1976

Factors affecting the trout fishery of Big Sky Lake, Montana

James E. Darling

The University of Montana

FACTORS AFFECTING THE TROUT FISHERY
OF BIG SKY LAKE, MONTANA

by

James E. Darling

B.A., University of California, Santa Barbara, 1972

Presented in partial fulfillment of the
requirements for the degree of

Master of Arts

University of Montana

1976

Approved by:

Andrew L. Sheldon
Chairman, Board of Examiners

John M. Stewart
Dean, Graduate School

Date Aug 4, 1976

ABSTRACT

Darling, James E., M.S., August, 1976 Zoology

Factors Affecting the Trout Fishery of Big Sky Lake, Montana (106 pp.)

Director: Andrew L. Sheldon *Andrew L. Sheldon*

Big Sky Lake lies in the Clearwater drainage system of Missoula County, Montana. Only property owners and their guests are allowed access to fishing at this relatively small, shallow lake. Homeowners requested that the fishery of the lake be investigated to determine management regulations needed to ensure future angling success.

The study was conducted from October 1974 through September 1975. Physical and chemical parameters were surveyed using standard limnological procedures. Plankton and bacteria were sampled. Rainbow trout (*Salmo gairdneri*) and brook trout (*Salvelinus fontinalis*) were collected by gill-netting, setting a Wolf-type trap in the inlet creek, and angling. Scale samples and stomachs were removed after the fish were weighed and measured. Creel census forms were distributed to property owners.

The lake exhibits seasonal trends in physical and chemical characteristics typical of a moderately productive, dimictic lake of the temperate zone. Pollution by enteric bacteria is absent. Rainbow and brook trout are in good condition, growing rapidly during their first 3 or 4 years, before reaching sexual maturity. Principal food items of both species are *Daphnia* and *Hyalella azteca*, although brook trout appear to consume more benthos and rainbow trout ingest more plankton. Fishing success at Big Sky Lake (1.04 fish per hour) compares favorable with other lakes and streams in Montana.

The following management practices are recommended: 1. larger rainbow fingerlings should be planted during late spring; 2. forage fish should not be introduced; 3. brown trout (*Salmo trutta*) and kokanee (*Oncorhynchus nerka*) should not be planted; 4. barriers to spawning fish should be removed from the inlet creek; 5. perhaps large rainbow trout should be released, and brook trout should be more fully exploited.

In futher studies, the lake should be monitored to detect indicators of increasing eutrophication. To determine proper stocking recommendations, sizes of fish populations and extent of natural recruitment should be estimated. The results of adopted management practices should be closely followed.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Andrew L. Sheldon, for his assistance and patience throughout this study. He also deserves praise for maintaining high standards in his own work, thereby setting a goal toward which his students can strive.

Dr. George F. Weisel was very generous with his time and laboratory facilities. I am grateful to him and Dr. M. Weber for their review of the manuscript.

Thanks are extended to Boyd Opheim and Don Peters of the Montana Department of Fish and Game for their continued help and advice. Dr. John F. Tibbs generously loaned equipment from the U. M. Biological Station. Dr. R. B. Brunson and Dr. M. Kinsella were kind in helping me identify mollusks and fish parasites.

The homeowners at Big Sky Lake were consistently cooperative and friendly. My very special thanks go to the Swenson family. Without the help and friendship of Floyd, Doris, Reid, and Jeff, this project would have been much more difficult.

The inspiration, and often consolation, of all my fellow graduate students is gratefully recognized. I would especially like to thank Mr. Mark W. Oswood. Without Mark's advice, encouragement, and aid, this study might not have been completed.

My parents, Mr. and Mrs. George E. Darling, provided constant and welcome support throughout my graduate career.

TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

Figure		Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

Only property owners and their guests are allowed access to fish at Big Sky Lake. Anglers, therefore, are personally concerned with their influence upon the quality of fishing. A committee of homeowners asked that a study of the lake and its fishery be conducted to help ensure future angling success through careful management. With their permission and cooperation, an investigation was undertaken from October 1974 through September 1975 to accomplish the following goals:

1. To determine the suitability of the lake water for supporting resident fishes by monitoring essential physical and chemical constituents.
2. To investigate possible sources of pollution by enteric pathogenic bacteria.
3. To determine whether benthic and planktonic organisms represented an adequate food source for the fishes, and whether certain items were preferentially eaten.
4. To determine the age, growth, and condition of the fishes.
5. To estimate the fishing pressure exerted by anglers upon the fish population.
6. To review the current fishing regulations (Appendix) and suggest possible improvements in management based on information gathered.

Study Area

Big Sky Lake, formerly Fish Lake, is located within Sections 28 and 29, Range 14W, Township 16N, in Missoula County, Montana. From an elevation of 1300 m (4,270 ft), the lake outlet, Fish Creek, wends 3.5 km (2.2 mi) before emptying into Salmon Lake (elev. 1.19 km; 3,904 ft) lying 1.6 km (1 mi) southeast in the Clearwater drainage system. This system is located in a valley bounded by the Mission Mountains on the west, and the Swan Range on the east. Both mountain ranges are predominantly sedimentary carbonate rocks. The lake rests on a gravel terrace formed by outwash from the Clearwater Glacier during the Pleistocene Epoch (Alden 1953). Surface soil, composed primarily of organic detritus and decaying material from trees, shrubs, and grasses, is underlaid with residual glacial soils of argillite and limestone (Anon. 1973a).

Water level has been stabilized in Big Sky Lake by the addition of dams to the southeastern end of the lake basin. The first dam, constructed during 1904, was destroyed by flooding in 1946. The present dam, constructed about 1950, limits fluctuation of water level to approximately 15 cm (6 in) annually.

Big Sky Lake Company of Great Falls, Montana, subdivided property surrounding the lake during 1966. The original subdivision included 82 lots, 33 of which have been sold. Approximately 25 dwellings have been built or are under construction.

Underground springs are the principal source of water for the lake. The small rill, Fish Creek, which enters from the North (Fig. 1), is a secondary water source.

The morphometry of Big Sky Lake is summarized in Table 1. Ice and snow usually cover the lake from November through early May.

Fishes known to inhabit the lake include: rainbow trout (Salmo gairdneri), eastern brook trout (Salvelinus fontinalis), brown trout (Salmo trutta), and cutthroat trout (Salmo clarki). Kokanee (Oncorhynchus nerka) have also been reported. Rainbow trout are stocked annually by K. Drew, owner of Rainbow Ranch, a private hatchery nearby. Fingerlings are supplied in return for eggs of brook trout and rainbow trout taken during spawning.

A mixed stand of three coniferous tree species, Douglas fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa), and western larch (Larix occidentalis), surround the lake. Dense and diverse understory grows beneath this stand. The immediate shoreline is dominated by mountain alder (Alnus tenuifolia). Submergent (Myriophyllum sp.) and emergent (Potamogeton sp.) plants thrive in the shallower southeastern end of the lake during summer.

Table 1. Morphometric data for Big Sky Lake

	Metric	English
Maximum length	1598 m	5213 ft
Orientation of main axis	ENE	
Maximum width	373 m	1225 ft
Orientation of max. width	NNE	
Circumference	4.25 km	2.65 mi
Maximum depth	16.8 m	55 ft
Mean depth	8.7 m	28.6 ft
Area	37.7 ha	93.16 acres
Volume (approx.)	3.28×10^9 l	1.16×10^8 ft^3
Shoreline development[1]	1.95	

[1]Wetzel 1975: 31.

CHAPTER II

MATERIALS AND METHODS

Physical Characteristics

Morphometry. Big Sky Lake was surveyed between 1 September 1965 and 30 May 1966. The resulting map, later revised by the surveying engineer, William F. Underwood, served as a work map. Bottom contours, determined with an echo-locating device, the Lawrence Fish Finder^{R}, were plotted (Fig. 1). A cartometer and polar planimeter were used to estimate lake circumference, area, and volume from dimensions on the map (Lind 1974).

Bottom types. Bottom samples were collected on 26 May 1975 from 17 stations using a 15 x 15 cm (5.9 x 5.9 in) Ekman dredge. Sample types were classified (Table 1) using a modification of Lagler's (1956) method. Abbreviations of these categories were plotted (Fig. 3) at points coinciding with sites sampled.

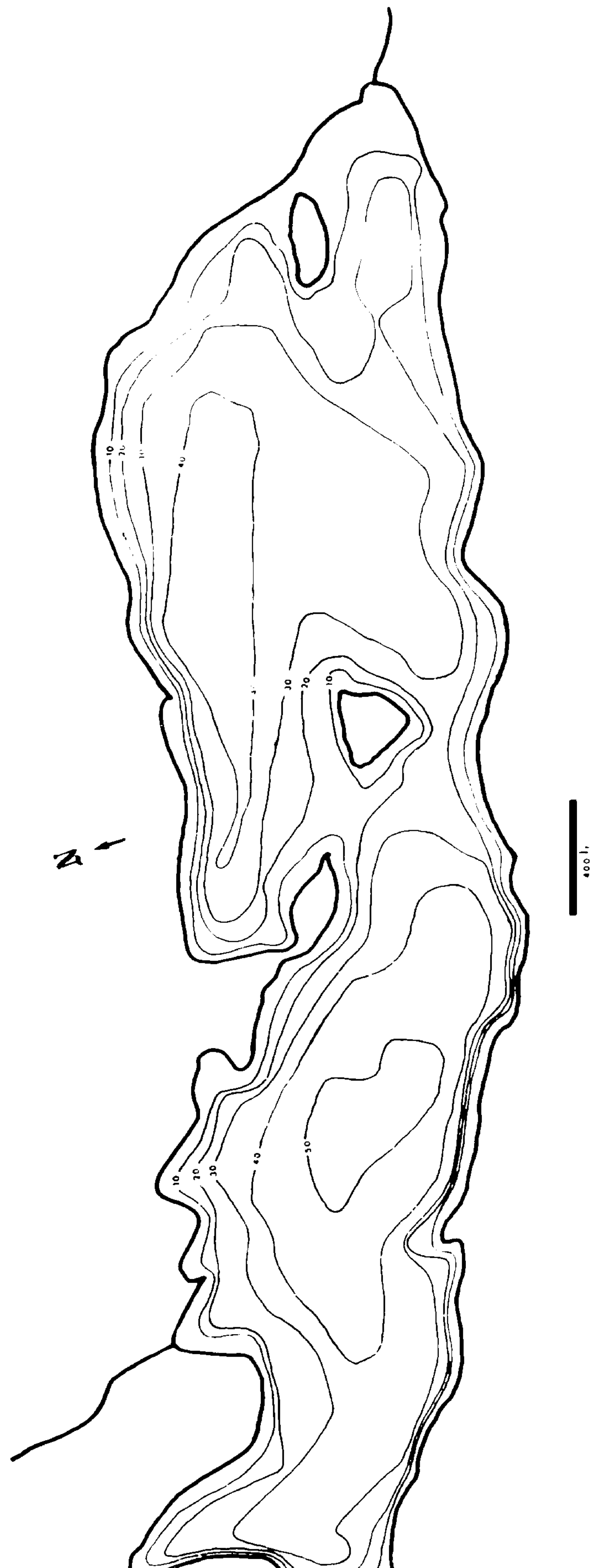
Inlet flow. Inlet flow rates were measured periodically with a hand-held current meter (Kahl Scientific Instrument Corp.).

Transparency. A Secchi disk was used each month when the lake was free of ice to determine transparency of the water column.

Color and turbidity. Color and turbidity of surface water were sampled monthly at three stations (Fig. 2):

1) the inlet creek, 15 m (49 ft.) upstream from its mouth;
2) approximately 10 m (33 ft.) southeast of the mouth of the inlet creek;

Fig. 1. Bathymetric map of Big Sky Lake (ten foot contour intervals)



10
20
30
40
50

3) adjacent to the lake outlet.

Water samples were collected in 1 liter (1.06 qt.) polyethylene bottles rinsed twice with creek or lake water. They were transported cold to the laboratory in a styrofoam chest. In the laboratory a photoelectric colorimeter, the Delta Scientific Model 260 Water Analyzer[R], was used to measure color and turbidity (Standard Methods 1971).

Temperature and Chemical Characteristics

Temperature. Inlet-creek temperatures were monitored continuously by a Ryan-Peabody[R] 30-day thermometer. Surface-water temperatures of Stations 1, 2, and 3 (described under "Color and turbidity") were measured with a mercury field thermometer. Temperature profiles were recorded monthly at the deepest section of the lake (Fig. 2) using a Model 54 Temperature and Oxygen Probe manufactured by the Yellow Springs Instrument[R] (YSI) Company.

Oxygen. Malfunction of the oxygen-recording equipment of the YSI probe interrupted the schedule for oxygen profiles. The Axide Modification of the Winkler Method (Standard Methods 1971) was substituted in the probe's absence and used to verify and calibrate the latter. Water samples for the Winkler tests were collected with a 1 liter (1.06 qt.) Kemmerer sampler and fixed in the field.

The remaining chemical characteristics were determined each month for surface water collected at Stations 1, 2, and 3. As listed below, other analyses were conducted either in the field using methods prescribed by the Hach Chemical Company (HACH), or in the laboratory following the

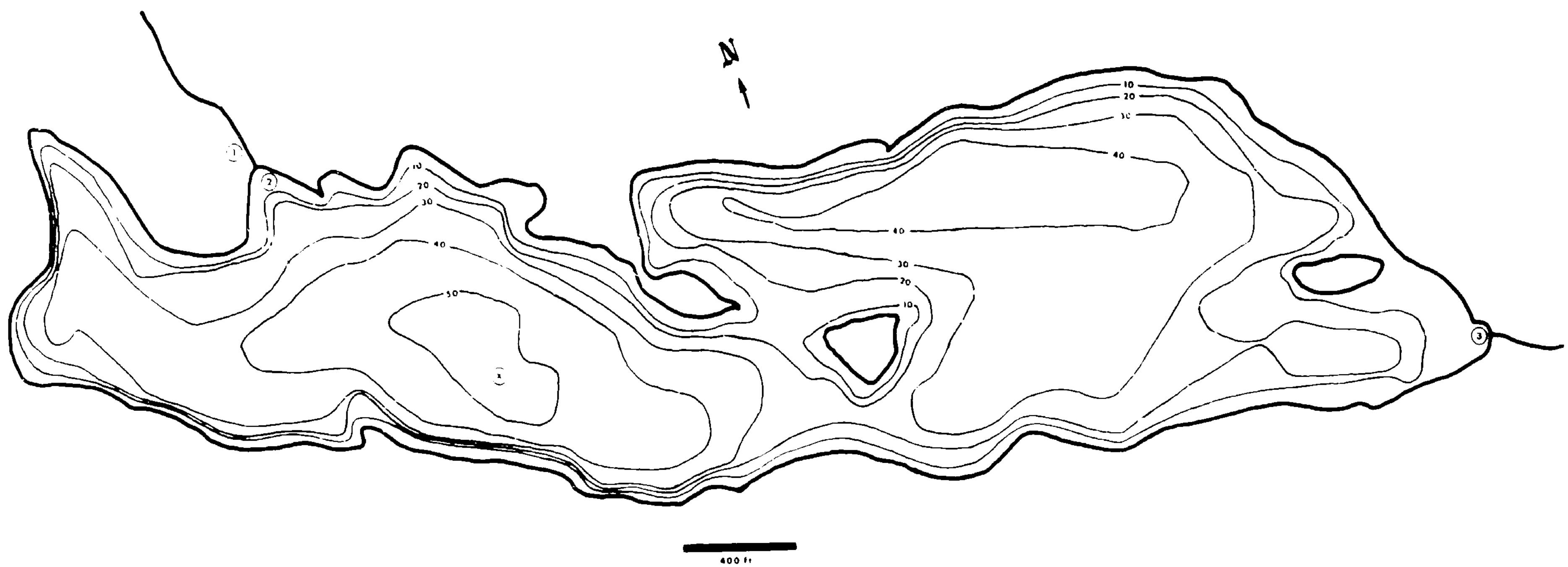
Table 2. Classification of bottom types collected on 26 May 1976 as adapted from Lagler (1956).

BOTTOM TYPE	DESCRIPTION
Organic	
Detritus (D)	undecomposed woody or herbaceous debris
Fibrous peat (fP)	composed of coarser, herbaceous material; parts of plants readily distinguishable; (often in shallow water)
Muck (Mk)	black, completely decomposed organic material
Inorganic	
Boulders (Bo)	rocks over 12 in.
Coarse rubble (Cr)	rocks 6 to 12 in.
Clay (C)	compact, sticky
Concretion mar (Cm)	containing calcareous nudules

Delta Method (DELTA) (Standard Methods 1971):

Chemical Character	Method
pH	Portable meter
Carbon dioxide	HACH
Alkalinity	HACH
Hardness	DELTA
Nitrate	DELTA
Orthophosphate	DELTA

Fig. 2. Locations of sampling stations 1, 2, and 3; and site (X) where temperature and oxygen profiles were recorded.



N
400 ft
10
20
30
40
50

Samples analyzed in lab were collected as described for color and turbidity tests. All tests were completed within 48 hours after collection.

Biological Characteristics

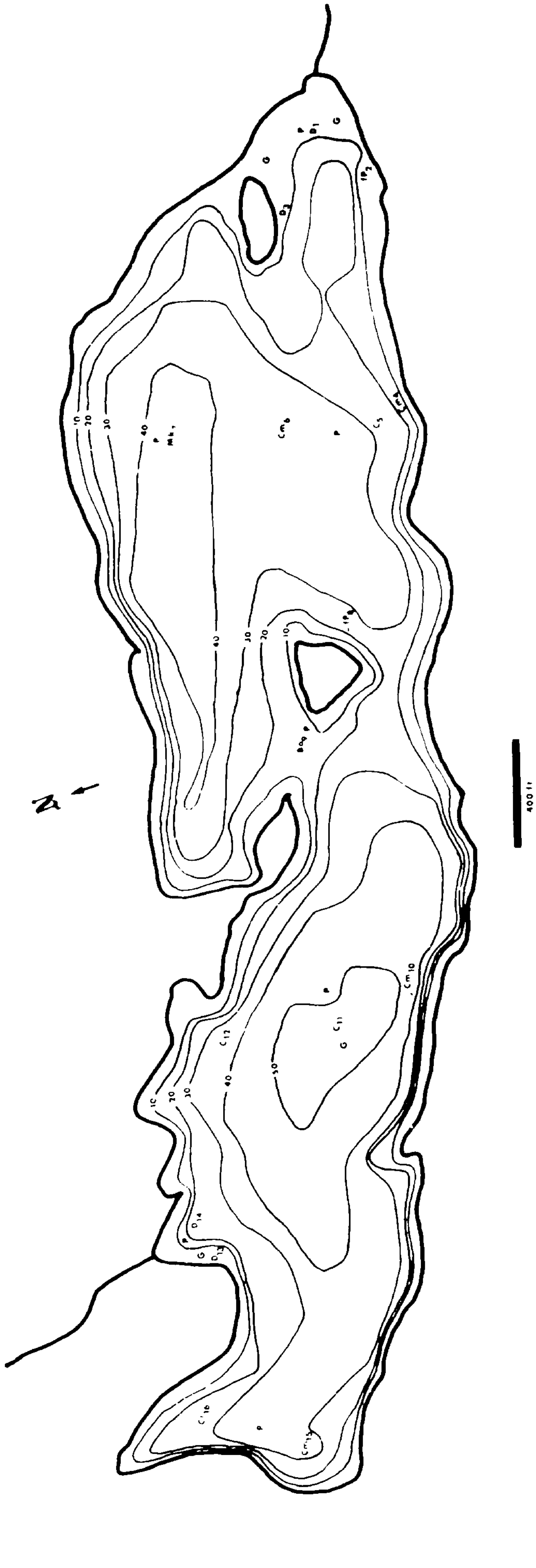
Bacteria. Stoppered pyrex bottles were autoclaved 15 minutes at 121°C (250°F) (Standard Methods 1971). These sterile 1-liter (1.06 qt.) bottles were used to collect monthly samples from stations 1, 2, and 3 for bacterial analyses. For each sample, 500 ml (19.1 oz), 300 ml (11.4 oz), and 200 ml (7.6 oz) portions were tested for coliform bacteria according to a membrane filtration technique (Standard Methods 1971). Samples were filtered through sterile 47μ(.0019 in) Type HAWG Millipore filters which were then incubated on M-Endo MF Broth Medium (Anon. 1973b). Incubated cultures were examined, and indicator colonies were counted under a dissecting microscope at 10x magnification.

Benthos and plankton. Benthos samples were collected from 16, and plankton from 7, locations throughout the lake (Fig. 3) on 26 May 1975.

Bottom samples were obtained with an 15 x 15 cm (5.9 x 5.9 in) Ekman dredge and poured through a number 30 sieve (0.6 mm mesh) to extract the organisms (Lind 1974). Sieve contents were preserved in 10% formalin.

A simple conical plankton net with 30 cm (11.8 in) mouth diameter and 20 μ (.0008 in) mesh was hauled vertically from just above bottom to surface. Net contents were preserved in 10% formalin (Lind 1974).

Fig. 3. Locations of benthic (see Table 2 for abbreviations) and planktonic (P) sampling sites on 26 May 1975. Placement of gill nets (G) on 15 November 1974 is also indicated.


10
20
30
40
N

Both benthic and planktonic organisms were identified using a dissecting microscope. Presence-absence data was compiled for the benthic samples.

Fishes (fieldwork). Information on the fishes of Big Sky Lake was obtained primarily from four sources:

1) gill netting

2) processing of anglers' catches

3) voluntary angler returns

4) Wolf-type inlet trap (Wolf 1951).

Four gill nets were suspended just above bottom in the lake for approximately 24 hours (Fig. 3 and Table 3) beginning at 7:00 p.m. on 15 November 1974. Sixty captured fish were measured for fork length, weighed on a spring balance, and sexed. Approximately 30 scales were removed from the side of each fish just above the lateral line and below the origin of the dorsal fin. Scales were placed into a small wax-paper square and inserted into a 5.6 x 8.9 cm (2.2 x 3.5 in) envelope. Digestive tracts were severed above the esophagus and at the pyloric sphincter, wrapped in cheezecloth, and preserved in 10% formalin.

Occasionally, I contacted anglers shortly after their successful outings and processed their fish as described above.

A Wolf-type trap (Wolf 1951) was constructed from 12.7 mm (0.5 in) plywood, 6.35 mm (0.25 in) mesh metal screen, and 1 mm (0.04 in) mesh nylon screen. The trap was installed in the inlet creek for 24 hours on three occasions (19 October 1974, 17 June and 1 Aug. 1975) to collect

Table 3. Gill net sizes and placement

Net	1	2	3	4
Mesh Size	60 to 120 mm[1] 2.4 to 4.8 in	75 & 120 mm[1] 3.0 to 4.8 in	120 mm. 4.8 in	35 mm 1.4 in
Length	36.6 m 120 ft.	36.6 m 120 ft.	22.9 m 75 ft.	13.7 m 45 ft.
Depth of Set	3.0 to 6.1 m 10 to 20 ft.	1.5 to 7.6 m 5 to 25 ft.	15.2 to 16.8 m 50 to 55 ft.	0.3 to 3.0 m 1 to 10 ft.

[1]variable-mesh net

emergent fry or small trout seen within the area. Captured fish were measured, weighed, and preserved in 10% formalin after scales were removed.

Parasitic nematodes found in the swimbladders and intestine of fish collected on 18 November 1974 were identified by Dr. M. Kinsella.

Creel census forms (Fig. 4) and fish-scale envelopes were distributed to lake property owners. Completed forms were returned to, and additional blank forms and envelopes made available at, the caretaker's cabin located on one access road.

Fig. 4. A sample of the creel census forms distributed to property owners at Big Sky Lake.

BIG SKY LAKE

CREEL CENSUS SHEET

DATE:____________________________ NAME OF FISHERMEN____________________

Kind of Fishing: (Circle One)
- Fly Fishing
- Spin Casting
- Trolling
- Other:____________

Comments (Boat? Tackle? Bait?)

Location Fished (Please indicate on map below)

Species of Fish	Total Number of Fish Kept	Not Kept
Rainbow Trout		
Cutthroat Trout		
RB-Cutt Hybrid?		
Brook Trout		
Brown Trout		
Other		

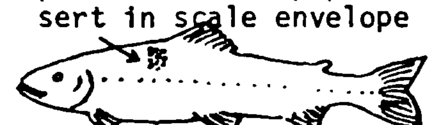
Total Time Fished (To Nearest 1/4 Hour)

____________Hrs.________________Min.

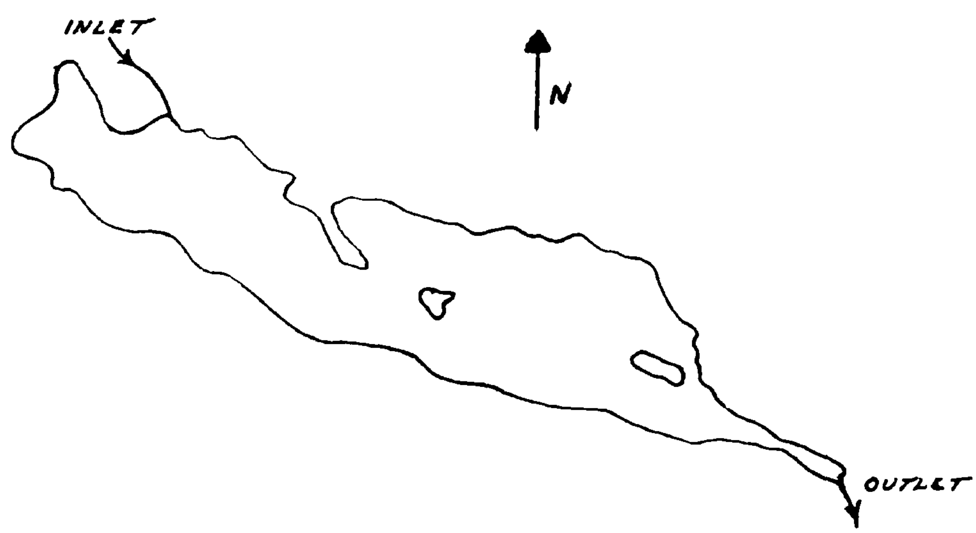
From_________ a.m./p.m. to_____________ a.m./p.m.

Directions

1. Use one sheet per party.
2. Fill in blanks, including numbers of fish caught and total time fished (combined for all fishermen in the party).
3. From each fish kept, take a dozen or more scales from designated area and place into wax-paper insert in scale envelope



4. On the scale envelope record: Date, Area and Method, Species and Length.



Fishes (laboratory work). Scales removed from rainbow trout, eastern brook trout, and brown trout were soaked in dilute (1%) ammonia solution and cleaned with toothpicks. Six scales from each fish were mounted on a 25 x 76 x 1 mm (1 x 3 x 0.4 in) glass slide in a glycerin-gelatin mounting medium (Lagler 1956). Mounted scales were magnified 65 x on a Tri-Simplex Micro-Projector manufactured by Bausch and Lomb Co. Scale radius and distances to annuli were measured along the median axis of the most legible scale on each slide (Ricker 1971).

A Fortran program, BMD 05R (Polynomial Regression) (Dixon 1974), was used to determine the best-fitting regression line for the graph of fork length versus scale radius. A second program, BMD 02R (Stepwise Regression), converted the selected curvilinear plot to a log-log relationship. Distances to scale annuli were inserted into the resulting polynomial equation to compute lengths at ages.

BMD 02R (Dixon 1974) was also used for plotting log of fish weight versus log of fork length.

A modification of the "points method" proposed by Hynes (1950) was used in analyzing the food of Big Sky Lake fishes. Full stomachs were alloted 20 points; half full, 10 points; etc. Noticeably distended stomachs received 25 points. Points assigned to food items present were proportional subdivisions of total points alloted to individual stomachs. Size of organisms as well as abundance were considered in evaluations. For each fish species, points gained by each food item were summed and converted to percentage composition of food of all fishes examined. Occurrence of each food item in stomachs was also noted. Total occurrence for each food item was converted to percentage of occurrences of all food items found in stomachs inspected.

