir. Since lake area would be increased by 71 percent, terrestrial insect contribution would be less per unit lake area. However, trout generally tend to utilize shoreline areas in a lake for feeding and are not uniformly distributed over the entire lake.

5.2.2.5 Stream Food

Stream benthos in areas inundated by the increased lake level would be replaced by lake benthos production. In the stream areas above the proposed reservoir benthic production and standing crop would be unchanged. Therefore, no change is anticipated in availability of stream and terrestrial invertebrates to stream feeding fish in stream areas which would exist with Ross Lake at 1725 feet elevation.

Drift entering the lake from stream area would also be unchanged because:
1) the distance that a benthic organism drifts per day is relatively short--on

the order of 50-60 m (Waters, 1965); therefore only a small proportion of the stream above its mouth contributes to the daily drift entering the lake, and 2) drift of a stream benthos is a density-dependent effect--a mechanism which removes excess benthic production in streams (Waters, 1966 and Dimond, 1967). This mechanism would also prevent any accumulation of benthos per unit of area in a given stream reach. The excess (above carrying capacity) would enter the drift and be removed.

5.2.2.6 Fish Growth

The expected increase in zooplankton and benthos per unit area during the fill and immediate post-fill years because of enrichment and the increase in lake size would be expected to provide growth conditions for trout in the lake equal to or better than at present even if a very substantial increase in the trout population occurs. A greater proportional use of benthos is probable. Allochthonous food would probably provide a lower proportion of the trout diet.

5.2.3 Fish Production

(by Fisheries Research Institute)

As indicated in Section 5.1.3, an increase in the trout spawning population should occur if fishing is restricted during the construction period. Possible reduced fishing effort during the fill period would allow some further buildup. Although spawning success may be affected during the period of adjustment of the population during the fill and immediate post-fill period, reduced fishing mortality would probably allow recruitment during this period to equal or exceed that occurring at present. A larger total fishable population would be expected immediately after the reservoir is completed and for the few years thereafter.

5.3 ROSS LAKE AT 1725 FEET - STABILIZED CONDITIONS

5.3.1 Spawning Time, Location, and Success

5.3.1.1 American Tributaries

(by Fisheries Research Institute)

No changes in spawning time are anticipated.

The distribution of spawning in American tributaries is expected to shift to greater proportional use of Lightning Creek. It is possible that lake beach spawning areas may develop as the shoreline soils are washed away by wave action during drawdown. However, to date we have not observed lake beach spawning away from stream estuaries. A buildup of gravel in stream estuaries would occur, which could be utilized for spawning.

It is probable that any increase in the spawning population would be accommodated by greater utilization of the upstream portion of available American streams. Assessment of this potential is continuing.

5.3.1.2 Skagit River

(by F.F. Slaney & Company)

The long term effects of Ross Lake at 1725 feet on rainbow spawning in the Skagit River will be minimal. As mentioned previously (Section 5.2.1.2) the spawning rainbows are expected to move upstream, where gravels are adequate (Section 4.2.3.1), and spawn successfully.

Annual lake elevation fluctuations will be reduced as will the length of the drawdown river. Both of these conditions should reduce the uncertainty in spawning success due to inundation of developing eggs.

The time of rainbow spawning is not expected to be influenced by the increased elevation of Ross Lake.

Silt loads in the gravels of the Skagit River will not be affected by the higher lake elevation.

5.3.2 Feeding Conditions and Fish Growth

(by Fisheries Research Institute)

5.3.2.1 Primary Producers - Ross Lake

The factors bearing on change in abundance of primary producers at the higher lake level are primarily the decreased flushing rate, greater mean depth, larger area and any change in thermal stratification. Discharge from the lake through the turbines will draw less from epilimnial waters than at present and the thermocline will be a little stronger than at present (Burt, 1971). As a result there may be a little less replenishment of nutrients upward into the euphotic zone during the summer, and nutrient replenishment will be more dependent on winter period overturns. Nutrient input from stream watersheds would remain essentially the same as at present. However, because of the decreased flushing rate, bottom nutrients released by decomposition will tend to be recirculated more without flushing out of the system. Furthermore, because of the decreased annual drawdown, more organic matter and sediment would remain on the bottom areas in the epilimnial zone, and decomposition in this area could then provide more release of nutrients into the euphotic zone than at present. It is difficult to predict with certainty how these factors would balance out, but it is probable that standing crop of primary producers per unit surface area would change in proportion to the ratio of volume to surface area of the euphotic zone as mentioned in Section 5.2.2.1. This ratio would be increased by about 28 percent. Therefore standing crop of primary producers per unit of lake surface area may increase. Because of the greater lake area and volume of the euphotic zone total standing crop of primary producers would be greater.

5.3.2.2 Ross Lake Zooplankton

Zooplankton production per unit lake surface area is expected to follow phytoplankton production trends. Little loss is expected through the deep turbine intakes. Total zooplankton standing crop would be greater because of the greater lake surface area.

5.3.2.3 Ross Lake Benthos

As indicated in Section 5.2.2.3 the lesser drawdown at the higher elevation would result in less lake bottom exposed during winter drawdown and twice the area of unexposed lake bottom. These factors favor increased production of benthic invertebrates. Production should also increase because bottom undisturbed by winter drawdown will include more areas exposed to warmer summer water above the thermocline depth. The effects of greater depth of the lake on benthic invertebrate production in deep water was discussed in Section 5.2.2.3.

5.3.2.4 Allochthonous Food

As indicated in Section 5.2.2.4, stream insect drift contribution to the lake would remain essentially unchanged, so that contribution per unit lake area would be less because of the increased lake area. Terrestrial insect contribution may increase somewhat in proportion to shoreline length, which will be 47 percent greater.

5.3.2.5 Stream Food

No substantial change is anticipated in availability of stream and terrestrial invertebrates to stream feeding fish (the discussion in 5.2.2.5 also applies here).

5.3.2.6 Fish Growth

Fish growth in the reservoir is dependent on population size and the combined factors of food production per unit of lake area, per unit of lake shoreline and per unit volume of stream inflow because of the food sources discussed in previous sections. In general, combined production of zooplankton and benthos per unit area is expected to be maintained, as is production per unit area of shoreline and per unit volume of stream flow. Lake area would increase by approximately 71 percent and shoreline length by 47 percent. Because stream inflow would be unchanged and the fish population would be larger stream drift entering the lake would provide less food per fish. This probably would be offset by increased production of snails and amphipods in shallow bottom areas; thus the utilization of these items by large fish would increase. The increased importance of these food items in the diets of large fish in summer and early fall (when stream flows are low) was discussed in Section 3.4.6.1.

If food supply is now limiting growth the lake could probably support a population of trout 50 percent larger with no decrease in growth rate of individual fish, if the relative availability of larger food organisms is unchanged. Growth of larger trout is probably now limited by availability of food of large particle size.

5.3.3 Fish Production

(by Fisheries Research Institute)

A buildup in the trout population during the construction period is expected. Maintenance of a higher population level will depend on the adaptability of the trout population to a shift in available spawning areas, the relative quality of these areas, lake-stream food resources, fishing pressure, and possible ameliorative measures. Over the long run with the greater area and shoreline of the lake, if raised, it should be capable of supporting a greater biomass of fish. Spawning area potential, still under evaluation, appears at this stage to be about equal to present potential. Fishing pressure will undoubtedly increase with time, a factor that will occur whether or not the reservoir is raised, but which will depend on changes in relative accessibility and attractiveness of the area to U.S. and Canadian anglers.

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