CHAPTER III

RESULTS

Physical Characteristics

Morphometry. Big Sky Lake is roughly elliptical in form (Fig. 1). The northwestern half (nearest the inlet) includes the deepest section of the lake and a steep drop along the southern shore. Two islands lie in the southeastern half where the steeper slope occurs along the northern shore. The lake covers approximately 37.7 ha (93.16 acres) and has a mean depth of 8.7 m (28.6 ft) (Table 1).

Bottom types. Detritus and fibrous peat (Table 2) were found in the shallower areas of the lake (Fig. 3) during the sampling session on 26 May 1975. Boulders and coarse rubble were encountered when bottom grabs were taken near the penninsula and at the extreme northwest end. Concretion marl and/or clay were found in the deeper areas, except in the basin between the islands, where dark organic muck predominated.

Inlet flow. Water velocities of the inlet creek ranged from 20 cps in January to 140 cps in May 1975 (0.67 to 4.6 fps), with a mean of 61 cps (2.0 fps) (Table 4).

Transparency. Monthly Secchi-disk readings were begun during October 1974 at the deepest area of the lake. Freezing of surface water precluded recording of transparency readings from November 1974 until May 1975. Depth of visibility ranged from 1.25 m (4.08 ft) during May to 5.0 m (16.4 ft) during September 1975 (Figs. 8-19).

Color and turbidity. Color and turbidity of surface water at stations 1, 2, and 3 (Fig. 5) showed similar variations seasonally. Maximum readings occurred in December (November for station 1) 1974 and May 1975.

Measurements of color and turbidity are equivalent in this study because the Delta method did not include filtration of the samples to remove suspensoids before determining color of water (Wetzel 1975).

Temperature and Chemical Characteristics

Temperature. Inlet-creek temperatures recorded continuously (Fig. 6) ranged from -0.3°C (31°F) during February and March 1975 to 10°C (50°F) during August 1974. Monthly field-thermometer readings of surface temperatures at stations 1, 2, and 3 are shown in Fig. 7. Temperature profiles are illustrated in Figs. 8 through 19.

Oxygen. During the few months when the YSI probe was functioning properly, vertical profiles of dissolved oxygen concentrations coincided closely with temperature clines (Figs. 8-19). The Winkler method produced results of similar agreement. A noteworthy exception to this agreement was the increase in oxygen recorded at 11 m (36 ft.) during August and September samplings.

pH. Lake surface water was consistently alkaline, i.e. pH was greater than 7 (Fig. 20). A general rise in pH began in April and continued through August 1975.

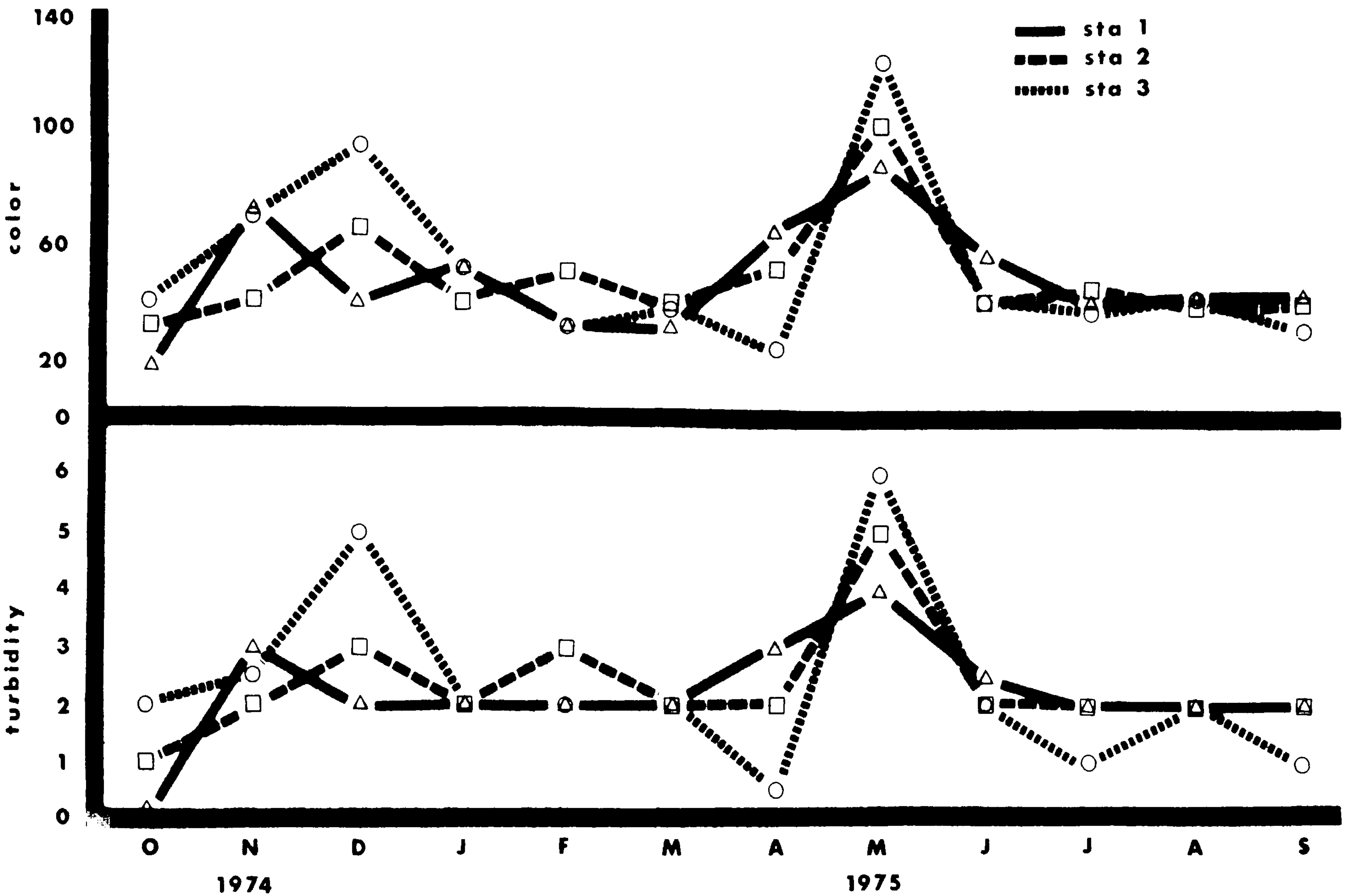
Carbon dioxide. Free carbon dioxide (CO_2) was never detected above trace quantities at any of the sampling stations.

Table 4. Flow rates of the inlet creek

Date	Velocity cm/sec.	Velocity ft/sec.
1974		
9/21	23	.75
12/6	46	1.5
1975		
1/19	20	.67
3/22	55	1.8
4/19	107	3.5
5/18	140	4.6
6/17	107	3.5
7/24	49	1.6
8/21	37	1.2
9/20	30	1.0
Mean	61	2.0
Range	20-140	0.67-4.6

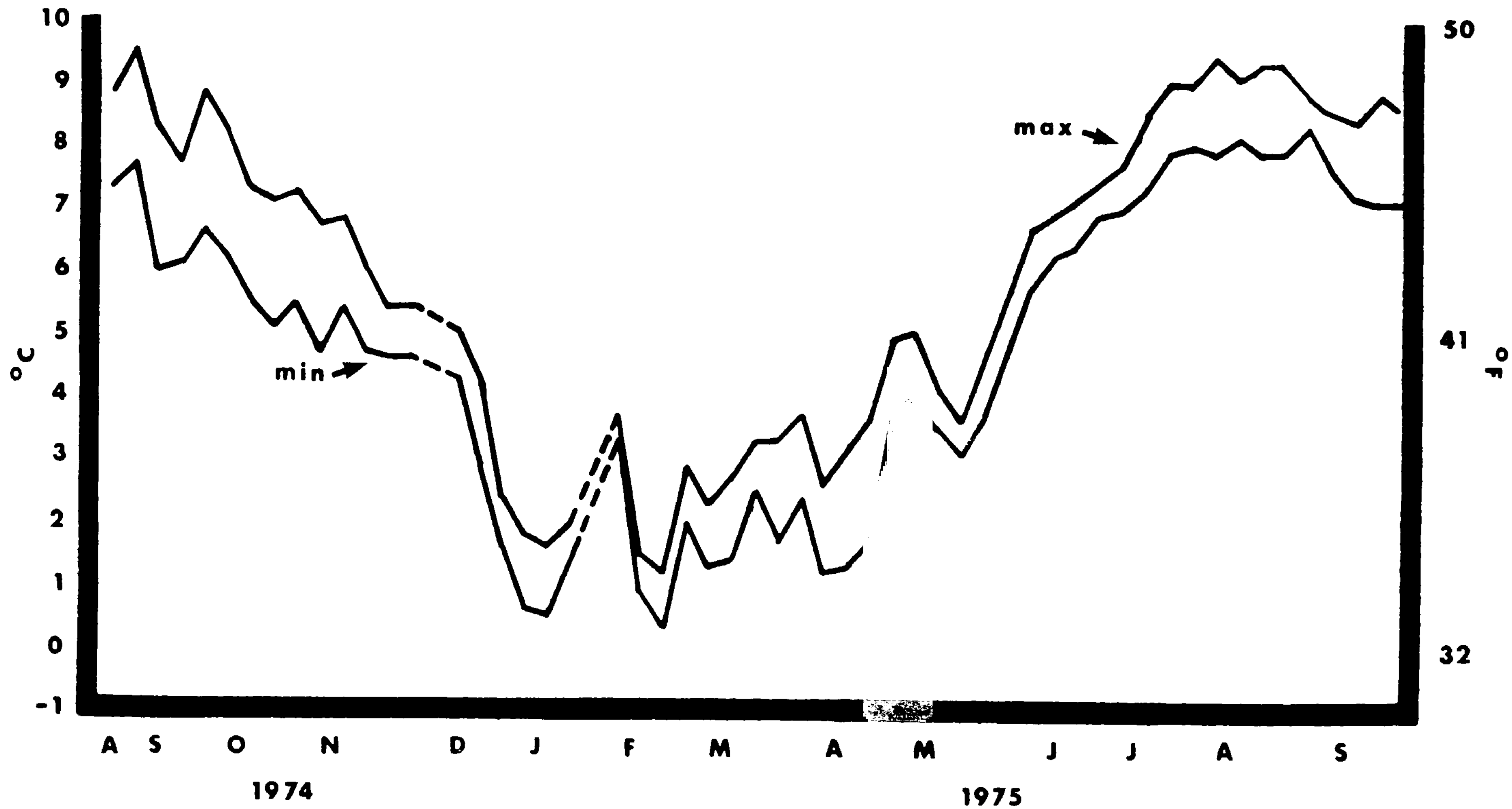
Alkalinity. Bicarbonate alkalinity measurements of the lake surface waters were generally higher than those of the inlet creek (Fig. 21). Also, station 3 remained consistently more alkaline than station 2.

Fig. 5. Color (A.P.H.A. platinum-cobalt units) and tubidity (ppm) of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.



sta 1
sta 2
sta 3
140
100
60
20
0
color
6
5
4
3
2
1
0
turbidity
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Fig. 6. Weekly maximum and minimum temperatures of inlet creek water as recorded by the Ryan-Peabody 30-day thermometer.


10
9
8
7
6
5
4
3
2
1
0
-1
°C
max
min
50
41
32
°F
A S O N D J F M A M J J A S
1974
1975

Hardness. Total hardness of surface water increased from station 1 to station 2, and again to station 3 (Fig. 22). Calcium hardness, one component of total hardness, showed a similar trend. Magnesium hardness, the second component, was generally higher at station 3 than at 1 and 2. Fluctuation in magnesium and total hardness was greatest at station 1, the inlet creek. Total hardness was lowest for all three stations during May 1975.

Nitrate. Nitrate levels followed very similar trends for the three sampling stations (Fig. 23). Highest nitrate concentrations were observed during November 1974, and lowest levels occurred during June 1975.

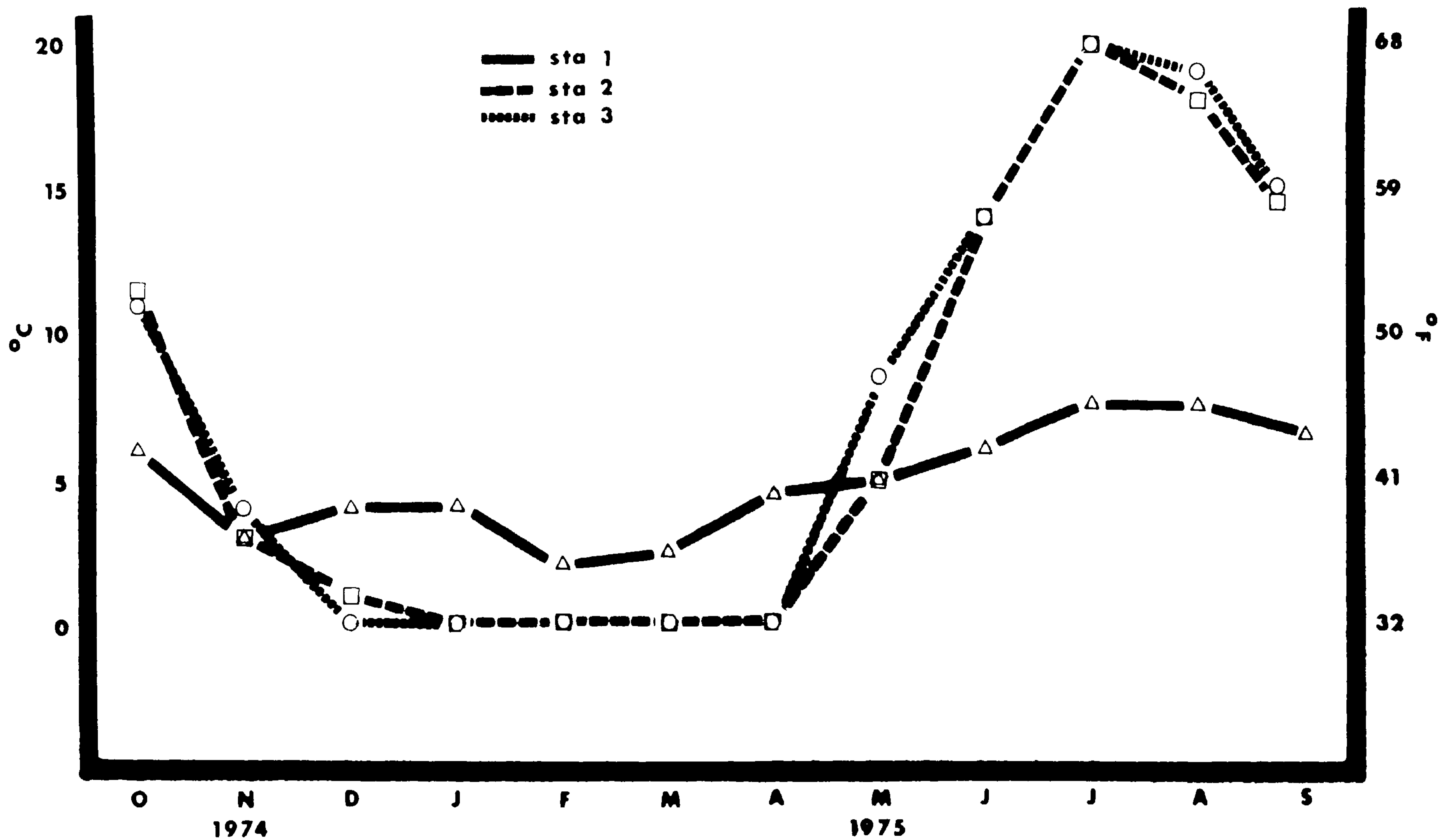
Orthophosphate. Concentrations of orthophosphate recorded at station 3 were lower than stations 1 and 2 throughout the sampling period (Fig. 24). From December 1974 through March 1975, orthophosphate levels for station 2 rose above those for station 1. Station 1 levels were higher the remainder of the year.

Biological Characteristics

Bacteria. The maximum number of total coliform bacteria found per 100 ml of sample was seven at station 3 during November 1975 (Table 5). All but four samples contained fewer than 2 coliform bacteria per 100 ml.

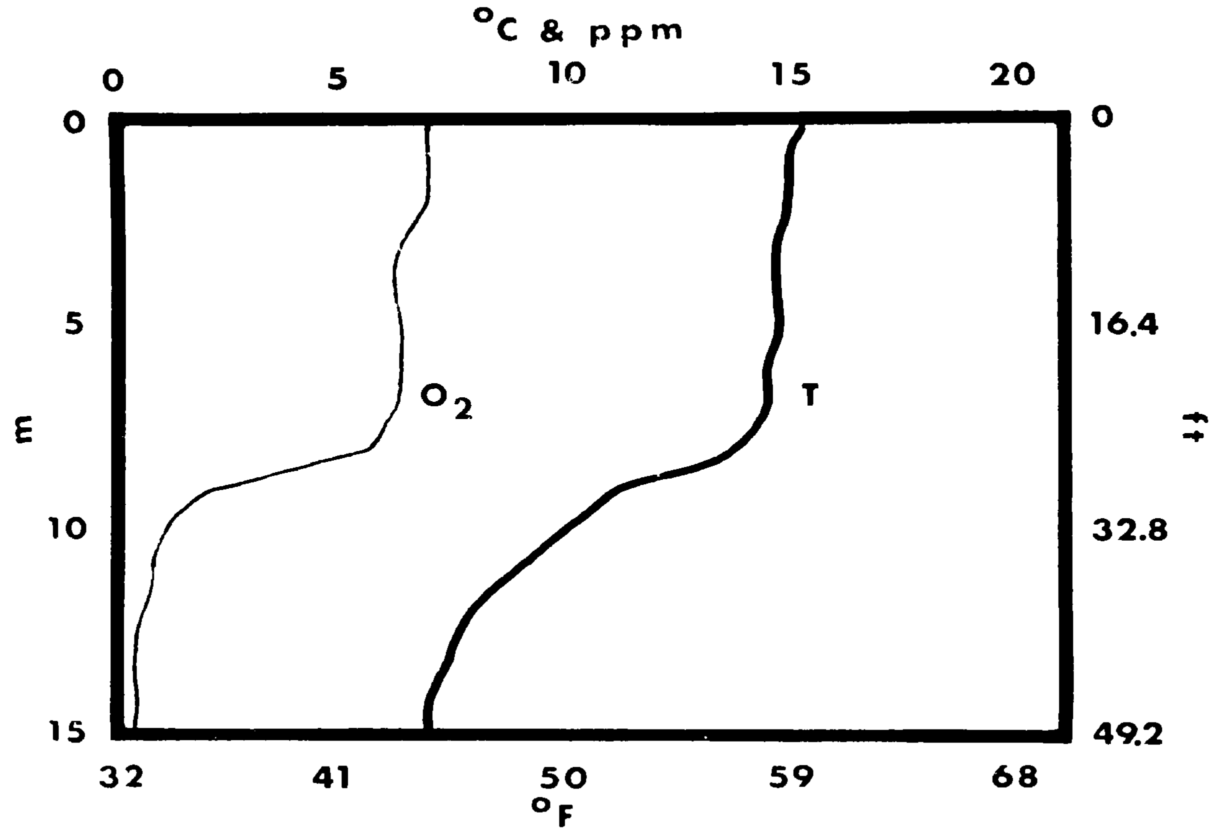
Benthos and plankton. Sampling locations for benthos and net plankton are illustrated in Fig. 3. Several different benthic organisms were identified (Table 6). Planktonic analysis proved more difficult

Fig. 7. Temperature of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.

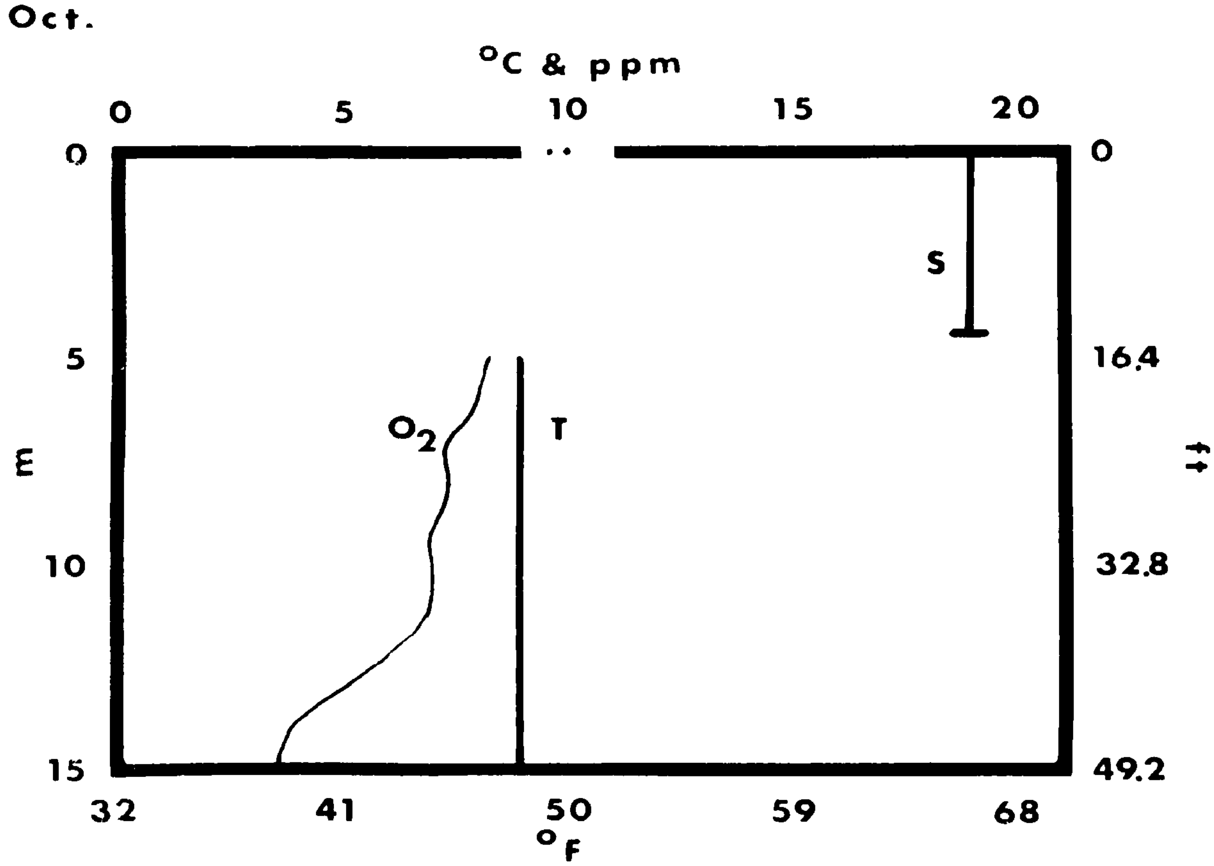

sta 1
sta 2
sta 3
°C
20
15
10
5
0
°F
68
59
50
41
32
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Figs. 8-19. Vertical distribution of dissolved oxygen (O_2) concentrations in ppm and temperature (T) in ^{o}C and ^{o}F at the deepest section (Fig. 2) of Big Sky Lake. Temperature alone is reported for months when the oxygen probe malfunctioned. Secchi-disk transparency (S) is included for months when the lake was ice-free.

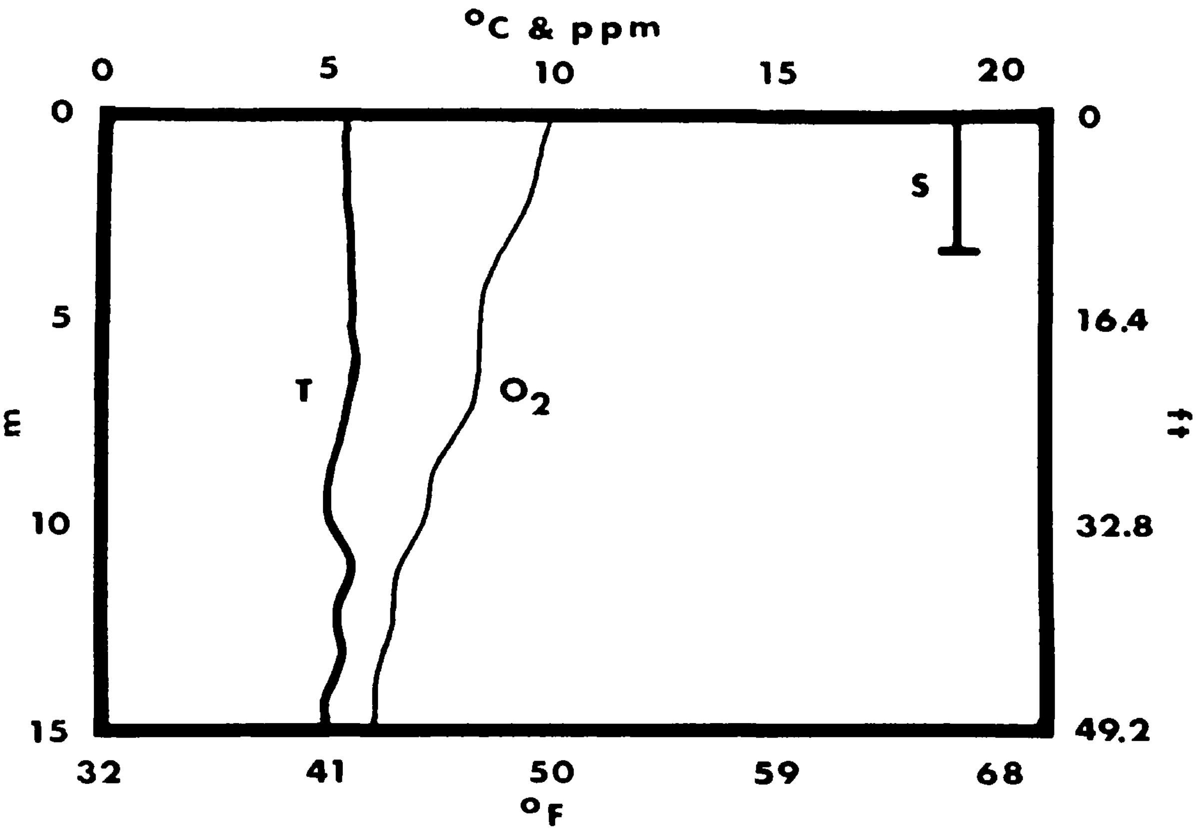
15 Sept. 1974



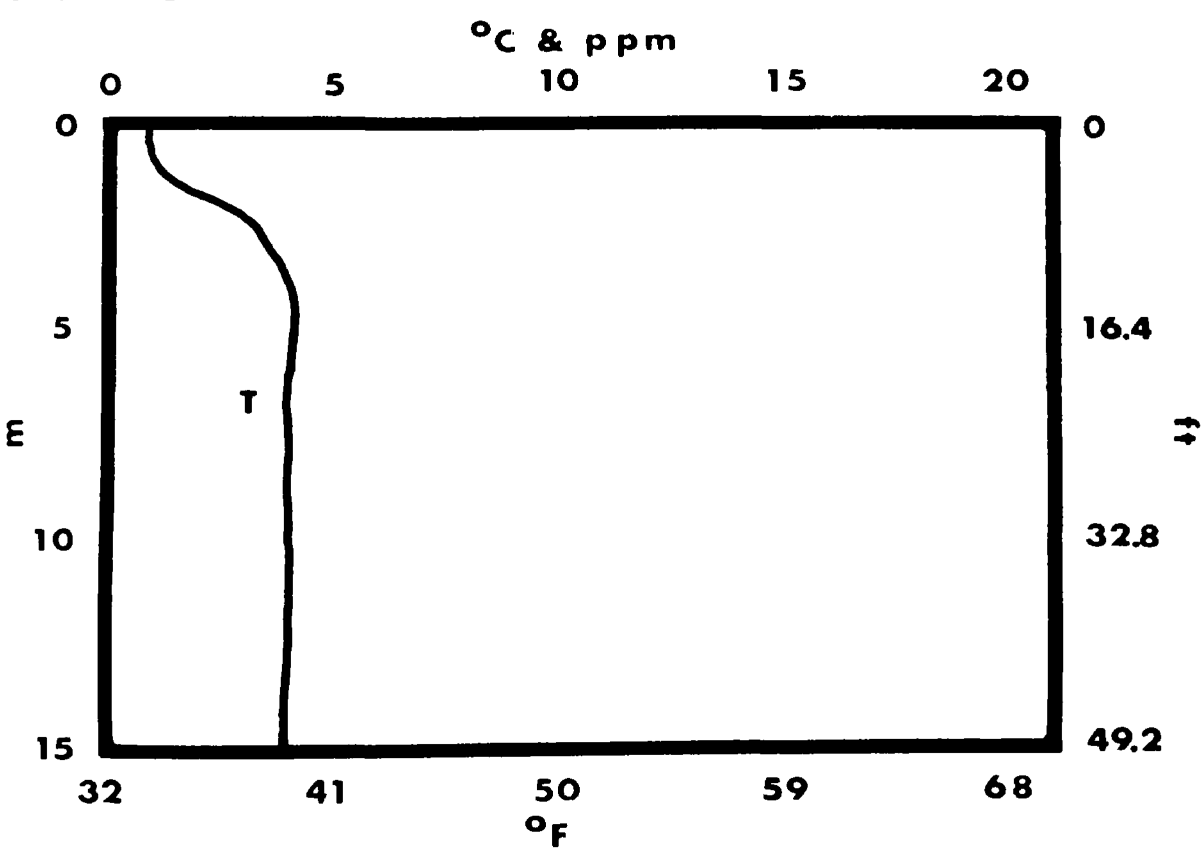
26 Oct.



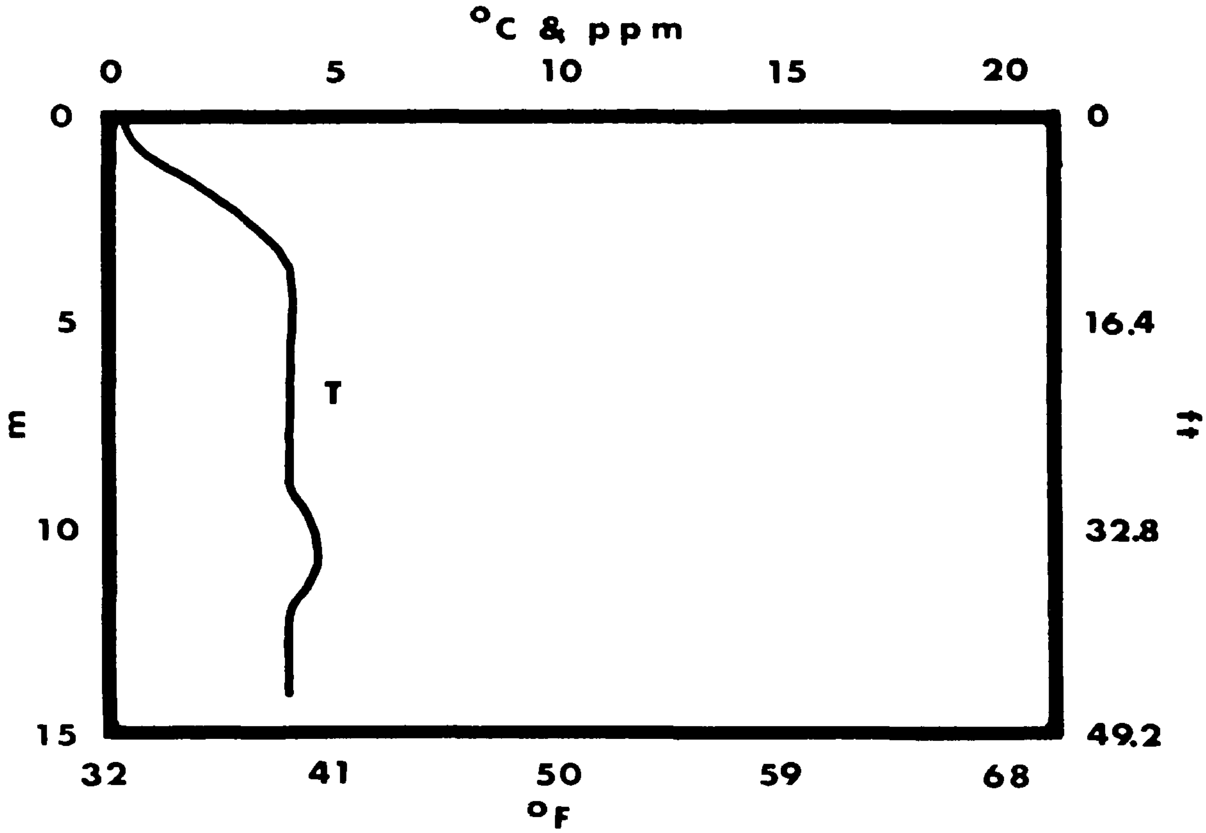
17 Nov.



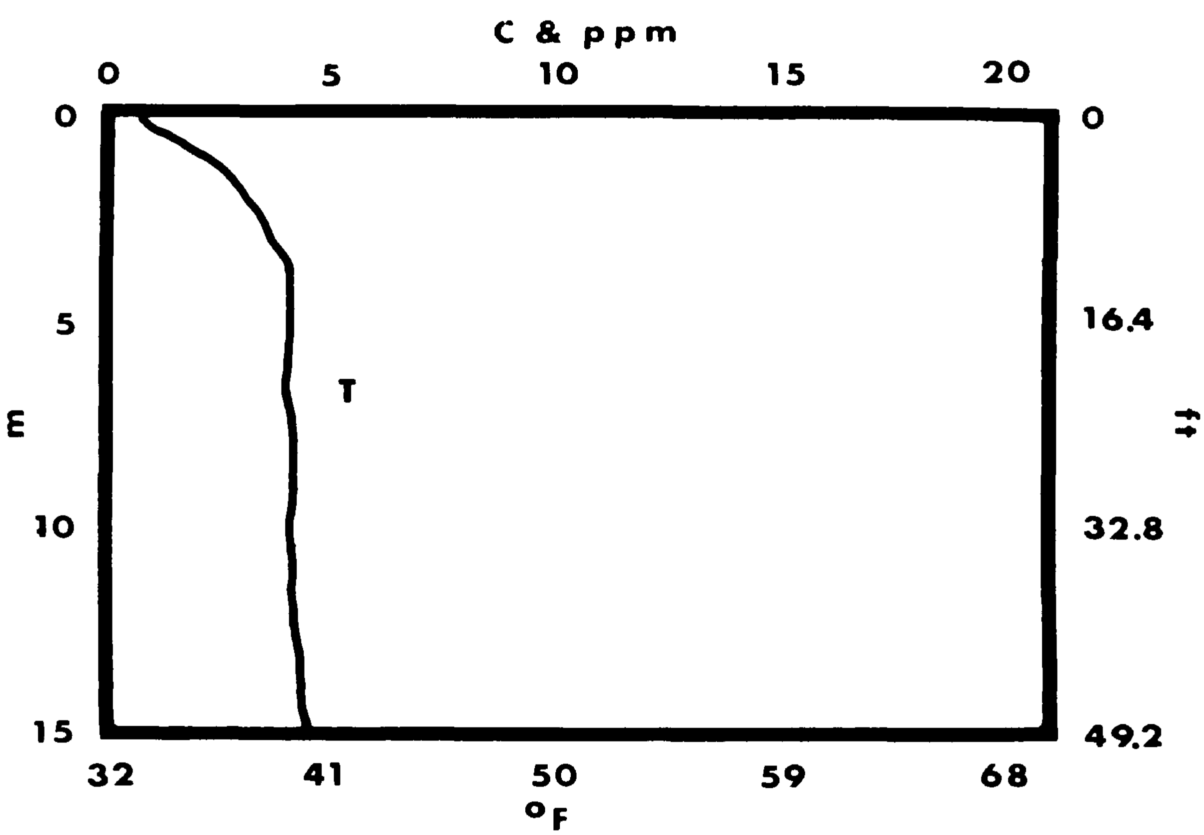
1 Mar. 1975



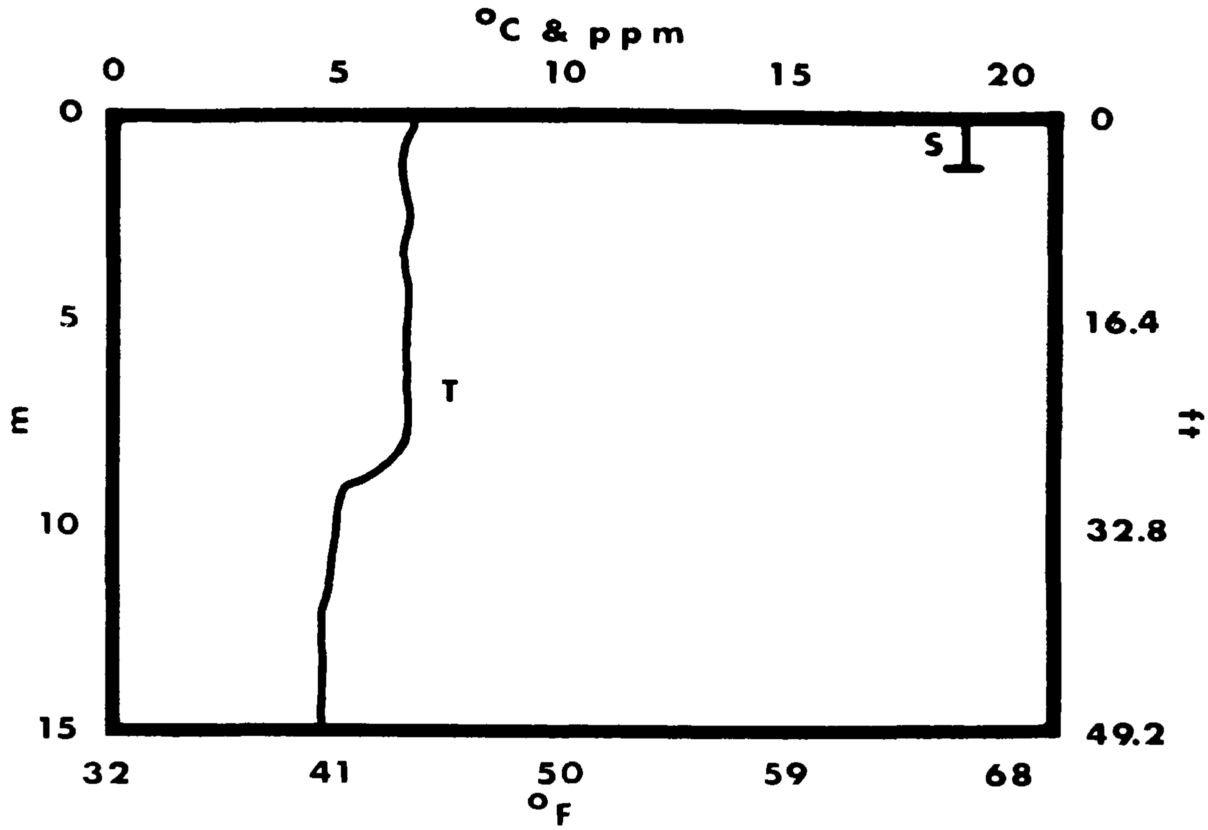
29 Mar.


°C & ppm
0
5
10
15
20
0
5
10
15
m
0
16.4
32.8
49.2
ft
T
32
41
50
59
68
°F

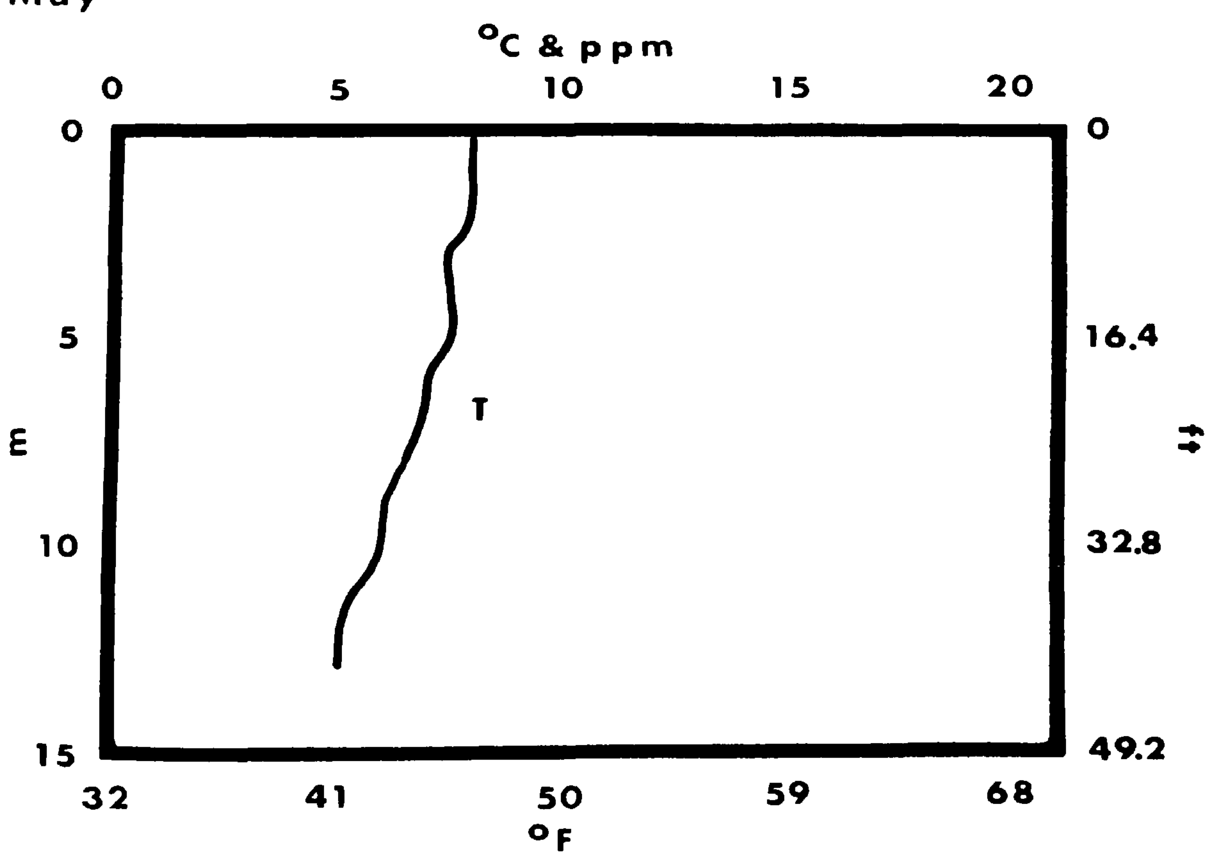
19 Apr.


C & ppm
0
5
10
15
20
0
5
10
15
m
0
16.4
32.8
49.2
ft
T
32
41
50
59
68
°F

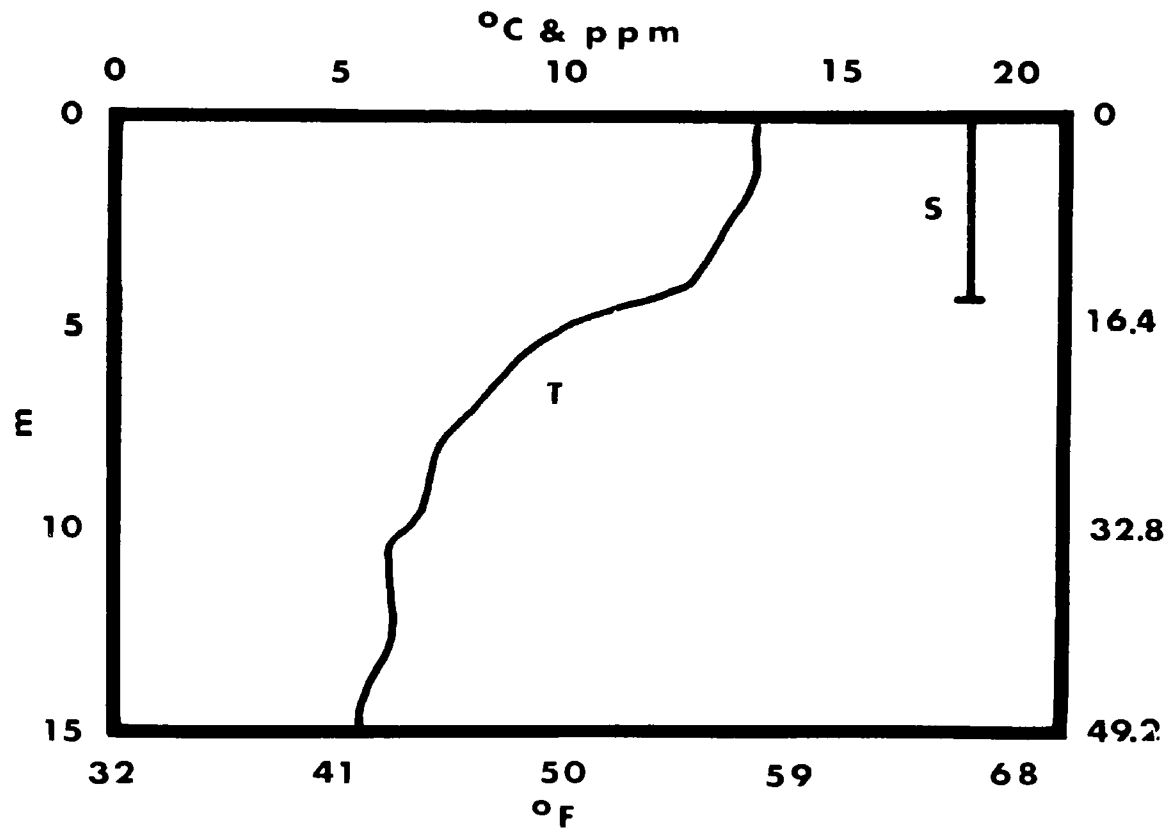
18 May


°C & ppm
0
5
10
15
20
0
5
10
15
m
0
16.4
32.8
49.2
ft
T
S
32
41
50
59
68
°F

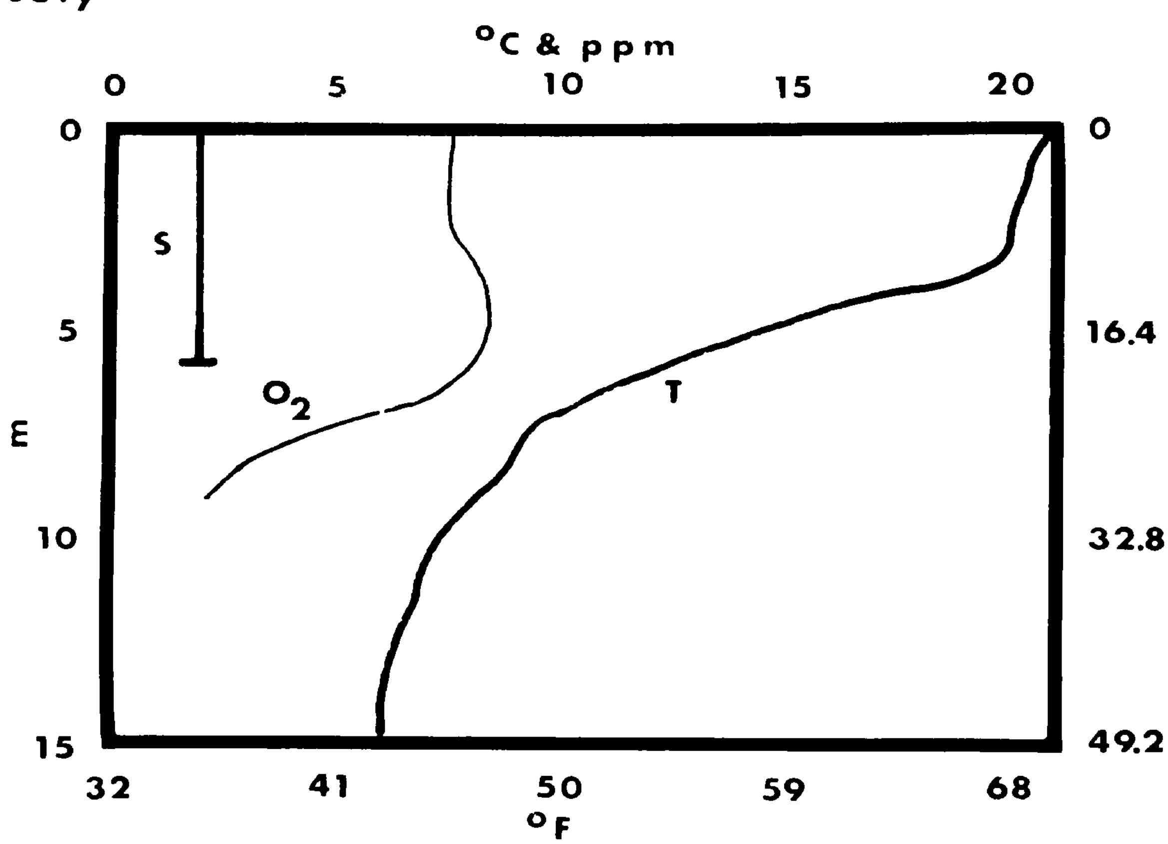
26 May


°C & ppm
0
5
10
15
20
0
5
10
15
m
0
16.4
32.8
49.2
ft
T
32
41
50
59
68
°F

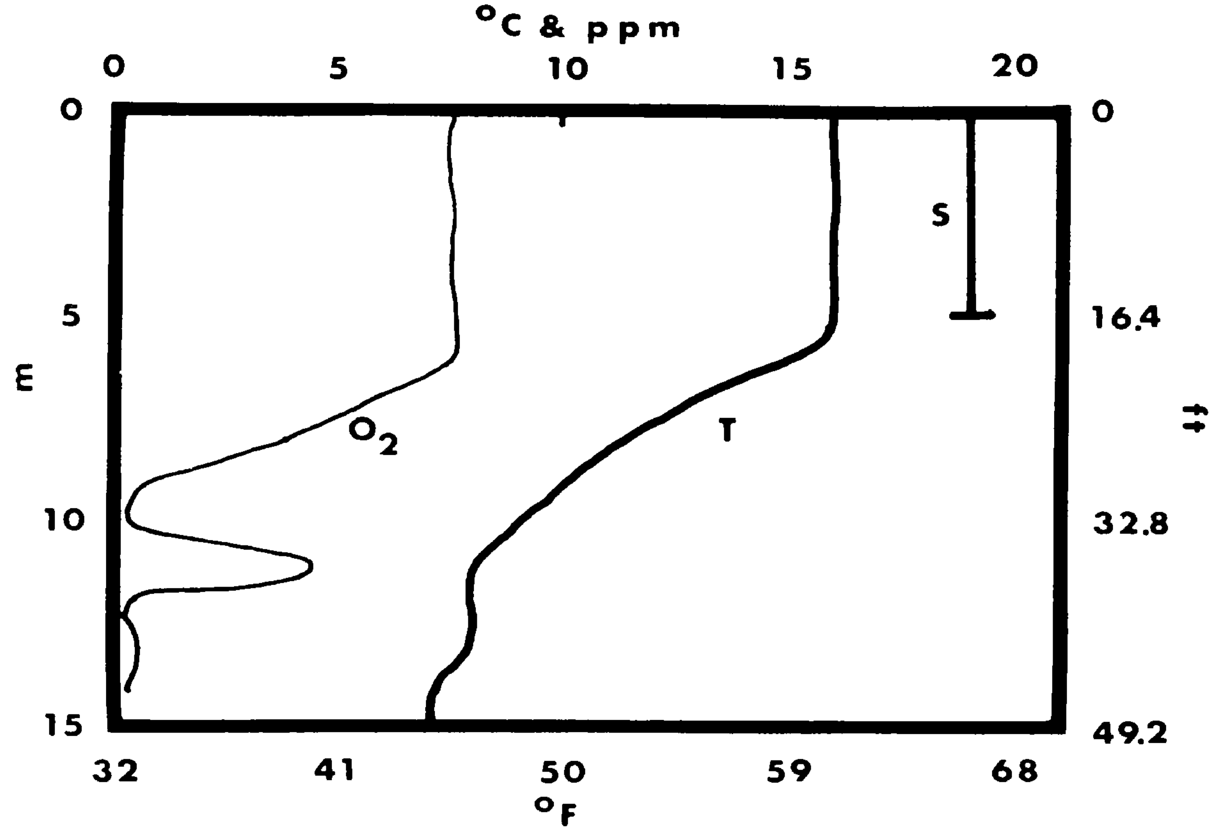
17 June



19 July



26 Aug.



28 Sept.

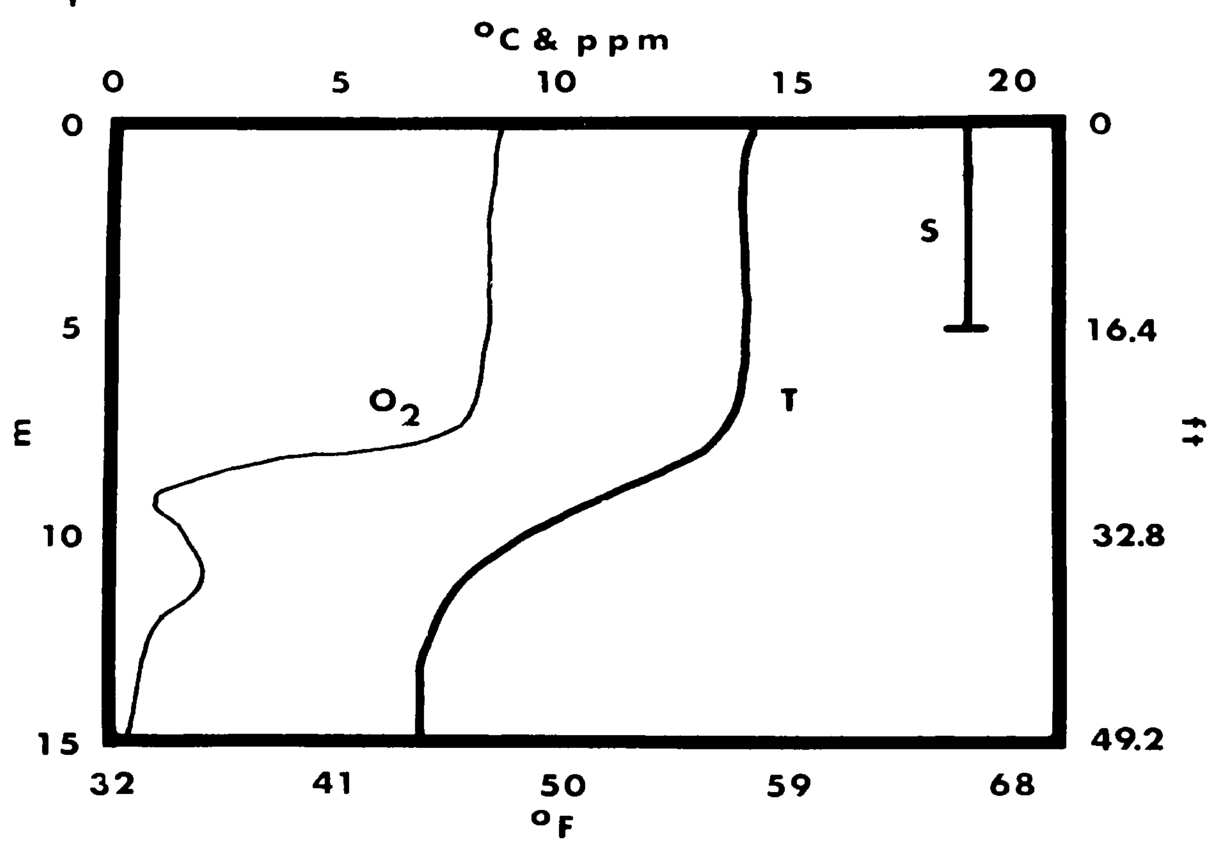
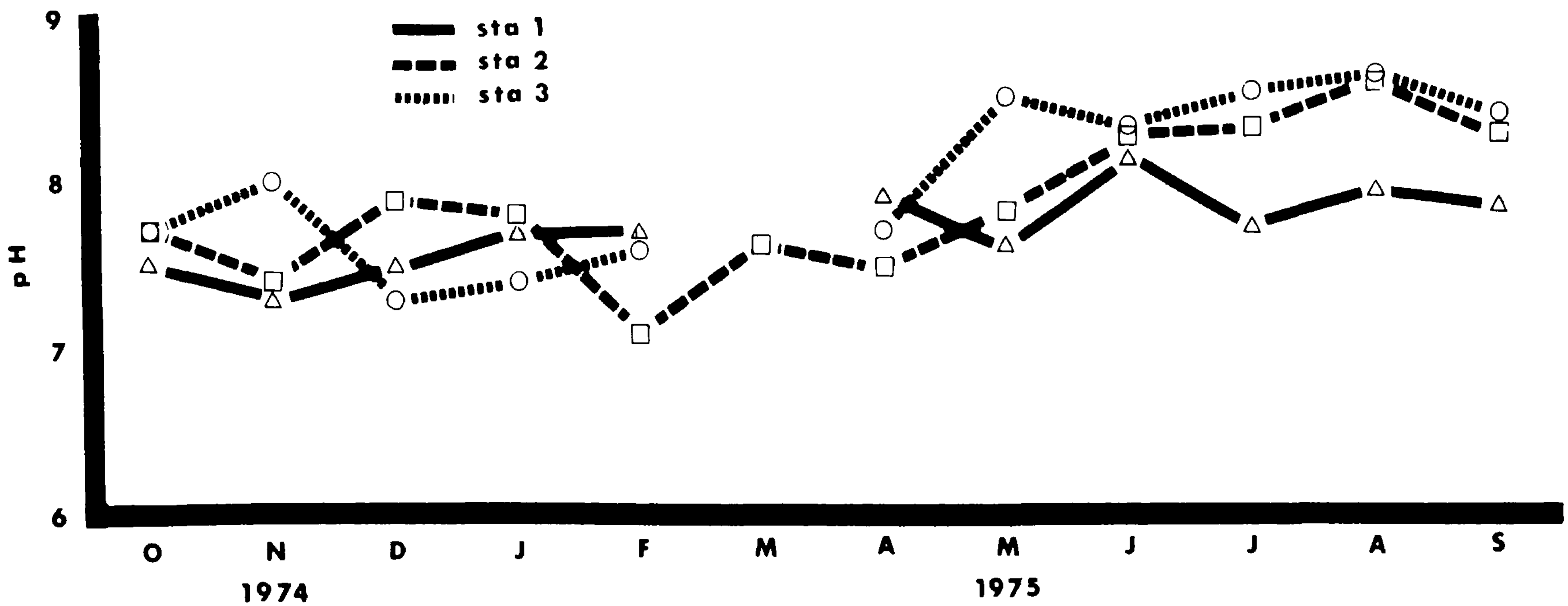
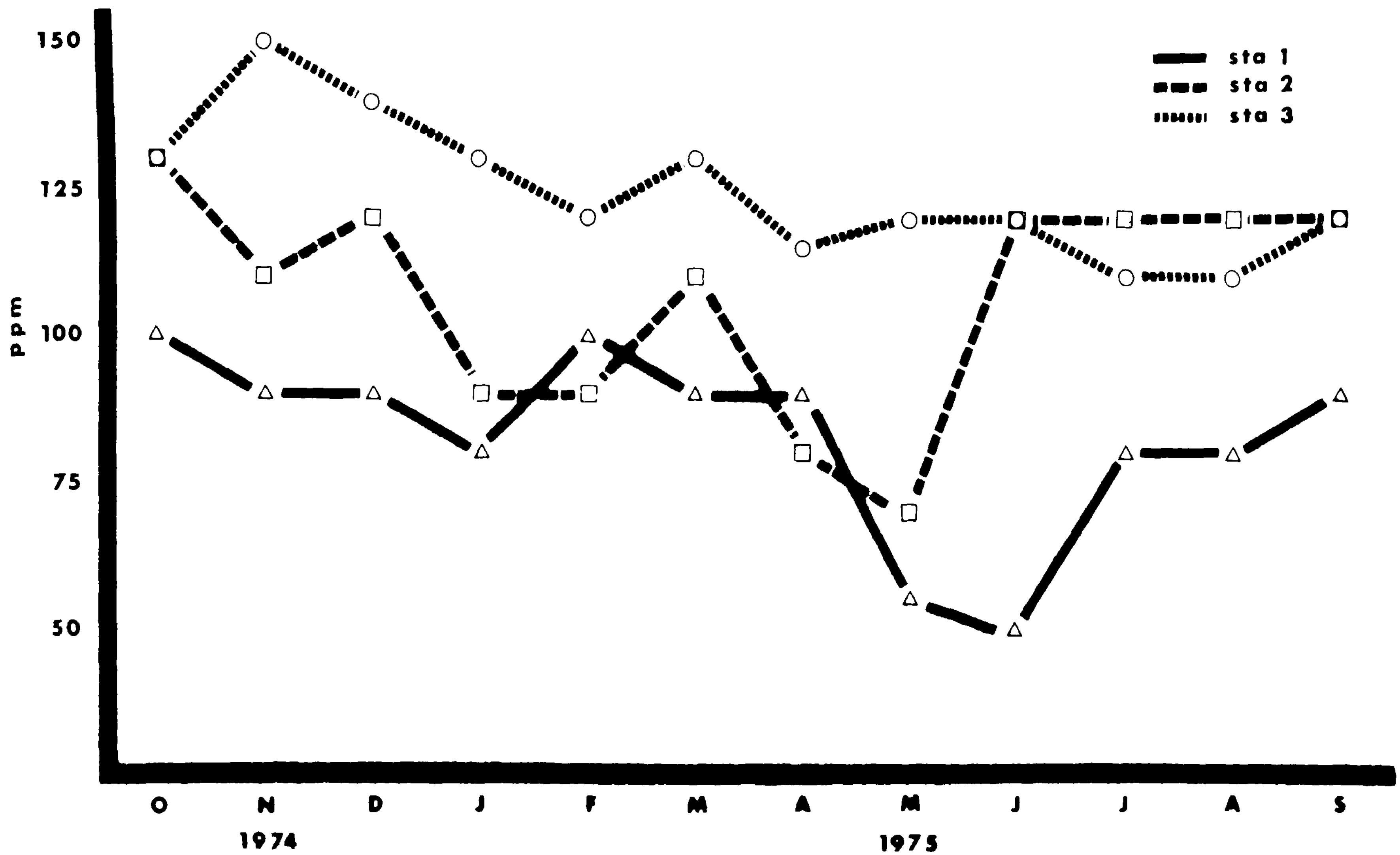


Fig. 20. pH of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.



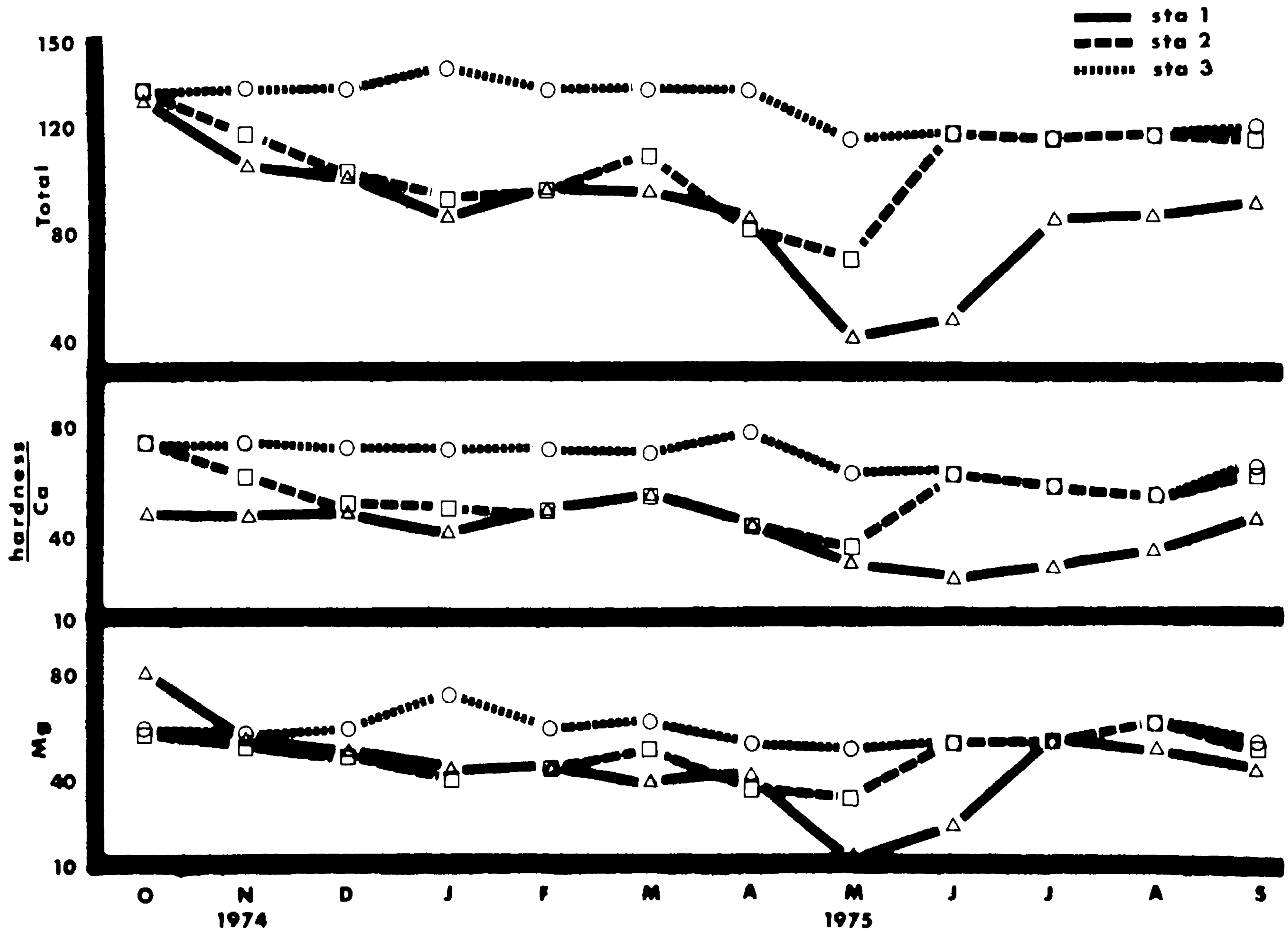
sta 1
sta 2
sta 3
9
8
7
6
pH
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Fig. 21. Bicarbonate alkalinity of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling season.



150
125
100
75
50
ppm
sta 1
sta 2
sta 3
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Fig. 22. Total, calcium, and magnesium hardness (ppm $CaCO_3$) of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.



sta 1
sta 2
sta 3
150
120
80
40
Total
80
40
10
hardness
Ca
80
40
10
Mg
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

as a result of animal distortion by preservative. Cladocerans (*Daphnia*) and copepods (adults and larvae) were dominant in the samples examined. Large *Daphnia* were examined as possible indicators of fishing quality in Big Sky Lake (Galbraith 1975). Most samples contained at least 100 *Daphnia* larger than 2 mm.

Fishes. Rainbow trout and brook trout were the principal fishes collected. Only these two species were sufficiently abundant to allow adequate analysis of their ages and growth, stomach contents, and catchabilities. A few brown trout and cutthroat trout were collected. Information on brown trout is inserted where appropriate. Cutthroat trout have essentially been eliminated by competition with rainbow and brook trout, as well as hydridization with rainbow trout.

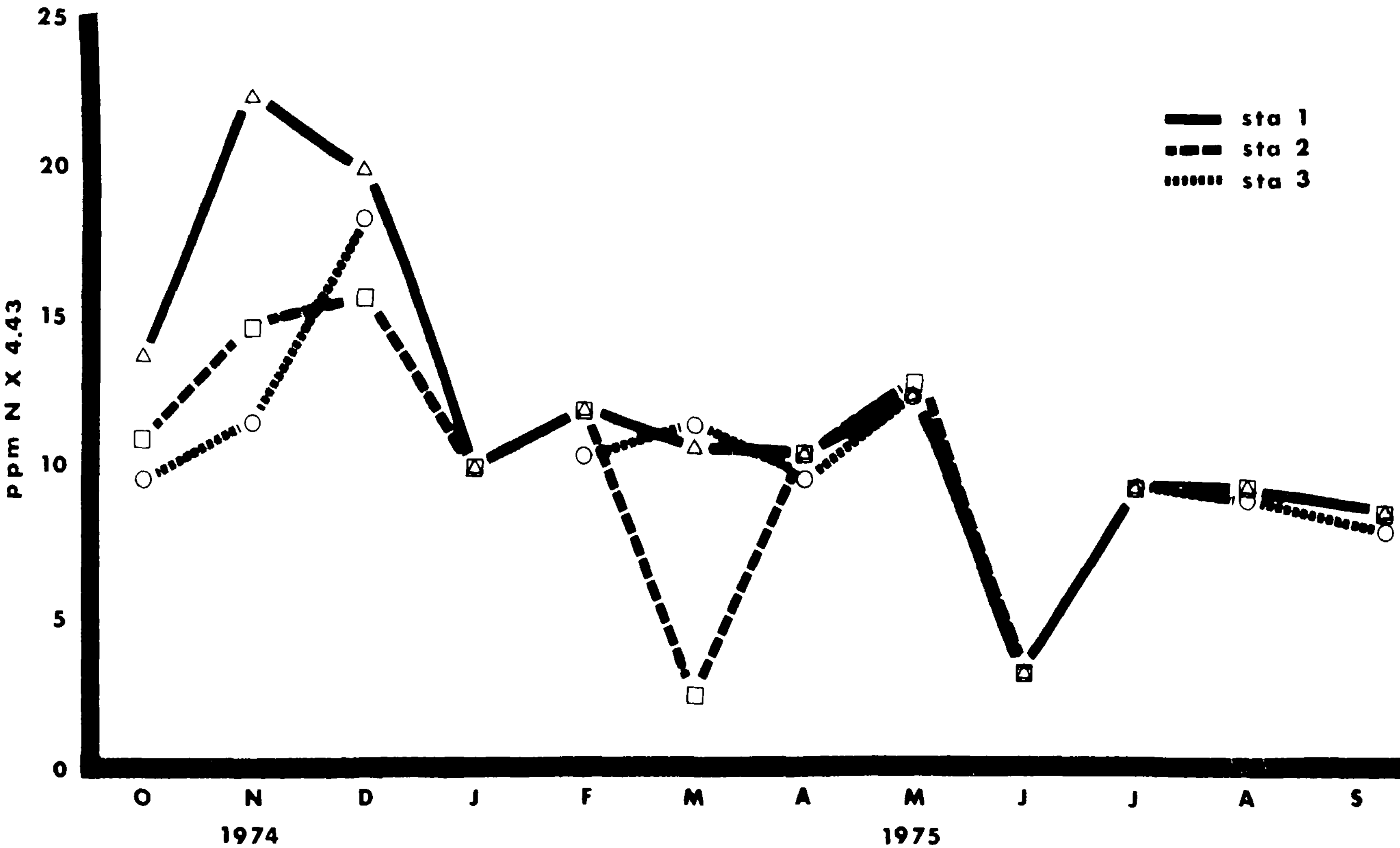
Sexes were combined in age-growth analyses. Simple linear through fourth degree polynomial regressions were fitted to a plot of fork length versus scale radius for both species. Second degree polynomial equations best described this relationship for both rainbow trout and brook trout. The axes were transformed to logarithms to straighten the parabolic curves and thus simplify conversions:

rainbow, $\log l = 0.36677 + 1.72283 \log s - 0.58170(\log s)^2$ $R = 0.9685$;

brook, $\log l = 0.64141 + 2.24815 \log s - 1.46764(\log s)^2$ $R = 0.8818$;

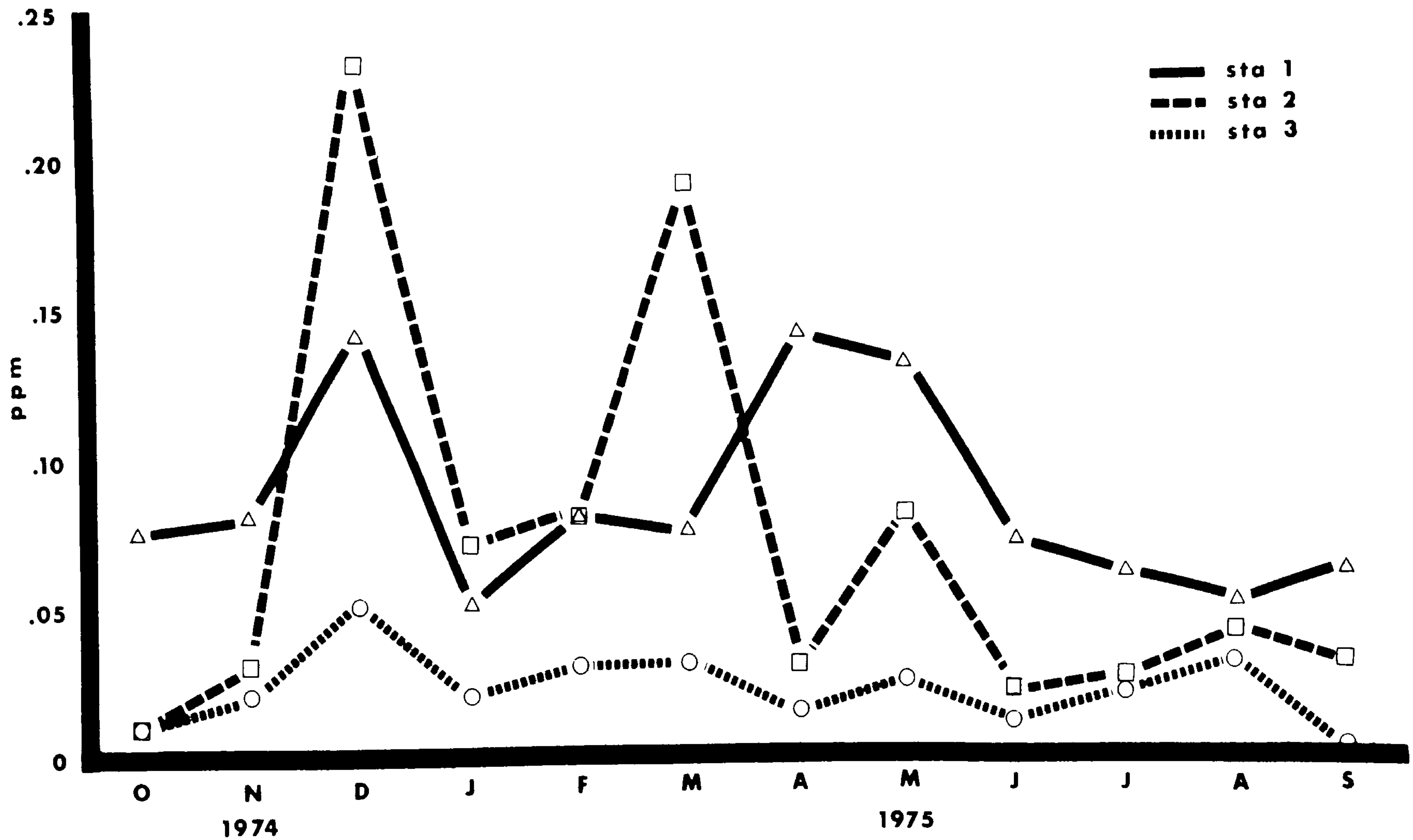
where l is fork length (mm) and s is anterior scale radius magnified 65x (mm). Lengths at ages were back-calculated (Ricker 1971) for scales from 123 rainbow trout (Table 7) and 86 brook trout (Table 8).

Fig. 23. Nitrate concentrations of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.



sta 1
sta 2
sta 3
ppm N X 4.43
25
20
15
10
5
0
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Fig. Fig. 24. Orthophosphate concentrations of surface water at stations 1, 2, and 3 at Big Sky Lake during the 1974-75 sampling period.



.25
.20
.15
.10
.05
0
ppm
sta 1
sta 2
sta 3
O
N
D
J
F
M
A
M
J
J
A
S
1974
1975

Table 5. Total coliform bacteria (organisms/100 ml) at stations 1, 2, and 3 of Big Sky Lake during the 1974-75 sampling period

Date	Sampling Station		
	1	2	3
1974			
20 October	2	1	2
23 November	1	4	7
15 December	5	6	4
1975			
19 January	1	1	0
16 February	1	0	1
23 March	0	0	1
19 April	0	0	0
18 May	1	0	1
18 June	1	0	0
19 July	2	4	0
21 August	3	0	4
20 September	0	1	0

Table 6. Qualitative benthos samples collected from Big Sky Lake on 26 May 1975

ORGANISM	Sample* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ANNELIDS																
Oligochaeta	X					X						X				X
Glossiphoniidae			X	X				X					X	X		
MOLLUSKS																
Helisoma	X															
Physa	X	X						X								
Valvata	X	X		X									X	X		
Gyraulus				X												
Pisidium	X	X	X	X	X			X	X				X	X		X
Sphaerium		X						X					X			
CRUSTACEANS																
Daphnia (ephippia)							X				X	X	X			
Hyalella azteca			X	X				X					X			
INSECTS																
Enallagma		X														
Aeshna		X														
Cordulia	X	X														
Limnephilidae		X									X					
Chironomidae					X			X	X				X	X		X
Chaoborus						X										
SEEDS										X					X	

*See Fig. 3 for location of sample sites.

Relative conditions of the two species were examined by plotting log of weight versus log of fork length for each (Fig. 25). Equations for best-fitting regression lines were as follows:

rainbow, $\log w = 4.67665 + 2.89079 \log l$, ($R = 0.9970$);

brook, $\log w = 5.23986 + 3.12005 \log l$, ($R = 0.9975$);

where w is weight in grams and l is fork length in millimeters.

The condition factors of rainbow and brook trout were computed as follows:

$$K = W \cdot 10^5 \, (L^{-3})$$

where W is weight in grams and L is fork length in millimeters (Carlander 1969).

The mean condition factor computed from data on 77 rainbow trout was 1.16, ranging from 0.67 to 1.57. Brook trout condition ranged from 0.53 to 1.43 with a mean of 1.11 as computed from data on 71 fish.

Results of the stomach analyses of both fish species, collected from 31 August to 16 November 1974, were reported as percentage composition of food as computed by the points method (Fig. 26) and occurrence method (Fig. 27). Further elucidation was effected by dividing each species into three size ranges (Figs. 28-31). These subdivisions are referred to as small, medium, and large. Stomach analyses of 20 rainbow trout collected during 15 February to 18 May 1975 are reported separately (Fig. 32).

Few nematodes were found in either rainbow or brook trout. Whether these were parasites or food items could not be confirmed.

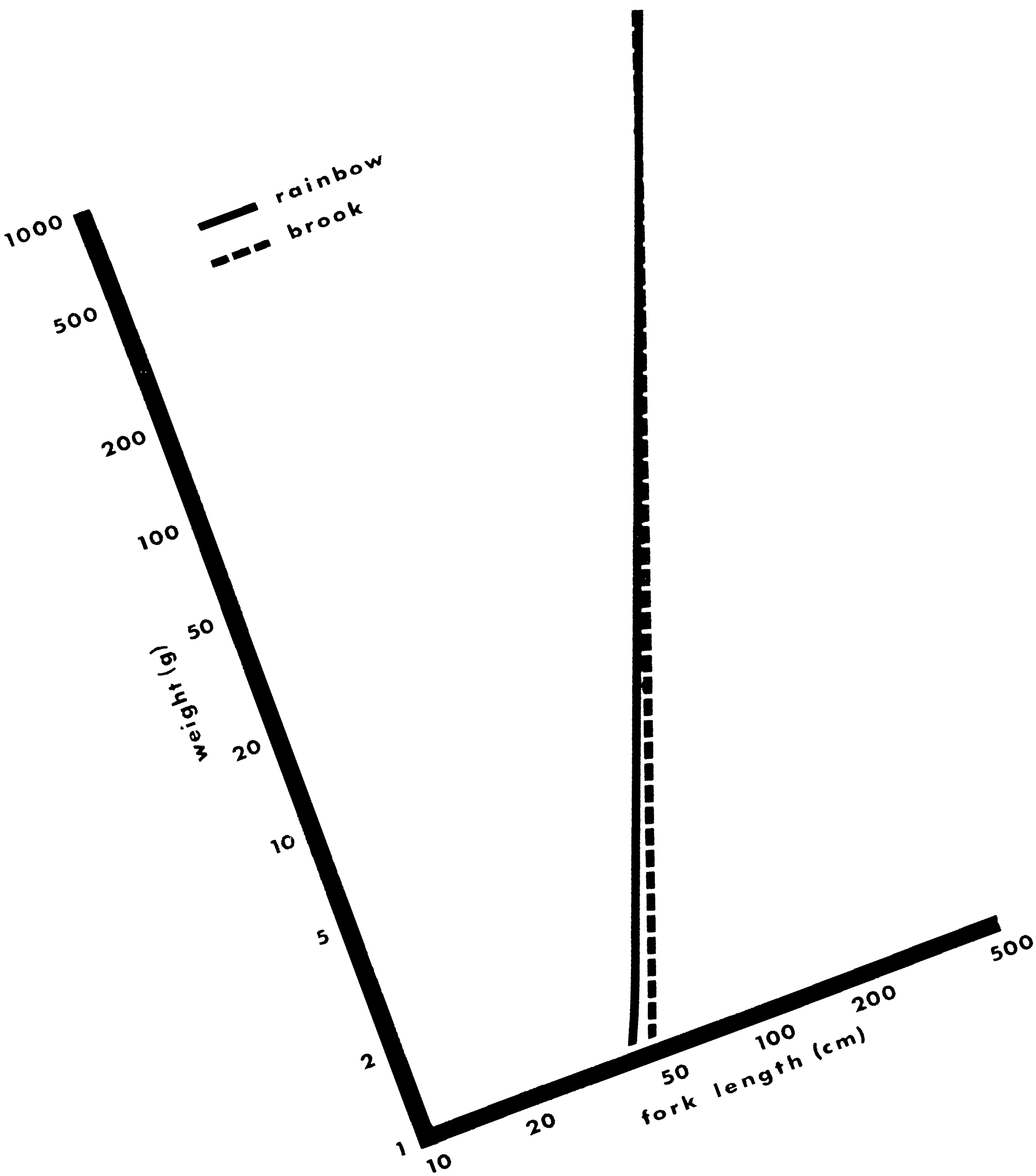
Table 7. Back-calculated fork length of rainbow trout from Big Sky Lake, 1974-75

Age Group	No. of Fish	Calculated fork length in mm & (in.) at each annulus													
		1		2		3		4		5		6		7	
I	15	70	(2.8)												
II	10	83	(3.3)	230	(9.1)										
III	46	79	(3.1)	219	(8.6)	319	(12.6)								
IV	37	72	(2.8)	208	(8.2)	301	(11.9)	350	(13.8)						
V	11	72	(2.8)	179	(7.0)	274	(10.8)	334	(13.1)	361	(14.2)				
VI	3	77	(3.0)	234	(9.2)	325	(12.8)	373	(14.7)	394	(15.5)	406	(16.0)		
VII	1	50	(2.0)	140	(5.5)	223	(8.8)	294	(11.6)	341	(13.4)	364	(14.3)	375	(14.8)
Weighted Mean	123	75	(3.0)	212	(8.3)	306	(12.0)	347	(13.7)	366	(14.4)	396	(15.6)	375	(14.8)

Table 8. Back-calculated fork length of brook trout from Big Sky Lake, 1974-75

Age Group	No. of Fish	Calculated fork length in mm & (in.) at each annulus									
		1		2		3		4		5	
I	2	70	(2.8)								
II	11	88	(3.5)	241	(9.5)						
III	57	79	(3.1)	190	(7.5)	277	(10.9)				
IV	15	92	(3.6)	182	(7.2)	282	(11.1)	306	(12.0)		
V	1	87	(3.4)	173	(6.8)	293	(11.5)	309	(12.2)	317	(12.5)
Weighted Mean	86	82	(3.3)	195	(7.7)	278	(10.9)	306	(12.0)	317	(12.5)

Fig. 25. Length-weight relationships of rainbow trout and brook trout from Big Sky Lake.


rainbow
brook
1000
500
200
100
50
20
10
5
2
1
weight (g)
10
20
50
100
200
500
fork length (cm)

Leeches (Glossiphoniidae) were also seldom found. Medium and large-sized brook trout stomachs contained the most (four).

Mollusks contributed more to the diet of brook trout than rainbow trout. The former preyed most heavily on Pisiduim; and the latter, on Physa.

Daphnia was a very important component of the diets of all size classes of both fish species. Daphnids occurred more frequently than any other food item. While frequency of occurrence was equal, percentage of volume eaten was larger for rainbow trout.

A few copepods were found in the stomach of one small rainbow trout.

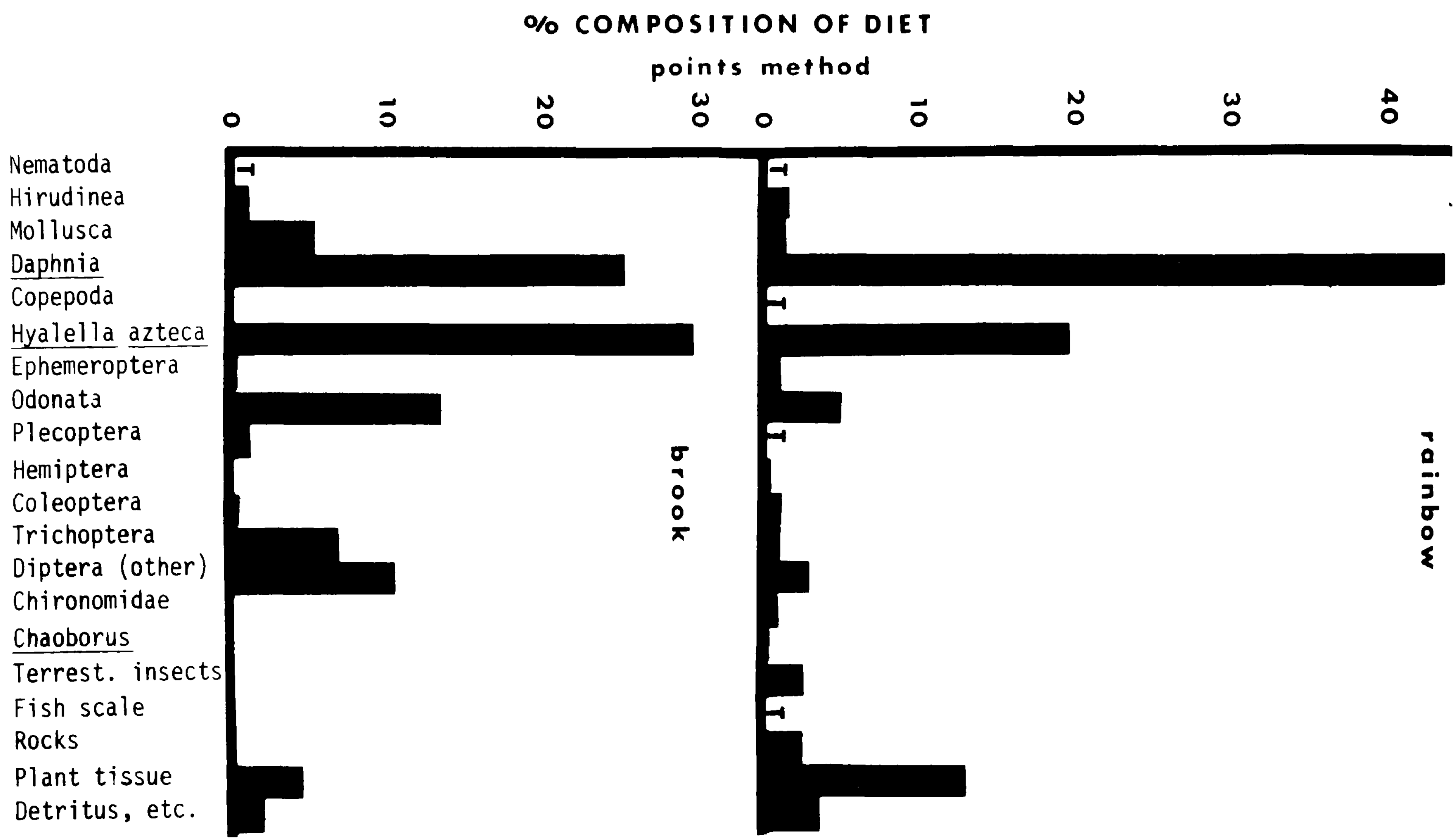
Hyalella azteca occurred more often than any food item except Daphnia. Amphipods accounted for a larger percentage volume of brook trout stomachs than of rainbow trout stomachs. Smaller fish of both species consumed more Hyalella than larger fish.

Mayfly nymphs (Ephemeroptera), although found more frequently in rainbow trout, contributed little to the diet of either species. Most nymphs were members of the family Baetidae.

Although a significant percentage of stomach volume was occupied by dragonfly nymphs (Odonata), a few samples accounted for most of this contribution. Small rainbow trout were principle consumers (especially of Enallagma), as were large brook trout, which selected for Cordulia.

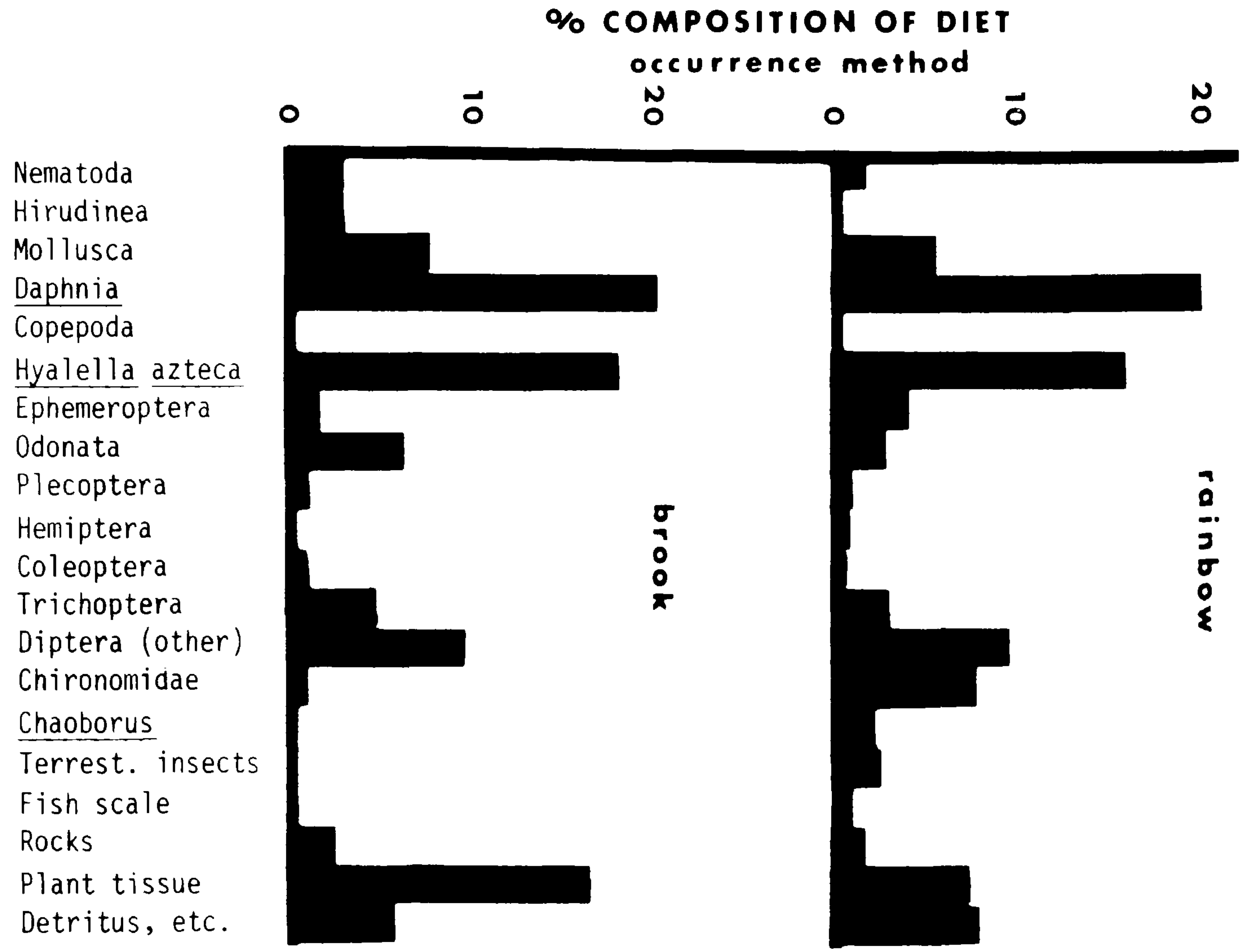
Stonefly nymphs (Plecoptera) were found in a total of three fish. The stomachs of two large rainbow trout contained nymphal parts, and one large brook trout had eaten several nymphs (Arcynopteryx aurea).

Fig. 26. Percentage composition of the diets of rainbow trout and brook trout from Big Sky Lake, calculated using the points method.



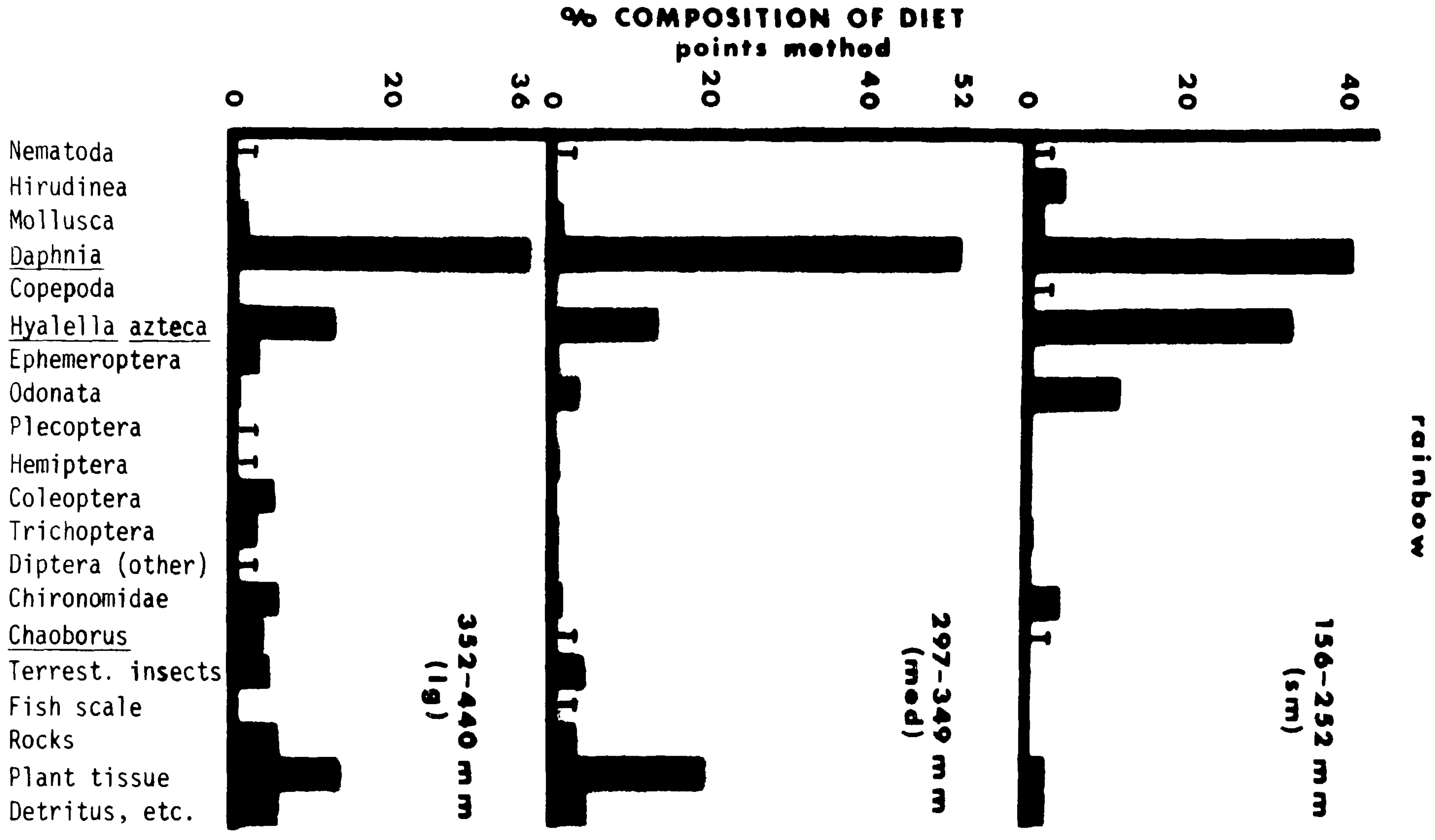
% COMPOSITION OF DIET
points method
0
10
20
30
0
10
20
30
40
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
T
T
T
T
T
brook
rainbow

Fig. 27. Percentage composition of the diets of rainbow trout and brook trout from Big Sky Lake calculated using the occurrence method.



% COMPOSITION OF DIET
occurrence method
0
10
20
0
10
20
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
brook
rainbow

Fig. 28. Changes in percentage composition of food of rainbow trout with increase in size of fish (points method).

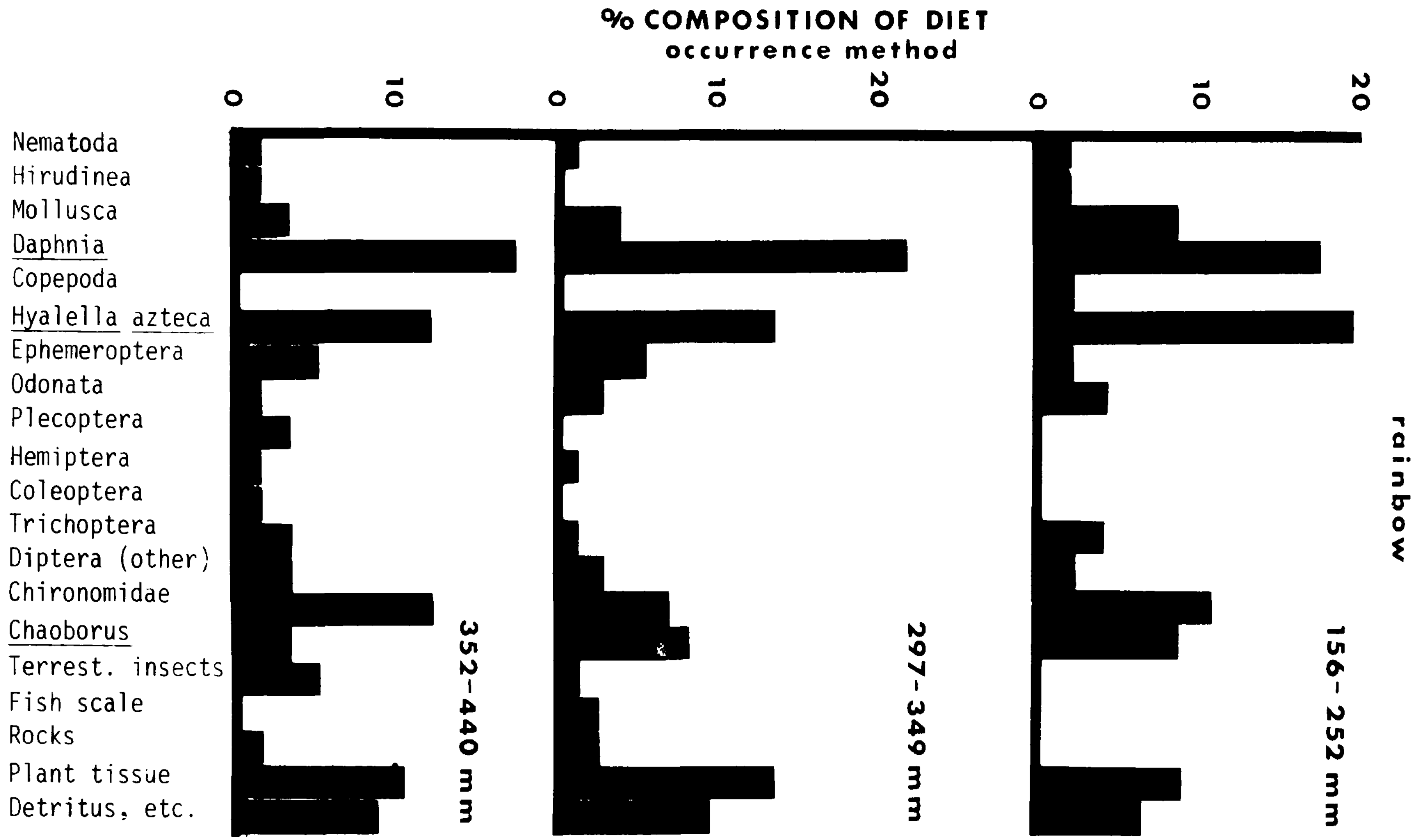


% COMPOSITION OF DIET
points method
0
20
36
0
20
40
52
0
20
40
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
352–440 mm
(lg)
297–349 mm
(med)
156–252 mm
(sm)
rainbow

Fig. 29. Changes in percentage composition of the food of brook trout with increase in size of fish (points method).

% COMPOSITION OF DIET
points method
0
20
40
0
20
0
20
40
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
T
T
T
T
T
302-346 mm
(lg)
261-300 mm
(med)
140-228 mm
(sm)
brook

Fig. 30. Changes in percentage composition of the food of rainbow trout with increase in size of fish (occurrence method).



% COMPOSITION OF DIET
occurrence method
0
10
0
10
20
0
10
20
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
352-440 mm
297-349 mm
156-252 mm
rainbow

Fig. 31. Changes in percentage composition of the food of brook trout with increase in size of the fish (occurrence method).

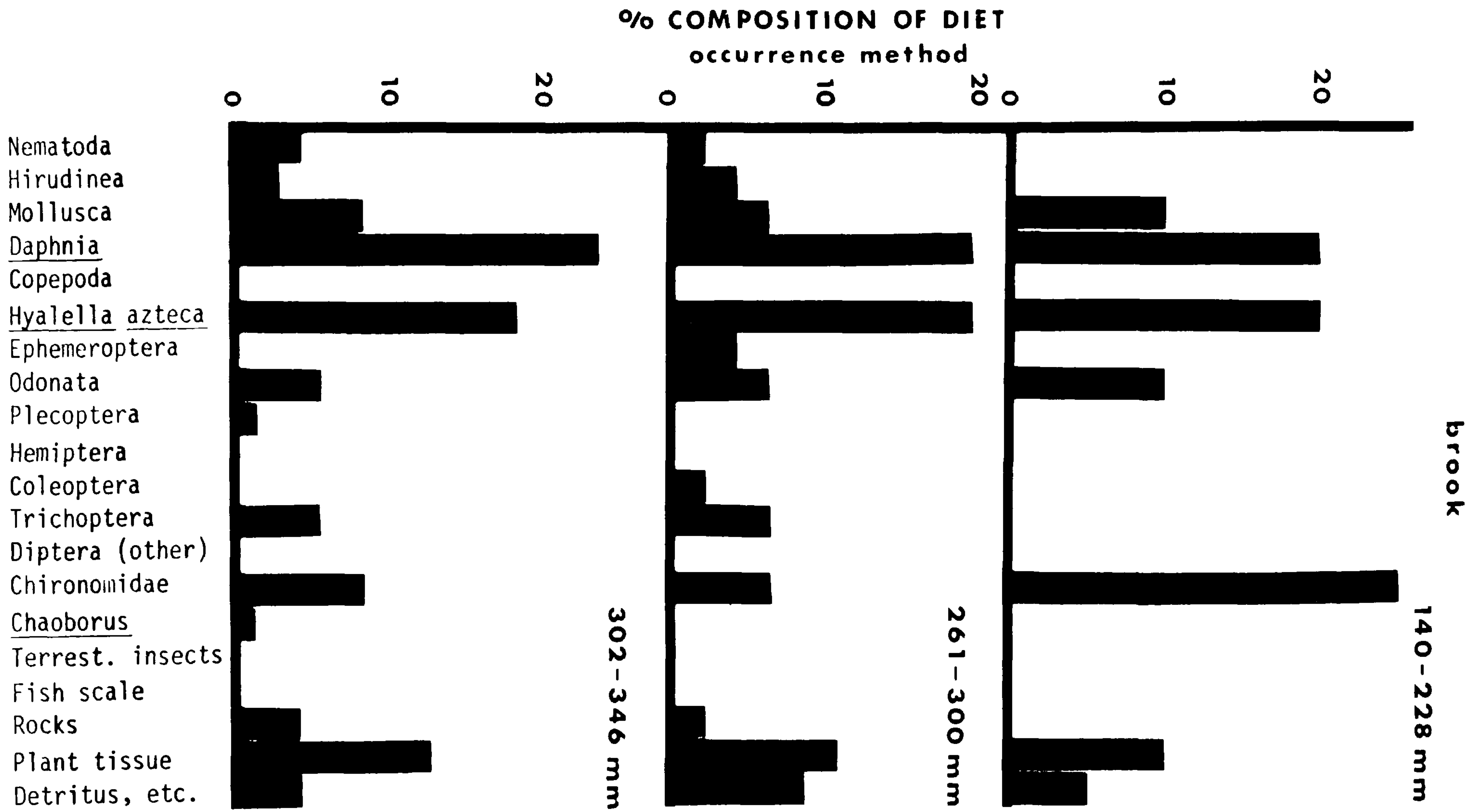
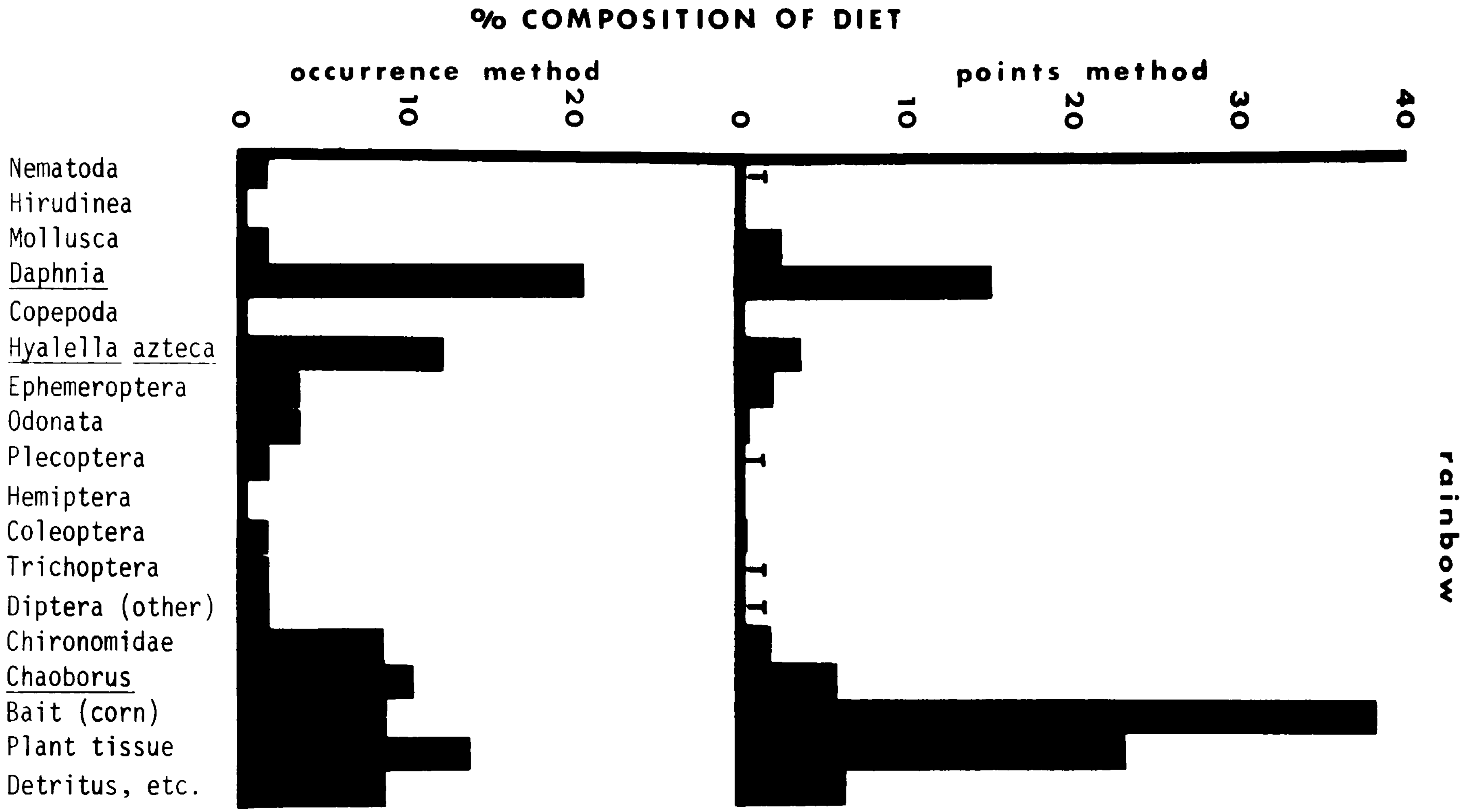

% COMPOSITION OF DIET
occurrence method
0
10
20
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Terrest. insects
Fish scale
Rocks
Plant tissue
Detritus, etc.
302-346 mm
261-300 mm
140-228 mm
brook

Fig. 32. Percentage composition of the food of 20 rainbow trout collected from 15 February to 18 May 1975 (points and occurrence methods).


% COMPOSITION OF DIET
occurrence method
points method
0
10
20
0
10
20
30
40
Nematoda
Hirudinea
Mollusca
Daphnia
Copepoda
Hyalella azteca
Ephemeroptera
Odonata
Plecoptera
Hemiptera
Coleoptera
Trichoptera
Diptera (other)
Chironomidae
Chaoborus
Bait (corn)
Plant tissue
Detritus, etc.
rainbow

No brook trout examined contained true bugs (Hemiptera). Several adults (Macrovelia) were found in one rainbow trout. One adult beetle (Coleoptera) was eaten by a large rainbow trout, and one was eaten by a small brook trout.

Caddis fly (Trichoptera) larvae comprised a larger percentage of brook trout diet than rainbow trout diet. All larvae consumed by the former were members of the family Phryganeidae. The latter contained a wide variety including larvae of Hydropsychidae, Limnephilidae, and Hydroptilidae.

Chironomids occurred with nearly equal frequency in both fish species, but accounted for a larger percentage volume of brook trout diet. Smaller trout were the principal consumers of the midge larvae. Chaoborus larvae were found in more rainbow trout stomachs. The phantom midge was eaten most often by larger fish of both species. Other Diptera contributed little to the fish diets.

Four large rainbow trout were the sole consumers of all terrestrial insects eaten. Insect orders ingested included: Lepidoptera, Hymenoptera, Homoptera, and Diptera. One spider (Arachnida) was also consumed.

A few rainbow trout scales were found in the stomachs of two medium-sized fish of that species.

Of the six fish stomachs containing rocks, four (3 brook trout and 1 rainbow trout) held very small pebbles. However two rainbow trout stomachs were half filled by relatively large rocks.

Plant tissue ingested included algae, moss, *Chara*, and from higher plant forms: sticks, bark, leaves, needles, buds, flowers, fruits, and seeds. Plant tissue represented a greater percentage volume of rainbow than brook trout stomachs.

Digestive processes often rendered a portion of stomach contents unidentifiable. This portion was included as the final category (detritus, etc.).

The diets of 20 rainbow trout collected from 15 February to 18 May 1975 were similar to those analyzed above: *Daphnia* and *Hyalella azteca* occurred frequently in stomachs as before, but represented about one-third of former volumetric percentage. *Chaoborus* larvae occupied nearly the same percentage of stomachs, but represented three times the percentage of volume of earlier samples. Plant tissue was consumed by the trout more frequently and in larger quantity. No terrestrial insects were found in later stomachs examined. Corn kernels, used by fishermen as bait, completely filled the stomachs of five fish.

Examination of the entrails removed from fish of both species collected during 18 November 1974 revealed two species of parasitic nematodes. *Cucullanus scotti* was associated with small intestines and *Cystidicola stigmatura* with swim bladders. Because all entrails were mixed, parasites could not be linked with a particular species of fish.

Fishing effort and angler success were computed (Table 9) from data provided on 71 creel-census forms returned by anglers. Variances of means were calculated using a formula proposed by Cochran (1953):

$$V(F) = (n(n-1)\ \bar{x}^2)^{-1}\ (\ y^2_i + R^2\ x^2_i - 2R\ y_i x_i)$$

where R is the ratio of fish caught to hours fished; n is the number of samples (census returns); $\bar{x}$ is the mean hours for the sample; y_i is the catch recorded on each return; and x_i is the hours per return. Standard errors, square roots of the variances, were reported with the fishing efforts calculated.

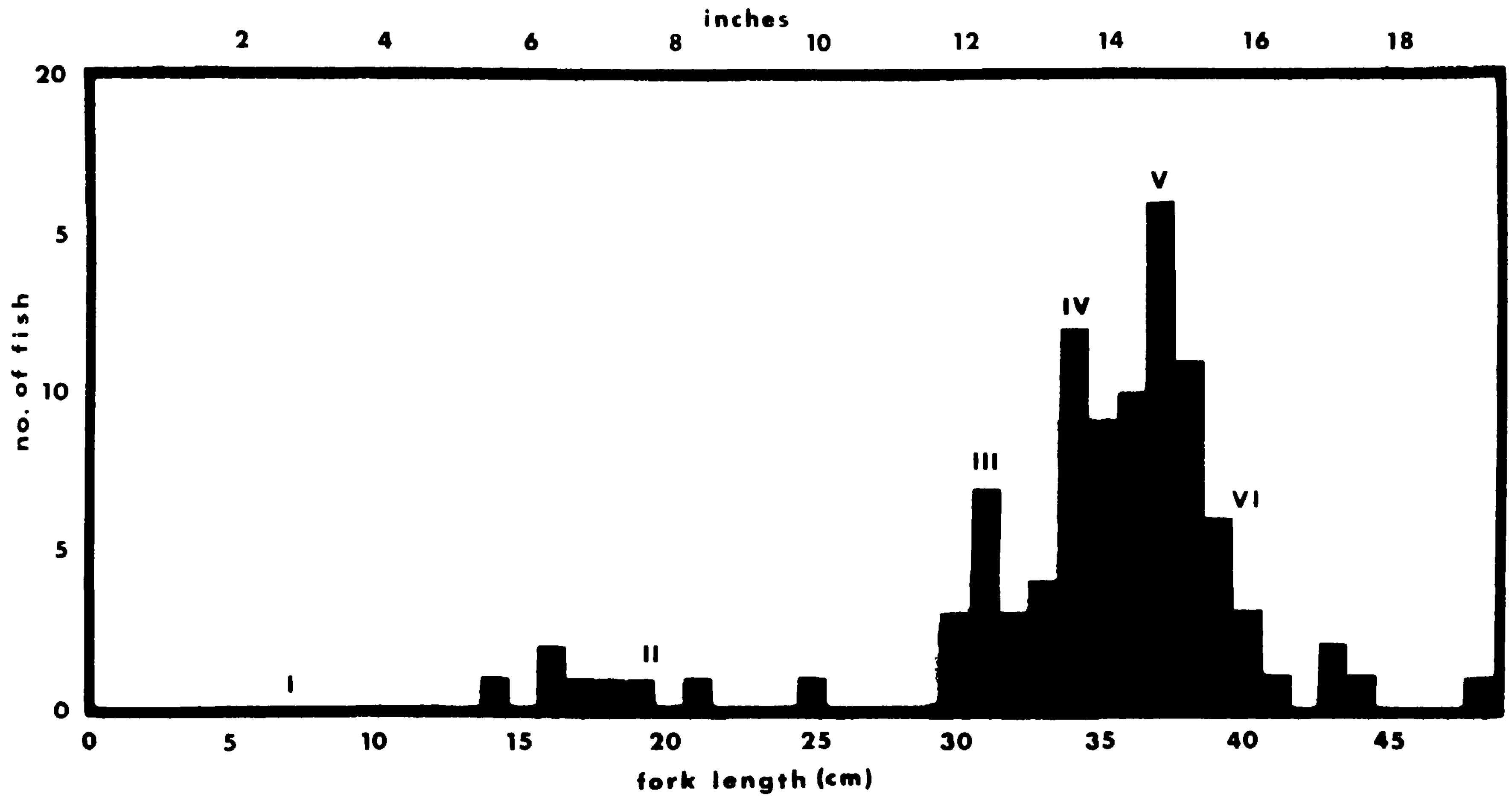
Anglers at Big Sky Lake were most successful when fishing through ice (Table E). During the ice-free season, fishing from shore was more profitable than from boats. Brook trout were caught more often than rainbow trout through the ice. However, more of the latter species were caught per hour both from shore and boats during the ice-free season. Brook trout were taken more often from shore than from boats.

Analysis of fish scales taken from anglers catches during 29 August 1974 to 13 April 1975 showed that fishing pressure was concentrated on specific age groups. Four- and five-year-old rainbow trout were kept more often by anglers than other age groups (Fig. 33). Brook trout with four years' growth contributed most to the catch (Fig. 34).

Table 9. Fishing effort and success of anglers at Big Sky Lake from 31 August 1974 to 31 October 1975

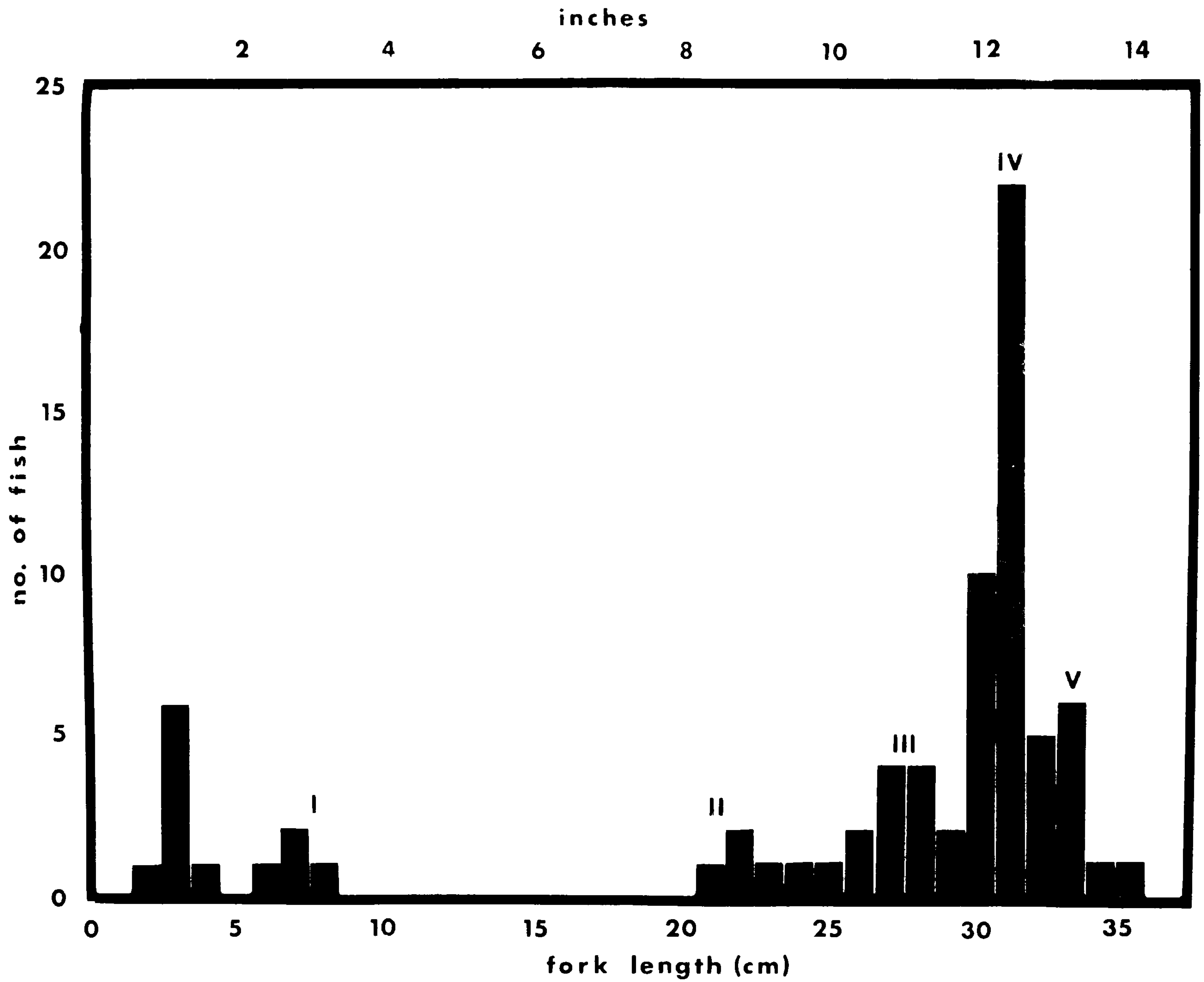
Method	Hours Fished	Rainbow Trout	Brook Trout	Total
Ice-free fishing from shore	93.17	0.6 ± 0.122	0.44 ± 0.105	1.04 ± 0.148
from boat	80.08	0.59 ± 0.134	0.29 ± 0.084	0.88 ± 0.179
Total	173.25	0.54 ± 0.089	0.37 ± 0.071	0.96 ± 0.114
Ice fishing	93.75	0.50 ± 0.164	0.68 ± 0.228	1.18 ± 0.318
Entire 14 months	267	0.56 ± 0.084	0.48 ± 0.084	1.04 ± 0.126

Fig. 33. Length-frequency distribution (Peterson method) of rainbow trout caught by anglers from 10 August 1974 to 2 August 1975.



inches
2
4
6
8
10
12
14
16
18
20
5
10
5
0
no. of fish
I
II
III
IV
V
VI
0
5
10
15
20
25
30
35
40
45
fork length (cm)

Fig. 34. Length-frequency distribution (Peterson method) of brook trout caught by anglers from 29 August 1974 to 13 April 1975.



inches
2
4
6
8
10
12
14
25
20
15
10
5
0
no. of fish
I
II
III
IV
V
0
5
10
15
20
25
30
35
fork length (cm)

CHAPTER IV

DISCUSSION

Big Sky Lake, like all lakes, is an ecosystem in which the physical, chemical, and biological characteristics are integrated. Tracing the contributions of those characteristics measured during October 1974 through September 1975 should show how they contribute to this aquatic system. Limitations in the accuracy of available equipment make absolute measurements questionable. However, seasonal trends established are probably real.

Physical and Chemical Characteristics

Fall 1974. By mid-September, when the limnological investigation began, summer stratification was well established in Big Sky Lake. The warmer upper water (epilimnion) of this relatively small (area = 37.7 ha), shallow (mean depth = 8.7 m) lake was separated from the colder, denser, water (hypolimnion) by a steep thermocline. This intermediate region, where water temperature dropped sharply, persisted between 8 m and 9 m below the surface until late October. Oxygen supplies were depleted in the hypolimnion by the oxygen demand of decaying organic material raining down from the upper waters, and the lack of mixing with oxygeneated surface waters.

During late October, cool autumn air caused a drop in epilimnetic temperature until it equaled that of the hypolimnion. The water column was therefore uniformly dense and subject to mixing by prevalent winds. The lake thus "turned over", resulting in higher oxygen concentrations throughout. Circulation also resuspended sediments of the lake basin causing an increase in color and turbidity of water and a decrease in Secchi-disk transparency.

Inlet flow increased with fall rain-showers. Leaves and other organic materials fell or were transported into the inlet creek causing an increase in color and turbidity.

Winter 1974-75. By late November, surface water of Big Sky Lake was near $0^{o}C$ ($32^{o}F$). Ice formed on the lake after only a few cold, still nights. Inverse stratification occurred during the 5 months of ice cover. Water near $0^{o}C$ overlaid warmer yet denser water (water is most dense near $4^{o}C$ ($39^{o}F$)). A very thin epilimnetic layer was separated from the hypolimnion by a thermocline established between 1 and 4 meters. Oxygen meter readings showed a definite decrease in hypolimnetic oxygen concentrations, although probe malfunction precluded accurate measurement. Color and turbidity of both lake and inlet water decreased from fall levels. Ice cover probably accounted for low lake turbidity by decreasing light (and thus the number of phytoplankton) and turbulence. As water velocity of the inlet creek decreased, turbidity also decreased.

Spring 1975. Warmer weather of late April and early May slowly eroded the ice and snow cover. Warmer nights and windy days then rapidly re-exposed the open water. Upper waters were quickly warmed, densities of the epilimnion and hypolimnion were equalized, and turnover resulted. Color and turbidity again increased, and transparency decreased, as basin sediments were resuspended. Bottom samples taken on 26 May still demonstrated the effects of winter oxygen depletion on the character of sediments and distribution of fauna. Sediments from 7.6 m (25 ft.) or deeper were dark clays containing primarily oligochaete worms and Daphnia ephippia. Shallower samples contained lighter sediments, vegetation, and a diverse fauna (Table 6).

Melting snow and spring rains contributed to the marked increase in inlet flows. Creek water became more turbid as runoff increased.

Summer 1975. Measurements recorded in mid-June revealed that the lake had restratified. Color and turbidity decreased from the spring maximum and remained at this lower level throughout the summer. This evidence refuted the supposition that boating stirred lake water and disturbed the sediments. Turbidity measured at the shallow outlet station (3) decreased during July, while boating activity was high.

A consistent bulge in the oxygen profile appeared at 11 m during August and September (Figs. 18 & 19). This phenomenon also occurs in Placid Lake (Juday and Keller 1975). Eberly (1964) compiled a list of 54 lakes in which metalimnetic oxygen maxima greater than 12.7 mg/l have been observed. In many of these lakes, the oxygen maxima are caused by a concentrated band of Oscillatoria, a blue-green algae. This concentration at a specific depth may be due to the presence of optimal (or tolerable and lacking competitors for nutrients) conditions of light and temperature in a plane of minimum turbulence. Metalimnetic stability would also minimize diffusion of oxygen produced by the algal blooms.

For lakes within the United States, oxygen maxima are most likely to be found in lakes under 30 ha and with relative depths of about 4% (Eberly 1964). Big Sky Lake has an area of 37.7 ha and relative depth of 2.42%, calculated according to Hutchinson (1957). Metalimnetic oxygen increases recorded during August and September of 1975 were, therefore, probably real. Whether Oscillatoria blooms cause these phenomena should be investigated. Presence of the blue-green algae would indicate stable and prolonged stratification in the lake and nutrient loading, suggesting a progression toward eutrophy.

Seasonal trends described for Big Sky Lake are typical of a moderately productive, dimictic lake in the temperature zone (Wetzel 1975). Placid Lake, nearby in the Clearwater River system, exhibited similar patterns. Dissolved oxygen levels were monitored at Placid Lake from October 1974 through September 1975 (Juday, personal communication, 1976). This lake is deeper (d_{max} = 27.1m) than Big Sky Lake (d_{max} = 16.8m); therefore it turned over approximately 3 weeks later during fall and retained an ice cover longer during spring. Winter and summer stratification in highly productive Placid Lake resulted in oxygen profiles similar to those in Big Sky Lake. Secchi-disk transparencies were comparable, averaging around 4 m. Placid Lake was more colored than Big Sky. The low transparency of the latter was probably due to suspended particulate matter, such as algae.

Other parameters monitored at Big Sky Lake were within expected ranges and comparable to neighboring lakes. A brief summary follows.

pH. pH values for Big Sky Lake fluctuated slightly around a mean of approximately 8. Results were consistent with those expected for calcareous hardwater lakes regulated by a CO_2^- - HCO_3^- - $CO_3^=$ buffering system (Wetzel 1975). Cladouhous (1971) obtained similar pH values at Seeley Lake during his 1970-71 sampling season. Increases in pH in the lake, which began during April and continued through August 1975, may have resulted from increases in abundance of phytoplankton (Wetzel 1975).

Alkalinity. Levels of bicarbonate alkalinity were higher at Big Sky Lake (mean values: 83, 107, 125) than Seeley Lake at comparable stations (mean values: 60, 50, 51). Streebin, et. al. (1973) found that alkalinity was highest at Rainy Lake, at the top of the Clearwater basin (100 mg/l) dropping gradually in concentration down the Clearwater drainage. Big Sky Lake is a puzzling exception to this trend. Edaphic sources cannot account for the phenomenon because bicarbonate alkalinity in the inlet creek was consistently lower than at lacustrine stations.

Hardness. Total hardness measured at Stations 1, 2, and 3 was two to three times higher than values recorded at similar stations on Seeley Lake during 1970-71 (Cladouhos 1971). Total and calcium hardness values were higher at the inlet to Seeley Lake than at lake or outlet stations. This pattern opposes that found for Big Sky Lake. Calcium influx from allochthonous limestone sources cannot explain the observed differences. In fact, hardness levels decreased most at stations 1 and 2 when inlet flow was highest and caused increased dilution of lake water.

Nitrate and Orthophosphate. Nitrogen and phosphorus are very important compounds in aquatic ecosystems. The former is vital for synthesis and maintenance of protein, and the latter in operation of energy transfer systems of cells. Both compounds occur in small concentrations in unpolluted fresh waters; the world average for nitrate nitrogen being 0.30 ppm, while total phosphorus ranges from about 0.01 to 0.03 ppm (Reid 1961). Unfortunately these low concentrations strain the lower limits of detectability of all but the most refined instruments. Caution must be used not only in overemphasizing absolute results, but also in considering only nitrate and orthosphosphate forms of these compounds. Wetzel (1975:196) warns, "Mean chemical mass,..., must be used with extreme caution when little consideration is given to the rates of mineralization, microbial transformation, and recycling".

Nitrate concentrations obtained by my analyses were two orders of magnitude larger than levels reported by the Water Quality Bureau of the Montana State Health Department for simultaneously collected samples. Interpretation of trends alone was therefore appropriate. High nitrate levels in the inlet creek during November may have been caused by leachate from direct leaf-fall or release during decomposition of foliage of mountain alder. Alder trees, which fix atmospheric nitrogen, can contribute significantly to the nitrogen levels of lakes (Goldman 1961). The decrease in nitrate at all three stations during June probably resulted from dilution during runoff (station 1) and increased assimilation by phytoplankton (stations 2 and 3). Low levels at station 2 during March had no obvious origin.

Orthophosphate concentrations were within expected ranges, being comparable to values reported for Seeley Lake (Cladouhos 1971). More pronounced increases in soluble inorganic phosphorus near the inlet during December 1974 and May 1975 suggest that primary sources were allochthonous. Circulation of basin sediments and deep water may also have contributed to higher levels in the lake during May. Throughout the sampling period, orthophosphate values were lowest near the outlet. Uptake by phytoplankton, followed by their sedimenting to the bottom, made the lake an effective phosphorus sink.

Biological Characteristics

Big Sky Lake, as shown by physical and chemical analyses, is a suitable habitat for resident fish populations. Lake temperatures were well within tolerance ranges of the rainbow trout (0 to 26.7$^{o}C^{+}$) and brook trout (0 to 20^{o}C) (McAfee 1966a & b). Oxygen concentrations in the Lake's upper layers were consistently higher than those required for trout survival (Doudoroff and Shumway 1967). Both trout species are capable of existing in waters with pH values lower and higher than those observed in Big Sky. Low coliform bacterial counts suggested no immediate pollution problem with respect to enteric pathogenic bacteria and enteric viruses. Further, a cursory examination of plankton samples revealed sufficient numbers of *Daphnia* larger than 1.34 mm to indicate, perhaps, high trout survival and good quality fishing (Galbraith 1975).

Food. Large *Daphnia* were important items in the diets of both species of fish, as were amphipods (*Hyalella azteca*). However, consideration of classes of food (Table 10) suggested segregation occurred between food habits of trout and char, as observed by Nilsson (1963) in Scandinavia. Rainbow trout ate more surface and planktonic foods

Table 10. Percentage composition of food classes of rainbow trout and brook trout from Big Sky Lake

	Classes of Food			
	Surface	Bottom	Plankton	Plants
Occurrence				
rainbow	4.3	47.8	29.5	7.4
brook	0.7	53.8	21.4	16.4
Points (Vol.)				
rainbow	3.9	33.0	44.2	13.0
brook	0.3	68.1	25.2	4.5

than brook trout, which preferred benthic organisms. Rainbows also ate a larger volume of plant material. Wales and German (1956) also observed this phenomenon in Castle Lake. Whether trout were actively consuming algae and aquatic plants, or ingesting them while pursuing food items they harbor, was not clear.

Interesting examples of dietary differences were observed in selection of mollusks and caddis flies. The preference of brook trout for Pisidium (a clam), and rainbow for Physa (a snail) was also noted by Gard (1961). Caddis fly larvae (Phryganeidae) eaten by brook trout were those common to lake bottoms. Rainbow trout stomachs contained larvae of three families (Hydropsychidae, Limnephilidae, and Hydroptilidae) often found in streams. At least one of the rainbows was gill-netted near the inlet creek, a logical source for these stream forms.

I suspect that the dietary separation exhibited in Big Sky Lake resulted from characteristic differences in the fish species rather than interactive segregation (Nilsson 1967). Rainbow trout are generally limnetic and have a greater tolerance for higher water temperatures than brook trout (McAfee 1966 a & b). The latter species prefers the cooler waters of the lower strata and often dwells near the bottom in shallower areas. Swift (1970) noted that during the summer in Castle Lake, California, rainbow trout adults were located in the epilimnion, while adult brook trout were found near the bottom of the lake beyond the littoral zone. He proposed that due to this spatial isolation, their diets differed considerably. Adult brook trout ate 20% terrestrial, 31% limnetic, and 49% benthic food (by volume). Adult rainbow trout ate 49% terrestrial, 33% limnetic, and 18% benthic food. In contrast, underyearling trout and char both inhabited the littoral zones of Castle Lake (Wurtsbaugh et. al. 1975). Brook trout underyearlings ate 13% terrestrial, 11% limnetic, and 76% benthic food. Rainbow trout underyearlings similarly consumed 15% terrestrial, 15% limnetic, and 70% benthic food.

Thus distributional preferences of species could account for differences in diets rather than direct competition. In fact, frequencies of occurrence of food classes differ little (Table 10) for fishes in Big Sky Lake. An abundance of food would explain this overlap in diets and diminish the likelihood that interspecific competition occurred (Hynes 1970).

Growth. Most rainbow and brook trout become sexually mature after three years. With more energy being used in reproduction, less is available for growth. In large California reservoires and lakes, trout usually grow rapidly up to 305 to 356 mm (12 to 14 in) and relatively slowly thereafter, with few exceeding 432 mm (17 in). The primary trout food in these lakes is zooplankton and/or immature midges (McAfee 1966a). In the absence of large forage items, maximum size of fishes depends on their growth rate before maturity, as well as the quality and quantity of available food. Growth of rainbow and brook trout in Big Sky Lake was therefore predictably good during their first three years of life. In fact, young fishes in the lake grew more rapidly during these years than in most other Montana lakes (Table 11). Large daphnids, amphipods, and immature aquatic insects were an excellent source of food for smaller fishes.

Condition. Judgements about the relative conditions of fish populations should not be based strictly on comparisons of means. Ranges of values can be significant, and values vary seasonally. Cooper and Benson (1951), during a study of fishes in the Pigeon River, Michigan, found that for both brook and brown trout the condition factor was low

Table 11. Comparison of calculated fork lengths in mm and (in) for rainbow trout and brook trout

	1	2	3	4	5	6	7
Rainbow trout							
Montana lakes (Peters 1964)[1]	83 (3.3)	192 (7.6)	302 (11.9)	379 (14.9)	434 (17.1)	462 (18.2)	486 (19.1)
Blackfoot River Drainage (Peters 1964)							
Browns Lake-1961	97 (3.8)	171 (6.7)	259 (10.2)				
Lake Alva-1948	76 (3.0)	176 (6.9)	268 (10.6)	387 (15.2)			
Meadow Creek Lake-1961	57 (2.2)	126 (5.0)	197 (7.8)	245 (9.6)	297 (11.7)		
Salmon Lake-1948	76 (3.0)	180 (7.1)	237 (9.3)				
Clark Fork-Columbia River Drainage							
Georgetown Lake-1960	74 (2.9)	162 (6.4)	223 (8.8)	360 (14.2)	539 (21.2)		
Big Sky Lake-1974-75	75 (3.0)	212 (8.3)	306 (12.0)	347 (13.7)	366 (14.4)	396 (15.6)	
Brook trout							
Montana lakes (Peters 1964)[2]	81 (3.2)	152 (6.0)	204 (8.0)	251 (9.9)	369 (14.5)	372 (14.6)	428 (16.9)
Placid Lake (Domrose 1963) 1959	69 (2.7)	123 (4.8)	171 (6.7)	209 (8.2)	242 (9.5)		
Georgetown Lake (Peters 1964) 1960	76 (3.0)	171 (6.7)	265 (10.4)	359 (14.1)			
Big Sky Lake 1974-1974	82 (3.2)	195 (7.7)	278 (10.9)	306 (12.0)	317 (12.5)		

[1]Within the Beaverhead, Big Hole, Gallatin, Madison, and Missouri drainages.

[2]Within the Beaverhead, Big Hole, and Gallatin drainages.

during winter and early spring. It rose rapidly to a peak in June, and subsequently declined to a winter low. Both species exhibited a drop in condition in late fall which was probably coincident with spawning. In contrast, an earlier study on streams of New York (Hazzard 1932), fish were heaviest during spawning season, losing weight thereafter and not recovering condition until after several weeks of feeding in spring. In addition, Sigler (1953) noted that condition of rainbow trout from Fish Lake, Utah, varied from 1.46 to 2.44, increasing irregularly as the length and age increased. Despite limitations of the measurement, comparison of conditions factors above does indicate that rainbow and brook trout in Big Sky Lake are as healthy as those in neighboring lakes.

The condition of fishes in Big Sky Lake also compared favorably with those recorded for several Montana waters. Mean condition factors, computed using fork lengths of rainbow trout, were reported by Carlander (1969):

Cliff Lake (MT)	1.05
Meadow Lake (MT)	0.93
Castle Lake (MT)	1.07
Hatchery trout (MT) (at stocking)	1.09

The mean condition factor of Big Sky rainbows was 1.16. Condition of brook trout was recalculated using total lengths to allow comparison with recorded values. Seven lakes in the Beartooth Mountains contained brook trout with an average condition of 0.98. In Wyoming, three char populations showed excellent development with condition factors of 1.09, 1.11, and 1.11 (Carlander 1969). Big Sky Lake also produced healthy brook trout (K = 1.04).

The condition of fishes containing parasitic nematodes was not noticeably deteriorated. *Cucullanus scotti* and *Cystidicola stigmatura* are both commonly found in the genera *Salmo* and *Salvelinus* and other fishes (Hoffman 1967). No reference to major infestations could be found.

Fishing Success. Anglers at Big Sky Lake are primarily concerned with the probability of catching these healthy fish during an outing. Observations of catch per angler hour are reasonable estimates of this probability. Fishing success at the lake was better from boats and shore than at Georgetown Lake (Spence 1970) (Table 12). The

Table 12. Comparison of catch per hour for summer seasons for Georgetown Lake during 1961, 1962, and 1970 with Big Sky Lake during 1974 and 1975

Georgetown Lake			Big Sky Lake		
Year		Catch/hr	Year		Catch/hr
1961	Boat	.51	1974-75	Boat	1.04
	Shore	.29		Shore	0.88
	Total	.38		Total	0.96
1962	Boat	.65			
	Shore	.30			
	Total	.48			
1970	Boat	.95			
	Shore	.75			
	Total	.83			

latter lake supports cutthroat trout, kokanee salmon, and arctic grayling along with rainbow and brook trout. Although ice fishing at Big Sky Lake was good (1.18 fish per hour) more fish were caught per hour spent at Georgetown Lake. From 1963 through 1974, catch per hour ranged from 0.55 to 2.18, averaging approximately 1.4 for this large lake (Miller and Marcoux 1974).

However, fishermen are less successful on Montana's blue-ribbon trout stream, Rock Creek, than at Big Sky Lake. Combined catch-per-hour values for that stream during 1958-60, 1961-64, and 1965-67 were 0.90, 0.64 and 0.67 respectively (Spence 1971). These estimates applied to rainbow trout, cutthroat trout, brook trout, brown trout, Dolly Varden, and whitefish.

A creel census study on Hebgen Reservoir during recent years showed that catch rates for trout species varied from 0.31 trout per hour in 1972 to 0.42 in 1967 and 1971 (Vincent 1975).

Mail surveys conducted by the Montana Department of Fish and Game from 1 July 1970 to 30 June 1971 provided a statewide estimate of fishing success (Holton 1971). Average catch per hour during winter was 1.2 game and sport fish; the average summer catch was 1.5. These estimates may have been positively biased. Better fishermen are more likely to keep accurate logs and respond to the surveys. Data from Big Sky Lake may have been negatively biased. Some property owners known to have fished heavily during the 1974-75 season returned no creel census forms.

The creels of fishermen at Big Sky Lake consistently contained rainbow trout approximately 356 mm (14 in) long and brook trout 305 mm (12 in) long. Very few larger or smaller fish were seen. Results reported in figures 33 and 34 support these observations. This selective fishing pressure, combined with observations of food availability, explain why anglers caught fewer large fish during 1974-75. In Big Sky Lake, most rainbow trout and brook trout probably mature at age 3. By that age they have grown to about 356 mm and 305 mm respectively. Growth, as explained earlier, proceeds slowly thereafter, especially in the absence of large forage items. When anglers first began exploiting the lake fishery, they probably caught fish with many years of growth. With increased fishing pressure, older, larger fish were removed from the population and not replaced. Younger fish were not represented in the creel, perhaps because of behavioral and/or distributional divergence from predominant fishing techniques. Anglers are now exploiting the largest size readily replaced by rapid growth of immature fishes.

Management Recommendations

Big Sky Lake is very similar to Castle Lake, located in northern California. Both lie at approximately the same elevation and are fed primarily by snowmelt in the spring and underwater springs throughout the year. Castle Lake is smaller yet deeper, with an area of 20.1 ha (49.6 acres) and maximum depth of 37 m (122 ft.). Ice covers both lakes from about December to May. Strong thermal stratification, with a lower thermocline developing in the more transparent (Secchi disk visibility 12 to 17 m) California lake.

The similarity between these lakes is most fortunate because the Castle Lake fishery has been studied since 1938 by the California Department of Fish and Game. Valuable insights into the fish dynamics of Big Sky Lake can be derived from a scrutiny of investigations conducted in California.

The Castle Lake investigation was executed in three phases. Phase 1 began in 1938 when rainbow, brown, eastern brook, and lake (*Salvelinus namaycush*) trout were present. The lake also contained small populations of golden shiner (*Notemigonus crysoleucas*) and speckled dace (*Rhinichthys osculus*). The results of the initial phase (Wales, 1946) showed that survival of stocked brook, brown, and rainbow fingerlings was very low, primarily as a result of predation by brown and lake trout. Brown trout fingerlings were the most wary and survived best. Planted rainbow trout, selected for fast growth, escaped some predation by rapidly developing out of the most vulnerable size range. Small, unwary brook trout fingerlings were preyed upon most often.

Phase 2 began in 1947 with the stocking of brook trout following the application of rotenone to eliminate all species previously inhabiting the lake. Wales and German (1956) noted that removal of the highly predatory brown and lake trout remarkably increased survival of brook trout fingerlings. The brook trout, which were able to spawn successfully in the numerous springs near the east shore of Castle Lake, established a self-sustaining population.

Phase 3 of the investigation began in 1952 with the reintroduction of rainbow trout, which continued through 1958. Two species were expected to better exploit the lake resources and therefore provide a greater yield. More fish weight was harvested by anglers, but at the expense of the brook trout (Wales and Borgeson 1961). The rainbow trout catch fluctuated considerably during this period. The proportion of brook trout in the Castle Lake catch dropped from 84% in 1954 to 27% in 1959. Poor survival of subsequent plants of fingerling rainbow and of newly-emerged brook trout was attributed to competition for food and to predation by large rainbows. Reduction in the size of the annual plant of rainbow fingerlings was recommended in hopes of minimizing competition and predation, thereby benefiting the brook trout.

Relative contributions of fish species in Big Sky Lake can be deduced from a comparison with Castle Lake. Some limitations must be imposed upon the analogy. Brown trout are not as numerous in Big Sky Lake as they were in Castle Lake before 1946; the inlet to the former does support some spawning rainbow trout; and Big Sky is more productive than Castle Lake. Even with these limitations, valuable lessons can be learned from the study in California. The following management recommendations were formulated in light of this and other relevant investigations:

1. Larger rainbow trout fingerlings should be planted. Higher costs of planting should be offset by better survival. No fish were found in the stomachs of larger trout during this study. However,

insufficient sampling rather than absence of piscivorous fishes probably explains this. If these larger fingerlings were introduced during June, increased size and faster growth during the summer should allow rapid development out of the most vulnerable size range. Autumn planting of small rainbow trout in Big Sky Lake is probably just a feeding session for brown and brook trout which congregate in the shallows to spawn.

Lack of fish population estimates and accurate stocking records preclude recommendation of proper numbers of fingerlings to stock. Continued monitoring of the relative proportions of fish species in anglers' creel would provide useful information. If rainbow trout clearly dominate the catch, reduction in stocking should be considered. Overabundance of brook trout might be controlled by an increased removal of eggs by hatchery personnel during spawning. Big Sky Lake is quite unique in having this regulatory mechanism available.

2. Forage fish should not be introduced. The larger rainbow and brook trout in Big Sky Lake might grow faster than their predecessors, but the trout numbers would probably drop drastically. A good forage fish is extremely prolific, and, once established, consumes a major portion of the trouts' former food supply, e.g. zooplankton, aquatic insects, other aquatic invertebrates, and terrestrial insects (Borgeson 1966). Thus, trout too small to eat forage fish must compete with them for food, resulting in a reduction in the survival and often the growth rate of small trout. This phenomenon has been demonstrated in Paul Lake, British Columbia, where redside shiners (<u>Richardsonius balteatus</u>) were introduced as forage (Larkin and Smith 1954). Shiners

and chubs introduced as bait into Fish Lake, Utah, multiplied rapidly and became a distinct annoyance to fly fishermen by attacking their lures (Hazzard 1935). Stomach contents of the "bait" fish showed that they competed with rainbow and brook trout for food. Trout stomachs contained no shiners or chubs, so no compensation was realized.

Bigger food items are not necessarily the solution to faster trout growth. Food availability is the key to fast growth (Borgeson 1966). The trout in Big Sky Lake can grow large on an invertebrate diet if population levels are maintained at levels where food availability remains high.

3. Brown trout and Kokanee should not be reintroduced. Millions of brown trout fingerlings were planted each year in California until 1941, when a drastic reduction occurred because of a growing consensus that they were too difficult to catch and therefore not providing as satisfactory angling as native rainbow trout (Staley 1966). This wariness leads to good survival to piscivorous size. The Castle Lake investigation demonstrated the marked effect of brown trout predation on recruitment of rainbow and brook trout fingerlings (Wales 1946). Eradication of established populations of brown trout has also proved difficult. Researchers trapped the inlet of Convict Lake, California, during late fall hoping to capture and remove large spawning browns known to reside in the lake (Nielson 1953). Only small trout were captured. Large browns were seen spawning over spring-fed areas within the lake. Big Sky Lake may also have spring-fed areas suitable for spawning.

Kokanee can also severely limit trout recruitment. Seeley and McCammon (1966) warn that in waters in which a limited zooplankton supply is the primary food source, competition for it could become serious for trout if the kokanee population was very large. Zooplankton, a primary food source in Big Sky Lake, is probably not yet in limited supply. However, the introduction of a strict planktivore into the system could deplete the population of large Daphnia now available to trout.

4. Barriers to fish movement during spawning seasons should be removed from the inlet creek. Spawning rainbow trout and redds have been observed along the entire length of the inlet creek, with the exception of the last few hundred yards. Large logs and a steep terrace just below the water source for the Swenson's house apparently obstruct further progress. Construction of a small channel around the barrier would increase useable spawning area.

Young trout resulting from natural spawning may be a valuable and inexpensive source of recruitment for Big Sky Lake. Also, they are the offspring of parents selected for their ability to survive in the lake. In contrast, hatchery brood fish are usually selected for such traits as rapid growth rate and production of numerous eggs (Schuck 1948).

The inlet creek may also provide nursery areas for rainbow and/or brook trout, allowing them to reach a less vulnerable size before entering the lake (Lewis 1967).

5. Anglers at Big Sky Lake should consider possible consequences of their desire for larger fish. Management practices such as those

suggested below are intended to increase the number of larger fish. However, their effects are not infallibly predictable.

a. Minimum size regulations could be imposed. For example, rainbow trout smaller than 38 cm (15 in), and brook trout smaller than 33 cm (13 in) might be released. Productivity in Big Sky Lake is probably sufficient to support these larger trout. A few years of slow (slower than growth of immature fishes) but continued fish growth should result in more larger fish. However mortality rates of older trout in the lake are not known. Although throwback mortality in a catch and release program should not be significant (Klein 1966), anglers might be returning good-sized fish only to have them die from senility and/or predation. Most studies indicate that brook trout usually are short-lived and that few exceed 4 years of age (McAfee 1966b). Also, increased fishing pressure on larger fish could allow increased survival and slower growth of smaller fish. Thus, minimum size regulations designed to provide anglers with more large fish, could possibly result in fewer large fish in the creel, and more small fish in the lake.

b. A second possible management scheme might decrease the probability of an influx of smaller fish. Anglers could agree to keep fewer trout larger than a designated length, e.g. rainbows, 356 mm (14 in) and brooks, 305 mm (12 in).

Fishing pressure would, therefore, be maintained on smaller fish and reduced on larger. Again high mortality of older fish might negate the benefits of allowing more time for growth. Reports of more large (908 g, 2 lb.) fish in Big Sky Lake before recent years, high productivity and availability of food, and observation of few natural predators, support the likelihood that this program would succeed. Shorter-lived brook trout would probably contribute little to this population of larger fish.

c. Perhaps separate regulations for rainbow and brook trout would be the best answer. Brook trout are predominantly about 305 mm (12 in) in fork length in Big Sky Lake. These fish are in excellent condition and are delicious. Creel returns indicate that few of these four-year-old brook trout survive to age five (Fig. 34). Rainbow trout, however, survive well into their fifth and sixth years (Fig. 33). These trout are also prized for their tasty flesh, as well as their aggressive fighting and leaping when hooked. Releasing rainbow trout larger than about 356 mm (14 in) and keeping all brook trout approximately 305 mm (12 in) and larger might provide the desired fishery. Brook trout and smaller rainbow trout could fill fishermen's skillets while larger rainbow satisfy angler's desire for aggressive fish. Selective pressure upon adult brook trout by anglers and upon young brook trout by large rainbows might also prevent overpopulation of the former, which some anglers fear.

Suggestions for Further Research

1. Big Sky Lake was described as moderately productive in this study. Prolonged stratification with the appearance of a metalimnetic oxygen maximum during August and September are signs that the lake may be progressing toward eutrophy. To explore this possibility, an investigation should include the following elements:

   a. An accurate, year-round analysis of oxygen profiles throughout the lake should be conducted. The marked stratification noted at the deepest section of the lake may be unique, with remaining areas being more oxygenated. Possible reappearance of an oxygen increase at 11 m during late summer should be monitored.

   b. Phytoplankton of Big Sky Lake should be analyzed to detect the presence of species frequently associated with eutrophic conditions. A sample taken from the depth at which a metalimnetic oxygen increase occurs should be examined for *Oscillatoria* or other algae.

2. Sizes of fish populations at Big Sky Lake must be estimated before reliable stocking recommendations can be made. A mark-recapture program (Ricker 1971) could estimate numbers of spawning rainbow and brook trout in the lake. Little extra handling would be required to fin-clip brook trout or rainbow trout being spawned by hatchery personnel during fall and spring respectively. Additional rainbow trout could be obtained for marking by constructing a weir with a trap near the mouth of the inlet creek. An estimate of population numbers based on spawners is negatively biased, because it doesn't include juvenile fish or any

adults not appearing in the spawning concentrations. However, sexually mature fish contribute most to the catch at Big Sky Lake, thus reducing effects of this bias.

Natural recruitment would also influence stocking recommendations. A weir across the inlet creek would serve to estimate numbers of adult rainbows (and perhaps brook trout) using the stream for spawning, and numbers of fry or fingerlings reentering the lake. Reproductive success of brook trout would be more difficult to assess. A diver using scuba gear might be able to locate spawning congregations near spring areas and estimate the number of redds constructed. Potential fry emergence and survival might be deduced based on established averages for brook trout redds examined in previous studies.

Under ideal conditions, lake springs might also serve as spawning grounds for rainbow trout. This species has been observed congregating in certain shallow regions of the lake during spawning season. If redds were located, eggs could be collected from ripe females, artifically fertilized, and placed within a screen basket and buried within a redd (Vestal 1943). Ensuing development, or lack of it, could be monitored. Survival of young would demonstrate a unique and valuable source of rainbow trout recruitment for Big Sky Lake, and would reduce the need for planting.

3. If any of the recommended management programs are adopted, effects upon the trout populations should be closely followed.

   a. If a minimum size limit is imposed, creel census should be employed to determine whether more larger fish are being caught and released, or smaller trout are dominating the catch.

b. A census should also show whether keeping few trout larger than a designated size is resulting in increased hooking of larger fish. If brook trout are living longer and growing well, this might also be demonstrated when the census data is compiled. Further age and growth studies could confirm these findings.

c. Shifts in the relative proportions of rainbow and brook trout in Big Sky Lake should be watched for if separate regulations are imposed on each species. A drastic reduction in numbers of brook trout should be avoided. This species provides an excellent, inexpensive, self-sustaining fishery for the lake.

CHAPTER V

SUMMARY

Big Sky Lake lies 1.6 km northwest of Salmon Lake in the Clearwater drainage system, Missoula County, Montana. Only property owners and their guests are allowed access to fishing at this relatively small (37.7 ha), shallow (mean depth = 8.7 m) lake. Homeowners requested that the lake and its rainbow and brook trout fishery be investigated to determine the management regulations needed to ensure future angling success.

The study was undertaken from October 1974 through September 1975. Depths were measured using an echo-locating device. Benthic sediments and organisms were collected with an Ekman dredge. Temperatures and chemical constituents were monitored monthly using HACH and DELTA methods. Chemical parameters surveyed included: pH, carbon dioxide, alkalinity, hardness, nitrate, and orthophosphate. Temperature and oxygen profiles were determined using a membrane-covered electrode or the Winkler method. Plankton and bacteria were also sampled. Fish were collected by gill-netting, setting a Wolf-type trap in the inlet, and angling. Rainbow and brook trout were measured and weighed; scale samples were taken and stomachs were removed. Creel census forms were distributed to property owners.

Big Sky Lake exhibits seasonal trends in physical and chemical characteristics which are typical of a moderately productive, dimictic

lake in the temperate zone. Fall turnover occurs during late October, with inverse stratification being established shortly after surface-ice formation in late November, and persisting through winter. The lake again destratifies and circulates during late April or early May. Restratification occurs quickly and persists from June until late October. Oxygen levels are near zero below about 9 m (29.5 ft) during stratification except near 11 m (36 ft) during August and September. Higher oxygen levels found there may be caused by blooms of algae such as *Oscillatoria*. Alkalinity (mean values = 83, 107, and 125 ppm for stations 1, 2, and 3 respectively) and hardness (means for total hardness = 87, 105, and 126 ppm respectively) levels are higher than those of surrounding waters. Pollution by enteric bacteria is absent.

Rainbow trout (mean K = 1.16) and brook trout (mean K = 1.11) are in good condition, growing rapidly during their first three or four years, before reaching sexual maturity. After about four years, rainbow trout attain fork lengths of approximately 35.5 cm (14 in); and brook trout, 30.5 cm (12 in). Principal food items of both species are *Daphnia* and *Hyalella azteca*, although brook trout appear to consume more benthos, and rainbow trout ingest more plankton.

Fishing success at Big Sky Lake compares favorably with other Montana lakes and streams. Approximately 1.04 fish are caught per hour of fishing, with four- and five-year-old trout contributing most to the catch. Anglers are most successful when ice-fishing, and more successful from shore than from boats during summer.

The following management practices are recommended:

1. Larger rainbow fingerlings should be planted during late spring.
2. Forage fish should not be introduced.
3. Brown trout and kokanee should not be planted.
4. Barriers to spawning fish should be removed from the inlet creek.
5. One of the following regulation schemes might be employed to provide anglers with more large fish:
   a. A minimum size limit could be established.
   b. Fish larger than a designated size might be released and smaller ones kept.
   c. Rainbow trout larger than a designated size could be released, and all brook trout of catchable size kept.

In further studies, the lake should be monitored for indicators of increasing eutrophication. Oxygen profiles should be analyzed year-round throughout the lake, and phytoplankton species should be identified.

To determine the proper stocking recommendations, sizes of resident trout populations should be estimated by a mark-recapture program using spawning adults. Observations from a weir constructed across the inlet could provide information on use of the creek for spawning and numbers of returning fry and fingerling trout (particularly rainbow trout). Estimation of returns of young brook trout from adults spawning over springs within the lake would require study using diving equipment.

Effects of adopted management practices should be monitored. Changes in the relative proportions of rainbow and brook trout, as well as shifts in dominant size classes and average sizes and growth rates of fishes should be followed.

LITERATURE CITED

Alden, W. C. 1953. Physiography and glacial geology of western Montana and adjacent areas. U.S. Dept. Int., Geol. Surv. Prof. Paper No. 231:107.

Anon. 1973a. Phase 2 report. Regional Planning Association of Western Montana. City Planning Board, Missoula, Montana.

Anon. 1973b. Biological analysis of water and wastewater. Millipore Corp., Bedford, MA 84 pp.

Borgeson, D. P. 1966. Trout lake management. Pages 168-178 _in_ A. Calhoun, ed. Inland fisheries management. Resources Agency, Calif. Dept. Fish and Game.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, vol. 1. Iowa State Univ. Press, Ames, Iowa. 752 pp.

Cladouhos, J. W. 1971. The water quality and cultural eutrophication of Seeley Lake, Montana. Univ. Montana, Missoula, M.A. thesis. 87 pp.

Cochran, W. G. 1953. Sampling techniques. John Wiley and Sons, Inc. New York: 119.

Cooper, E. L., and N. G. Benson. 1951. The coefficient of condition of brook, brown, and rainbow trout in the Pigeon River, Otsego County, Michigan. Prog. Fish-Cult. 13(4): 181-192.

Dixon, W. J., ed. 1974. Biomedical computer programs. Univ. of Ca. Press, Berkeley and Los Angeles: 305-330; 365-372.

Domrose, R. J. 1963. Age and growth of brook trout, _Salvelinus fontinalis_, in Montana. Proc. Mont. Acad. Sci. 23: 47-63.

Duodoroff, P., and D. L. Shumway. 1967. Dissolved oxygen criteria for the protection of fish. Pages 13-19 in E. L. Cooper, ed. A symposium on water quality criteria to protect aquatic life. Amer. Fish Soc. Spec. Publ. No. 4.

Eberly, W. R. 1964. Further studies on the metalimnetic oxygen maximum, with special reference to its occurrence throughout the world. Invest. Indiana Lakes Streams 6: 103-139.

Galbraith, M. G., Jr. 1975. The use of large Daphnia as indices of fishing quality for rainbow trout in small lakes. Verh. Internat. Verein. Limnol. 19: 2485-2492.

Gard, R. 1961. Effects of beaver on trout in Sagehen Creek, California. J. Wildl. Mgmt. 25: 221-242.

Goldman, C. R. 1961. The contribution of alder trees (Alnus tenuifolia) to the primary productivity of Castle Lake, California. Ecology 42: 282-288.

Hazzard, A. S. 1932. Some phases of the life history of the eastern brook trout, Salvelinus fontinalis. Mitchell.-Trans. Amer. Fish. Soc. 62: 344-350.

__________, 1935. A preliminary study of an exceptionally productive water, Fish Lake, Utah. Trans. Amer. Fish. Soc. 65: 122-128.

Hoffman, G. L. 1967. Parasites of North American freshwater fishes. Univ. Calif. Press, Berkeley and Los Angeles: 255 and 259.

Holton, G., ed. 1971. Statewide creel census. Montana Fish and Game Dept., Fisheries Division, D.-J. Job Completion Report F-4-R-20 (Job 1-a).

Hutchinson, G. E. 1957. A treatise on limnology. 1. Geography, physics, and chemistry. John Wiley and Sons, Inc., New York. 1015 pp.

Hynes, H. B. N. 1950. The food of freshwater sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius), with a review of methods used in studies of the food of fishes. J. Animal Ecol. 19(1): 36-58.

__________, 1970. The ecology of running waters. Univ. of Toronto Press: 365-376.

Juday, R. E. and E. J. Keller. 1975. Progress report on a water quality survey of Placid Lake and its drainages. Univ. Mont., Missoula. 46 pp.

Klein, W. D. 1966. Mortality of trout caught on artificial lures and released by fishermen. Trans. Amer. Fish. Soc. 95(3): 326-328.

Lagler, K. F. 1956. Freshwater fishery biology. Wm. C. Brown Co., Dubuque, Iowa. 421 pp.

Larkin, P. A., and S. G. Smith. 1954. Some effects of introduction of the redside shiner on the Kamloops trout in Paul Lake, British Columbia. Trans. Amer. Fish. Soc. 83: 161-175.

Lewis, W. M. 1967. Predation as a factor in fish populations. Pages 386-390 in Reservoir Fishery Resources Symposium. Reservoir Committee, Southern Division Amer. Fish. Soc.

Lind, O. T. 1974. Handbook of common methods in limnology. C. V. Mosby Co., St. Louis, Mo. 154 pp.

McAfee, W. R. 1966a. Rainbow trout. Pages 192-215 in A. Calhoun, ed. Inland fisheries management. Resources Agency, Calif. Dept. Fish and Game.

__________. 1966b. Eastern brook trout. Pages 242-260 in A. Calhoun, ed. Inland fisheries management. Resources Agency, Calif. Dept. Fish and Game.

Miller, W., and R. Marcoux, eds. 1974. Montana Fish and Game Dept. Fisheries Division, C.-J. Job Progress Report F-12-R-20 (Job 1-a) 13 pp.

Nielson, R. S. 1953. Should we stock brown trout? Progve. Fish Cult. 15(3): 99-100.

Nilsson, N.-A. 1963. Interaction between trout and char in Scandanavia. Trans. Amer. Fish. Soc. 92(3): 276-285.

__________. 1967. Interactive segregation between fish species. Pages 295-313 in S. D. Gerking, ed. The biological basis of fresh-water fish production. Blackwell Scientific Publ., Oxford and Edinburgh.

Peters, J. C. 1964. Summary of calculated growth data on Montana fishes 1948-61. Montana Fish and Game Dept. Fisheries Division, D.-J. Job Completion Report F-23-R-6 (Jobs 1-2) 76 pp.

Reid, G. K. 1961. Ecology of inland waters and estuaries. Van Nostrand Reinhold Co., New York: 183-193.

Ricker, W. E. 1971. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publ., Oxford and Edinburgh. 348 pp.

Schuck, H. A. 1948. Survival of hatchery trout in streams and possible methods of improving quality of hatchery trout. Progr. Fish-Cult. 10(1): 3-14.

Seeley, C. M., and G. W. McCammon. 1966. Kokanee. Pages 274-294 in Inland fisheries management. Resources Agency, Calif. Dept. Fish and Game.

Sigler, W. F. 1953. The rainbow trout in relation to the other fish in Fish Lake. Utah State Agric. Exp. Sta. Bull. 358: 1-26.

Spence, L., ed. 1970. Georgetown Lake summer creel census. Montana Fish and Game Dept., Fisheries Division, D.-J. Job Progress Report F-12-R-17 (Job 1-b). 11 pp.

__________. 1971. Rock Creek creel census 1958-1967. Montana Fish and Game Dept., Fisheries Division, D.-J. Job Final Report.

Staley, J. 1966. Brown trout. Pages 233-242 in A. Calhoun, ed. Inland fisheries management. Resources Agency, Calif. Dept. Fish and Game.

Standard Methods. 1971. Standard methods for the examination of water and wastewater. American Public Health Association, Inc., New York. 874 pp.

Sturbin, L. E., et. al. 1973. Water quality study of the Clearwater River and selected tributaries. School of Engineering and Environmental Science, Univ. Okla., Norman. 154 pp.

Swift, M. C. 1970. A qualitative and quantitative study of trout food of Castle Lake, California. Calif. Fish and Game 56(2): 109-120.

Vestal, E. H. 1943. Creel returns from hatchery trout in June Lake, California. Calif. Fish Game 29(2): 51-63.

Vincent, E. R., ed. 1975. Montana Fish and Game Dept., Fisheries Division, D.-J. Job Progress Report F-9-R-23 (Job 1-a). 12 pp.

Wales, J. H. 1946. Castle Lake trout investigation. First phase: inter-relationships of four species. Calif. Fish Game 32(3): 109-143.

__________, and E. R. German. 1956. Castle lake investigation - second phase: eastern brook trout. Calif. Fish Game 42(2): 93-108.

__________, and D. P. Borgeson. 1961. Castle lake investigation - third phase: rainbow trout. Calif. Fish Game 47(4): 399-414.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia, Pa. 743 pp.

Wolf, P. 1951. A trap for the capture of fish and other organisms moving downstream. Trans. Amer. Fish. Soc. 80: 41-45.

Wurtsbaugh, W. A., et. al. 1975. Food and distribution of under-yearling brook and rainbow trout in Castle Lake, California. Trans. Amer. Fish. Soc. 104(1): 88-95.

APPENDIX

BIG SKY LAKE
FISHING REGULATIONS

All fishing shall be with BARBLESS HOOKS. Lures shall have only one (1) hook with the barb removed.

There shall be no fishing with minnows or live fish. THIS IS MOST IMPORTANT!

All persons, including guests, will be encouraged to release almost all of the fish which they catch. THE FOLLOWING ARE THE ABSOLUTE MAXIMUM LIMITS:

Each fisherman shall keep not more than FIVE (5) pounds of fish per day and not more than TEN (10) pounds per week for any family.

For each tract the total number of fish kept by all of the residents and guests shall not exceed ONE HUNDRED (100) pounds of fish per year.

The above limits are the absolute maximums. Each owner shall encourage his family and guests not to be "FISH HOGS" and to keep their catches below the absolute maximums as a matter of sportsmanship and in order to preserve the fishing for others and for future years.

All fish not being kept shall be carefully removed by handling them with wet hands and allowing them to slide (do not throw them) into the water. There shall be no waste of fish.

Insofar as applicable the Montana fishing regulations shall apply. However, there shall be no season upon the fishing in the lake.

If you catch the fish and keep them you CLEAN THEM.

All fish innards and heads from cleaning the fish WILL BE DISPOSED OF ELSEWHERE. None will be disposed of in the lake or stream.

Artificial food for feeding fish and use of fertilizer around the edge of Big Sky Lake is detrimental to the ecology of the lake.

BOATING, WATER-SKIING AND HUNTING REGULATIONS

Lights shall be on all boats after dark in accordance with the state law.

There shall be no buzzing of swimmers by boaters or water skiers.

Whenever there is water skiing there shall be two people in the boat.

On the area between the island closest to the outlet and the shore on the north side thereof there shall be no water skiing, and boats going through that inlet shall be restricted to approximately five miles per hour.

All water skiers and all power boats, including the pontoon boats, going in excess of ten miles per hour shall generally proceed around the lake in a counterclockwise direction.

Power boats going in excess of five miles per hour (which includes water skiers) shall not start before 10:00 a.m. and shall stop by 6:30 p.m. except from June 15th to September 15th, when stopping time is extended to 7:30 p.m.

A motorboat shall be so equipped that it cannot exceed the speed of 35 miles per hour. There shall be no motorboat racing.

There shall be no hunting of ducks, grouse, deer or elk or any game birds or animals upon Big Sky Lake and the surrounding area at any time.

All owners and guests will abide by the above regulations.

Color (A.P.H.A. platinum-cobalt units) and turbidity (ppm) of Big Sky Lake during the 1974-75 sampling period

Date	Color			Turbidity		
Stations:	1	2	3	1	2	3
1974						
10/20	18	32	40	0	1	2
11/23	73	40	70	3	2	2.5
12/15	40	67	95	2	3	5
1975						
1/19	52	40	52	2	2	2
2/16	32	51	32	2	3	2
3/23	32	40	37	2	2	2
4/19	65	52	23	3	2	0.5
5/18	88	102	124	4	5	6
6/18	57	40	41	2.5	2	2
7/19	40	46	37	2	2	1
8/21	42	40	42	2	2	2
9/20	42	40	30	2	2	1
Mean	48	49	52	2	2	2
Range	32-88	32-102	30-124	0-4	1-5	0.5-6

Weekly maximum and minimum temperatures of inlet-creek water as recorded by the Ryan-Peabody 30-day thermometer.

Week	Min.	Max.
1974		
Aug. 18-24	7.3	8.8
Aug. 25-31	7.7	9.5
Sept. 1-7	6.0	8.3
Sept. 8-14	6.1	7.7
Sept. 15-21	6.6	8.8
Sept. 22-28	6.2	8.2
Sept. 29-Oct. 5	5.5	7.3
Oct. 6-12	5.1	7.1
Oct. 13-19	5.5	7.2
Oct. 20-26	4.7	6.7
Oct. 27-Nov. 2	5.4	6.8
Nov. 3-9	4.7	6.0
Nov. 10-16	4.6	5.4
Nov. 17-23	4.6	5.4
Nov. 24-30		
Dec. 1-7	4.3	5.0
Dec. 8-14	2.9	4.2
Dec. 15-21	1.6	2.4
Dec. 22-28	0.6	1.8
1975		
Dec. 29-Jan. 4	0.5	1.6
Jan. 5-11	1.5	2.0
Jan. 12-18		
Jan. 19-25	3.3	3.7
Jan. 26-Feb. 1	0.9	1.5
Feb. 2-8	0.3	1.2
Feb. 9-15	2.0	2.9
Feb. 16-22	1.3	2.3
Feb. 23-Mar. 1	1.4	2.7
Mar. 2-8	2.5	3.3
Mar. 9-15	1.7	3.3
Mar. 16-22	2.4	3.7
Mar. 23-29	1.2	2.6
Mar. 30-Apr. 5	1.3	3.1
Apr. 6-12	1.7	3.7
Apr. 13-19	3.8	4.9
Apr. 20-26	4.0	5.0
Apr. 27-May 3	3.5	4.1
May 4-10	3.1	3.6
May 11-17	3.7	4.6
May 18-24	4.8	5.3
May 25-31	5.7	6.6
June 1-7	6.2	6.9
June 8-14	6.4	7.1
June 15-21	6.9	7.4
June 22-28	7.0	7.7
June 29-July 5	7.3	8.5
July 6-12	7.9	9.0
July 13-19	8.0	9.0
July 20-26	7.9	9.4
July 27-Aug 2	8.1	9.1
Aug. 3-9	7.9	9.3
Aug. 10-16	7.9	9.3
Aug. 17-23	8.3	8.8
Aug. 24-30	7.6	8.5
Aug. 31-Sept. 6	7.2	8.4
Sept. 7-13	7.1	8.8
Sept. 14-20	7.1	8.6

Surface temperatures in ^{o}C (^{o}F) of Big Sky Lake during 1974-75 sampling period.

Date	Sampling Site		
1974	1	2	3
10/20	6 (43)	11.5 (53)	11 (52)
11/23	3 (37)	3 (37)	4 (39
12/15	4 (39)	1 (34)	0 (32)
1975			
1/19	4 (39)	0 (32)	0 (32)
2/16	2 (36)	0 (32)	0 (32)
3/23	2.5 (37)	0 (32)	0 (32)
4/19	4.5 (40)	0 (32)	0 (32)
5/18	5 (41)	5 (41)	8.5 (47)
6/18	6 (43)	14 (57)	14 (57)
7/19	7.5 (46)	20 (68)	20 (68)
8/21	7.5 (46)	18 (64)	19 (66)
9/20	6.5 (44)	14.5 (58)	15 (59)
Mean	4.9 (41)	7 (45)	7.6 (46)
Range	2-7.5 (36-46)	0-20 (32-68)	0-20 (32-68)

Vertical distribution of temperature, density, and oxygen in Big Sky Lake

15 Sept. 1974

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	15.4	9.99038	7.0
1	15.0	9.99099	7.0
2	14.9	9.99114	7.0
3	14.8	9.99129	6.7
4	14.7	9.99144	6.4
5	14.7	9.99144	6.4
6	14.5	9.99173	6.4
7	14.5	9.99173	6.4
8	14.0	9.99244	5.8
9	11.3	9.99574	1.9
10	10.0	9.99700	1.2
11	9.0	9.99781	0.9
12	8.0	9.99849	0.7
13	7.5	9.99877	0.6
14	7.2	9.99893	0.6
15	7.0	9.99902	0.6
16	7.0	9.99902	0.65
17	7.0	9.99902	0.6
18	7.0	9.99902	0.4

26 Oct. 1974

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	10	9.99700	9.8
5	9	9.99781	8.5
6	9	9.99781	8.1
7	9	9.99781	7.5
8	9	9.99781	7.4
9	9	9.99781	7.1
10	9	9.99781	6.9
11	9	9.99781	6.9
12	9	9.99781	6.3
13	9	9.99781	5.0
14	9	9.99781	3.8
15	9	9.99781	3.4

17 Nov. 1974

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	5.5	9.99955	10
1	5.5	9.99955	9.8
2	5.5	9.99955	9.6
3	5.5	9.99955	9.1
4	5.5	9.99955	8.6
5	5.5	9.99955	8.5
6	5.5	9.99955	8.3
7	5.5	9.99955	8.2
8	5.25	9.99959	7.6
9	5	9.99965	7.3
10	5	9.99965	7.1
11	5.5	9.99955	6.6
12	5.25	9.99959	6.4
13	5.25	9.99959	6.2
14	5	9.99965	6.0
15	5	9.99965	6.0

1 March 1974

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	0.8	9.99889	8.2
1	1	9.99900	8.2
2	2.8	9.99962	7.1
3	3.5	9.99971	5.0
4	3.8	9.99973	4.5
5	3.9	9.99973	4.2
6	4	9.99973	3.0
7	4	9.99973	3.0
8	4	9.99973	2.8
9	4.1	9.99973	2.1
10	4.1	9.99973	0.8
11	4.1	9.99973	0.6
12	4.1	9.99973	0.5
13	4.1	9.99973	0.5
14	4	9.99973	0.4
15	4	9.99973	0.4

29 March 1975

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	0	9.99841	9.4
1	1	9.99900	6.2
2	2.5	9.99955	4.4
3	3.5	9.99971	3.9
4	4	9.99973	3.6
5	4	9.99973	3.0
6	4	9.99973	2.8
7	4	9.99973	2.7
8	4	9.99973	1.4
9	4	9.99973	0.9
10	4.5	9.99972	0.7
11	4.5	9.99972	0.5
12	4.1	9.99973	0.4
13	4.1	9.99973	0.4
14	4.1	9.99973	0.4

19 April 1975

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	0.5	9.99872	9.6
1	2	9.99941	7.5
2	3	9.99965	4.1
3	3.5	9.99971	2.8
4	4	9.99973	2.4
5	4	9.99973	2.0
6	4	9.99973	1.6
7	4.1	9.99973	1.4
8	4.1	9.99973	1.2
9	4.1	9.99973	1.1
10	4.1	9.99973	1.0
11	4.1	9.99973	1.0
12	4.1	9.99973	1.0
13	4.2	9.99973	0.9
14	4.2	9.99973	0.9
15	4.3	9.99972	0.9
16	4.3	9.99972	0.8

18 May 1975

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	6.8	9.99911	10.8
1	6.5	9.99924	8.0
2	6.5	9.99924	4.9
3	6.5	9.99924	3.2
4	6.5	9.99924	2.4
5	6.5	9.99924	2.0
6	6.5	9.99924	1.9
7	6.5	9.99924	1.8
8	6.5	9.99924	1.8
9	5.2	9.99959	1.7
10	5.0	9.99965	1.6
11	4.8	9.99968	1.4
12	4.7	9.99969	1.2
13	4.7	9.99969	1.1
14	4.7	9.99969	1.0
15	4.7	9.99969	0.8
16	4.5	9.99972	0.7

26 May 1975

D(m)	Temp (°C)	Density x 10	O_2 (ppm)
0	8	9.99849	9.8
1	8	9.99849	10.6
2	8	9.99849	6.2
3	7.5	9.99877	3.2
4	7.5	9.99877	2.5
5	7.5	9.99877	2.2
6	7	9.99902	1.9
7	6.8	9.99911	1.7
8	6.5	9.99924	1.6
9	6	9.99941	1.6
10	6	9.99941	1.6
11	5.3	9.99959	1.2
12	5	9.99965	1.0
13	5	9.99965	0.8

17 June 1975

D(m)	Temp (^oC)	Density x 10	O_2 (ppm)
0	14.3	9.99202	9.1
1	14.3	9.99202	8.4
2	13.9	9.99258	6.3
3	13.6	9.99299	5.8
4	13.0	9.99377	5.1
5	10.2	9.99682	5.0
6	8.8	9.99796	4.7
7	8.0	9.99849	4.2
8	7.2	9.99893	3.6
9	6.9	9.99907	3.2
10	6.4	9.99927	2.4
11	6.2	9.99935	1.4
12	6.0	9.99941	0.7
13	6.0	9.99941	0.5
14	5.5	9.99955	0.4
15	5.5	9.99955	0.35
16	5.2	9.99961	0.3
17	5.2	9.99961	0.3

19 July 1975

D(m)	Temp (^oC)	Density x 10	O_2(ppm) Probe	Winkler
0	21	9.97992	8.1	7.7
1	20.3	9.98141	7.3	7.7
2	20.1	9.98183	4.3	7.7
3	19.9	9.98224	4.4	7.9
4	17.5	9.98686	3.3	8.3
5	14	9.99244	2.95	8.3
6	11.5	9.99553	2.7	7.9
7	9.6	9.99734	2.45	5.5
8	8.8	9.99796	1.7	3.1
9	8.0	9.99849	1.2	2.1
10	7.2	9.99793	0.45	
11	6.8	9.99911	0.4	
12	6.4	9.99927	0.25	
13	6.2	9.99935	0.25	
14	6.0	9.99941	0.2	
15	6.0	9.99941	0.2	.1-.21

26 August 1975

D(m)	Temp (^oC)	Density x 10	O_2(ppm) Probe	Winkler
0	16	9.98943	9.3	7.7
1	16	9.98943	5.9	7.5
2	16	9.98943	3.3	7.6
3	16	9.98943	1.95	7.6
4	16	9.98943	1.5	7.6
5	16	9.98943	1.3	7.7
6	15.2	9.99069	1.18	7.6
7	12	9.99498	1.1	5.7
8	10.2	9.99682	0.82	3.7
9	9	9.99781	0.4	0.7
10	8	9.99849	0.3	0.2
11	7.1	9.99898	0.3	4.3
12	7	9.99902	0.2	0.05
13	6.8	9.99911	0.2	0.4
14	6.2	9.99935	0.13	0
15	6.1	9.99938	0.11	5.3

28 September 1975

D(m)	Temp (^oC)	Density x 10	O_2(ppm) Probe	Winkler	
0	14.2	9.99216	8.6	8.2	
1	14.1	9.99230	8.4	8.4	
2	14	9.99244	8.3	8.4	
3	14	9.99244	8.3	8.4	
4	14	9.99244	8.3	8.45	
5	14	9.99244	8.3	8.3	
6	14	9.99244	8.2	8.2	
7	13.8	9.99272	8.0	8.1	
8	13.0	9.99377	4.6	6.7	
9	11.2	9.99585	0.9	1.1	wind
10	9.0	9.99781	1.6	0.25	
11	7.8	9.99861	2.0	0.1	
12	7.0	9.99902	1.0		
13	6.8	9.99911	0.6		
14	6.8	9.99911	0.4		
15	6.8	9.99911	0.3		

Hydrogen ion activity (pH) of Big Sky Lake during 1974-75 sampling period

Date	Sampling Site		
	1	2	3
1974			
10/20	7.5	7.7	7.7
11/23	7.3	7.4	8.0
12/15	7.5	7.9	7.3
1975			
1/19	7.7	7.8	7.4
2/16	7.7	7.1	7.6
3/23	--	7.6	--
4/19	7.9	7.5	7.7
5/18	7.6	7.8	8.5
6/18	8.1	8.25	8.3
7/19	7.7	8.3	8.5
8/21	7.5	8.55	8.6
9/20	7.8	8.25	8.35
Mean	7.7	7.8	8.0
Range	7.3-8.1	7.1-8.55	7.3-8.6

Bicarbonate alkalinity (ppm) of Big Sky Lake during 1974-75 sampling period

Date	Sampling Site		
	1	2	3
1974			
10/20	100	130	130
11/23	90	110	150
12/15	90	120	140
1975			
1/19	80	90	130
2/16	100	90	120
3/23	90	110	130
4/19	90	80	115
5/18	55	70	125
6/18	50	120	120
7/19	80	120	110
8/21	80	120	110
9/20	90	120	120
Mean	83	107	125
Range	50-100	70-130	110-150

Total, calcium, and magnesium hardness (ppm Ca CO_3) of Big Sky Lake during the 1974-75 sampling period

Date	Hardness								
	Total			Calcium			Magnesium		
Stations	1	2	3	1	2	3	1	2	3
1974									
10/20	128	132	132	48	74	72	80	58	60
11/23	104	116	132	48	62	74	56	54	58
12/15	100	102	132	48	52	72	52	50	60
1975									
1/19	86	92	140	42	50	72	44	42	72
2/16	96	96	132	50	50	72	46	46	60
3/23	96	108	132	56	56	70	40	52	62
4/19	86	82	132	44	44	78	42	38	54
5/18	42	70	114	30	36	62	12	34	52
6/18	48	116	116	24	62	62	24	54	54
7/19	84	114	114	28	58	58	56	56	56
8/21	86	116	116	34	54	54	52	62	62
9/20	90	114	118	42	62	64	44	52	54
Mean	87	105	126	41.5	55	67.5	45.7	49.8	58.7
Range	42-128	70-132	114-140	24-56	36-74	54-78	12-80	34-62	52-72

Nitrate (ppm N x 4.43) of Big Sky Lake during 1974-75 sampling period

Date	Sampling Station 1	2	3
1974			
10/20	13.7	10.85	9.66
11/23	22.24	14.62	11.43
12/15	19.9	15.6	18.16
1975			
1/19	9.97	9.83	--
2/16	11.96	11.96	10.41
3/23	10.72	2.30	11.43
4/19	10.63	10.50	9.75
5/18	12.45	12.94	12.45
6/18	3.21	3.21	3.16
7/19	9.3	9.3	9.3
8/21	9.3	9.3	8.86
9/20	8.51	8.46	7.93
Mean	11.8	9.9	10.2
Range	3.21-22.24	2.3-15.6	3.16-18.16

Orthophosphate (ppm) of Big Sky Lake during 1974-75 sampling period

Date	Sampling Station 1	2	3
1974			
10/20	0.75	.01	.01
11/23	.08	.03	.02
12/15	.14	.23	.05
1975			
1/19	.05	.07	.02
2/16	.08	.08	.03
3/23	.075	.19	.03
4/19	.14	.03	.015
5/18	.13	.08	.025
6/18	.07	.02	.01
7/19	.06	.025	.02
8/21	.05	.04	.03
9/20	.06	.03	trace
Mean	.08	.07	.02
Range	.05-.14	.01-.23	.01-.03

STATE HEALTH DEPT. WATER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	MISSOULA
LAT.-LONG.	47 650N 1132352W	SAMPLE LOCATION	16N 14W 29
STATION CODE		ANALYSIS NUMBER	75W0952
DATE SAMPLED	06-18-75	DRAINAGE BASIN	
TIME SAMPLED	0530	WATER FLOW RATE	
METHOD SAMPLED	GRAB	FLOW MEASUREMENT METHOD	
SAMPLE SOURCE	STREAM	ALTITUDE OF LAND SURFACE	4270. FT
WATER USE	UNUSED	TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE (+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	.1 FT

SAMPLING SITE: BIG SKY LAKE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	13.0	0.648	BICARBONATE (HC03)	61.	1.000
MAGNESTUM (MG)	5.7	0.551	CARBONATE (C03)	0.	0.0
SODIUM (NA)			CHLORIDE (CL)		
POTASSIUM (K)			SULFATE (504)		
IRON (FE)			FLUORIDE (F)		
MANGANESE (MN)			NITRATE (N03 AS N)		
ALUMINUM (AL)			N03+N02 (TDT AS N)	.05	0.001
HYDROGEN (H+)	0.00	0.000	PHOSPHATE (P04 AS P)	.035	0.001
TOTAL CATIONS		1.199	TOTAL ANIONS		1.001

LABORATORY PH	7.73	TOTAL HARDNESS AS CACO3	60
FIELD WATER TEMPERATURE (C)	6.0	TOTAL ALKALINITY AS CACO3	50
DISSOLVED SOLIDS CALCULATED		LAB TURDIDITY (JTU)	1.6
LAB CONDUCTIVITY-UMHOS-25C		SODIUM ADSORPTION RATIO	

A D D I T I O N A L P A R A M E T E R S

REMARKS: LAKE STUDY

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITTER ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED (N)=MEASURED (R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

SAMPLE NO 1 SAMPLE JED HANDLING B100 ANALYST ME LAD WQBH
COMPLETED 07-10-75 COMPUTER RUN 07/18/75 PROGRAM SYS 75 FUND 0650

		CA	NG	NA	K	CL	S04	HC03	C03	N03
STND DEV.	ION BALANCE -1.81									
SEGMENT	MPDES	54.0	46.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0

STATE	MONTANA	COUNTY	MISSOULA
LAT.-LONG.	47 65)N 1132352W	SAMPLE LOCATION	16N 14W 2B
STATION CODE		ANALYSIS NUMBER	75W0953
DATE SAMPLED	06-18-75	DRAINAGE BASIN	
TIME SAMPLED	0600	WATER FLOW RATE	
METHOD SAMPLED	GRAB	FLOW MEASUREMENT METHOD	
SAMPLE SOURCE	LAKE	ALTITUDE OF LAND SURFACE	4270. FT
WATER USE	UNUSED	TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	.1 FT

SAMPLING SITE: BIG SKY LAKE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	26.3	1.312	BICARBONATE (HC03)	148.	2.419
MAGNESIUM (MG)	13.3	1.094	CARBONATE (C03)	0.	0.0
SODIUM (NA)			CHLORIDE (CL)		
POTASSIUM (K)			SULFATE (S04)		
IRON (FE)			FLUORIDE (F)		
MANGANESE (MN)			NITRATE (N03 AS N)		
ALUMINUM (AL)			N03+N02 (TOT AS N)	.13	0.002
HYDROGEN (H+)	0.00	0.000	PHOSPHATE (P04 AS P)	.005	0.000
TOTAL CATIONS		2.408	TOTAL ANIONS		2.421

LABORATORY PH	8.10	TOTAL HARDNESS AS CA003	120
FIELD WATER TEMPERATURE (0)	14.0	TOTAL ALKALINITY AS CA003	121
DISSOLVED SOLIDS CALCULATED		LAB TURBIDITY (JTU)	1.1
LAB CONDUCTIVITY-OMHOS-250		SODIUM ADSORPTION RATIO	

A D D I T I O N A L   P A R A M E T E R S

REMARKS: LAKE STUDY

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITTER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)= MEASURED (R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

SAMPLE NO 2 SAMPLER JED HANDLING 3100 ANALYST ME LAB WQBH
COMPLETED 07-10-75 COMPUTER RUN 07/18/75 PROGRAM SYS 75 FUND 0650

		CA	MG	NA	K	CL	S04	HC03	C03	N03
STND DEV.	ION BALANCE 0.11									
SEGMENT	MPDES	54.5	45.5	0.0	0.0	0.0	0.01	100.0	0.0	0.0

STATE HEALTH DEPT. WATER QUALITY BUREAU HELENA, MONTANA 59601

STATE	MONTANA	COUNTY	MISSOULA
LAT.-LONG.	47 650N 1132235W	SAMPLE LOCATION	16W 14W 28
STATION CODE		ANALYSIS NUMBER	75W0954
DATE SAMPLED	06-18-75	DRAINAGE BASIN	
TIME SAMPLED	0630	WATER FLOW RATE	
METHOD SAMPLED	GRAB	FLOW MEASUREMENT METHOD	
SAMPLE SOURCE	LAKE	ALTITUDE OF LAND SURFACE	4270. FT
WATER USE	UNUSED	TOTAL WELL DEPTH BELOW LS	
AQUIFER(S)		SWL ABOVE(+) OR BELOW LS	
SAMPLED BY	WQBH	SAMPLE DEPTH BELOW SURFACE	.1 FT

SAMPLING SITE: BIG SKY LAKE

	MG/L	MEQ/L		MG/L	MEQ/L
CALCIUM (CA)	27.3	1.360	BICARBONATE (HCO3)	148.	2.439
MAGNESIUM (MG)	13.3	1.094	CARBONATE (CO3)	0.	0.0
SODIUM (NA)			CHLORIDE (CL)		
POTASSIUM (K)			SULFATE (SO4)		
IRON (FE)			FLUORIDE (F)		
MANGANESE (MN)			NITRATE (NO3 AS N)		
ALUMINUM (AL)			NO3+NO2 (TOT AS N)	.02	0.000
HYDROGEN (H+)	0.00	0.000	PHOSPHATE (PO4 AS P)	.005	0.000
TOTAL CATIONS		2.454	TOTAL ANIONS		2.440

LABORATORY PH	8.13	TOTAL HARDNESS AS CACO3	123
FIELD WATER TEMPERATURE (C)	14.0	TOTAL ALKALINITY AS CACO3	122
DISSOLVED SOLIDS CALCULATED		LAB TURBIDITY (JTU)	.6
LAB CONDUCTIVITY-UMHOS-25C		SODIUM ADSORPTION RATIO	

A D D I T I O N A L   P A R A M E T E R S

REMARKS: LAKE STUDY

EXPLANATION: MG/L=MILLIGRAMS PER LITER MEQ/L=MILLIEQUIVILENTS PER LITER
ALL CONSTITUENTS DISSOLVED (DISS) EXCEPT AS NOTED. TOT=TOTAL SUSP=SUSPENDED
(M)=MEASURED (R)=REPORTED (E)=ESTIMATED M=METERS TR=TOTAL RECOVERABLE

SAMPLE NO 3 SAMPLER JED HANDLING 3100 ANALYST ME LAB WQBH
COMPLETED 07-10-75 COMPUTER RUN 07/18/75 PROGRAM SYS 75 FUND 0650

		CA	MG	NA	K	CL	SO4	HCO3	CO3	NO3
STND DEV.	ION BALANCE -0.10									
SEGMENT	MPDES	55.4	44.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0

Food Item	Rainbow[1] 42 fish	Brook[2] 51 fish	% Composition of Diet (Points Method) Rainbow Trout 156-242mm	Rainbow Trout 297-349mm	Rainbow Trout 352-440mm	Brook Trout 140-228mm	Brook Trout 261-330mm	Brook Trout 302-346mm
Nematoda	T	T	T	T	T	--	T	T
Hirudinea	1.7	1.1	4.8	--	0.4	--	1.7	1.7
Mollusca	1.5	5.4	1.8	1.3	1.7	3.8	8.2	4.6
Daphnia	43.4	25.2	40.2	51.0	36.9	17.9	18.6	41.2
Copepoda	T	--	T	--	--	--	--	--
Hyalella azteca	19.8	29.7	33.3	13.0	13.1	43.6	20.8	17.3
Ephemeroptera	0.9	0.3	0.3	0.3	3.0	--	1.7	--
Odonata	5.0	13.4	11.3	3.1	0.4	T	17.7	17.3
Plecoptera	T	1.1	--	--	T	--	--	2.3
Hemiptera	0.2	--	--	0.5	T	--	--	--
Coleoptera	1.2	0.3	--	--	5.1	--	0.9	--
Trichoptera	1.1	6.8	0.3	0.5	3.0	--	9.5	8.4
Chironomidae	2.9	10.3	3.9	1.0	5.5	30.8	12.1	0.6
Chaoborus	0.8	--	T	T	3.4	--	--	T
other Diptera	0.1	--	--	0.3	T	--	--	--
terrestrial insects	2.5	--	--	3.6	4.2	--	--	--
fish scale	T	--	--	T	--	--	--	--
rocks	2.3	0.1	--	2.8	5.1	--	T	0.6
plant tissue	13.0	4.5	2.1	18.9	13.1	2.6	6.9	3.7
detritus, etc.	3.5	1.9	2.1	3.8	5.1	1.3	1.7	2.3

[1] No empty stomachs

[2] Six empty stomachs

Food Item	Rainbow 42 fish[1]	Brook 51 fish[2]	% Composition of Diet (Occurrence Method) — Rainbow Trout 156-252mm	Rainbow Trout 297-349mm	Rainbow Trout 352-440mm	Brook Trout 140-228mm	Brook Trout 261-330mm	Brook Trout 302-346mm
Nematoda	1.8	2.8	2.2	1.4	1.8	--	2.2	4.2
Hirudinea	0.6	2.8	2.2	--	1.8	--	4.3	2.8
Mollusca	5.5	7.6	8.7	4.1	3.5	10.0	6.5	8.3
Daphnia	20.9	20.7	17.4	21.9	17.5	20.0	19.6	23.6
Copepoda	0.6	--	2.2	--	--	--	--	--
Hyalella azteca	16.0	17.9	19.6	13.7	12.3	20.0	19.6	18.1
Ephemeroptera	4.3	1.4	2.2	5.5	5.3	--	4.3	--
Odonata	3.1	6.2	4.3	2.7	1.8	10.0	6.5	5.6
Plecoptera	1.2	0.7	--	--	3.5	--	--	1.4
Hemiptera	1.2	--	--	1.4	1.8	--	--	--
Coleoptera	0.6	0.7	--	--	1.8	--	2.2	--
Trichoptera	3.1	4.8	4.3	1.4	3.6	--	6.5	5.6
Chironomidae	9.8	9.6	10.9	6.8	12.3	25.0	6.5	8.3
Chaoborus	8.0	0.7	8.7	8.2	3.5	--	--	1.4
other Diptera	2.4	--	2.2	2.7	3.5	--	--	--
terrestrial insects	2.5	--	--	1.4	5.3	--	--	--
fish scale	1.2	--	--	2.7	--	--	--	--
rocks	1.8	2.1	--	2.7	1.8	--	2.2	4.2
plant tissue	7.4	16.6	8.7	13.7	10.5	10.0	10.9	12.5
detritus, etc.	8.0	5.5	6.5	9.6	8.8	5.0	8.7	4.2

[1] No empty stomachs

[2] Six empty stomachs

% Composition of diets of 20 rainbow trout collected from 15 February to 18 May 1975

Food Item	Points Method	Occurrence Method
Nematoda	T	1.7
Hirudinea	---	---
Mollusca	2.5	1.7
Daphnia	15.3	20.7
Copepoda	---	---
Hyalella azteca	3.7	12.1
Ephemeroptera	1.9	3.5
Odonata	0.6	3.5
Plecoptera	T	1.7
Hemiptera	---	---
Coleoptera	0.3	1.7
Trichoptera	T	1.7
Chironomidae	1.9	8.6
Chaoborus	5.9	10.3
other Diptera	T	1.7
bait (corn)	38.3	8.6
plant tissue	23.4	13.8
detritus, etc.	6.2	8.6