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A LIMNOLOGICAL SURVEY OF PAXSON AND SUMMIT LAKES IN INTERIOR ALASKA

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A LIMNOLOGICAL SURVEY OF PAXSON AND SUMMIT LAKES IN INTERIOR ALASKA[1/]

With Special Reference to the Lake Trout and Lake Whitefish

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INTRODUCTION

A survey of Summit and Paxson Lakes was initiated by the Alaska Department of Fish and Game, Sport Fish Division, in 1962. The objectives of the survey were: (1) evaluate the potential lake trout (Salvelinus namaycush) sport fishery, (2) determine the possibility of a commercial whitefish fishery, (3) gather information on growth rates and age of maturity for these fish in Interior Alaska, and (4) provide limnological information for management of these populations.

Lake trout and whitefish populations are found scattered throughout Interior Alaska lakes. The importance of the lake trout as a trophy sport fish has become very evident in the past five years while the economic value of the whitefish has not as yet been determined.

Little prior information of these fishes is available for this region. Additional data on the life history of the round whitefish (Prosopium cylindraceum) was collected in conjunction with, but not presented in this study and was reported in the form of a thesis written as partial fulfillment of the require-

1/ This work was carried out under Dingle-Johnson Federal Aid to Fish Restoration, Project No. F-5-R-3 Job B between the dates of June 1, 1962 and May 1, 1964.

ments for a Master of Science Degree from the University of Michigan[2/].

LOCATION AND DESCRIPTION OF THE STUDY AREA

Paxson and Summit Lakes lie at the head of the Gulkana River in the Copper River Basin. This basin is located in southcentral Alaska at approximately latitude 63° N and longitude 145° W, between the 2,600 and 3,300 foot elevations, and drains into the Gulf of Alaska, Figure 1.

Historically, both Paxson and Summit Lakes were formed as a result of Pleistocene glaciation. Glaciers in the Chugach Mountains dammed the Copper River forming a large lake within the Copper River Basin. The present lakes and river valleys were carved out of deposited sediment after retreat of the ice and drainage of the Copper River Basin. Between the river valleys, muskeg and marshes occupy depressions in the poorly drained, permanently frozen old lake floor. The soil type surrounding both lakes is glacial moraine. The rock type is sedimentary in origin which, in many cases, has become metamorphosed. Paxson and Summit Lakes drain an area of approximately 3,000 square miles in the southern foothills of the Alaska Range. Tributaries are short, clearwater streams. Summit Lake is drained by the Gulkana River which flows into Paxson Lake 15 miles downstream.

LIMNOLOGY OF THE LAKES

Physical Characteristics

Morphometry of Paxson Lake. Paxson Lake has a surface area of 6.08 square miles, is 10.3 miles long, and has a maximum width of 0.9 miles. The maximum depth is 89 feet, and the mean depth is 35 feet.

Paxson Lake exhibits a regular basin type bottom (Figure 2). The total area between shore and the outer extreme of the 40-foot depth zone is 3.68 square miles or 60 percent of the total surface area. The greater part of the shoal area lies in the southern portion of the lake toward the outlet.

2/ Peck, James W. A comparative study of the growth of the round whitefish, Prosopium cylindraceum, in the Copper River Drainage, Alaska. 53 pages.

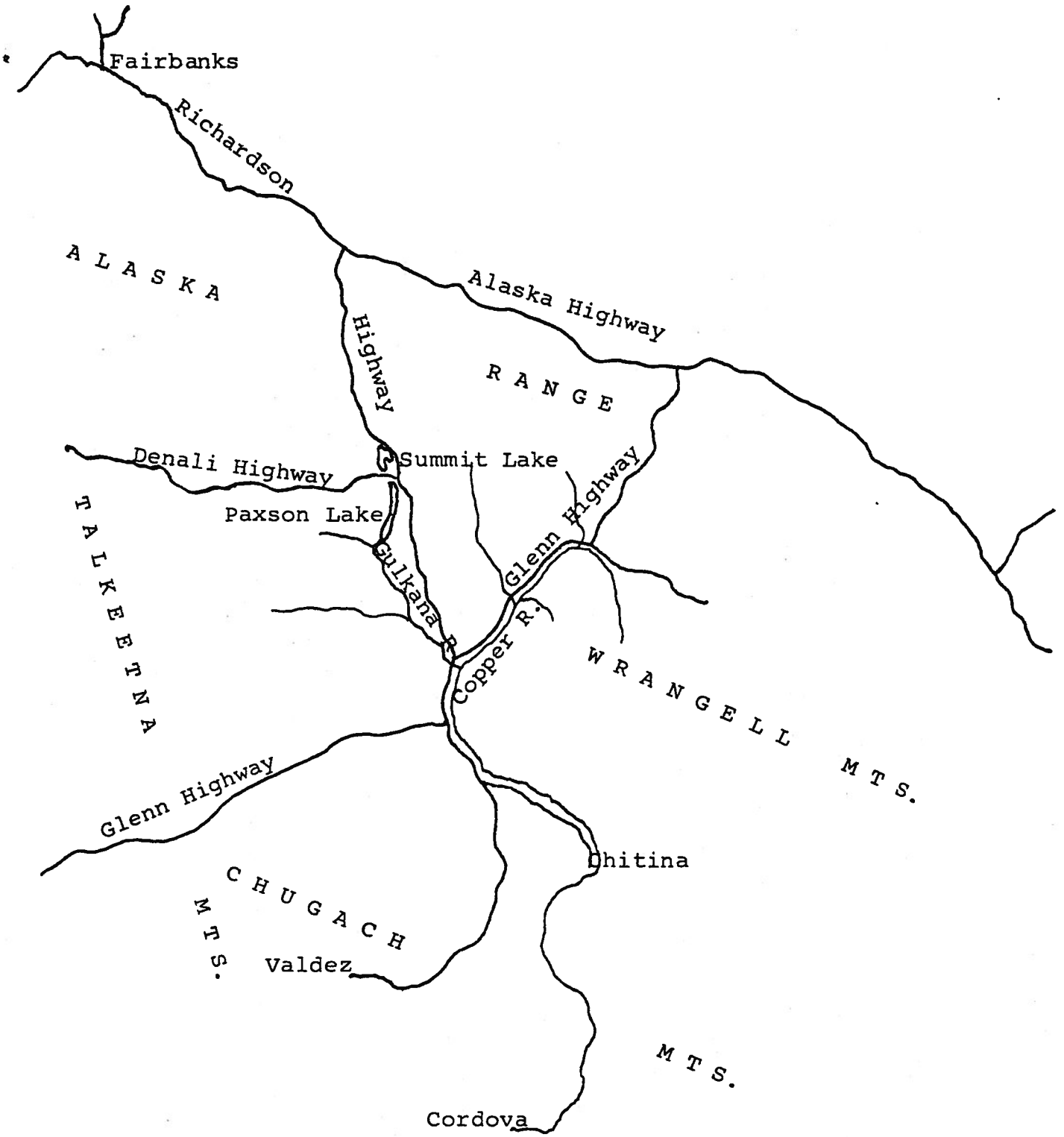


FIGURE 1. PORTION OF STATE OF ALASKA SHOWING STUDY AREA.

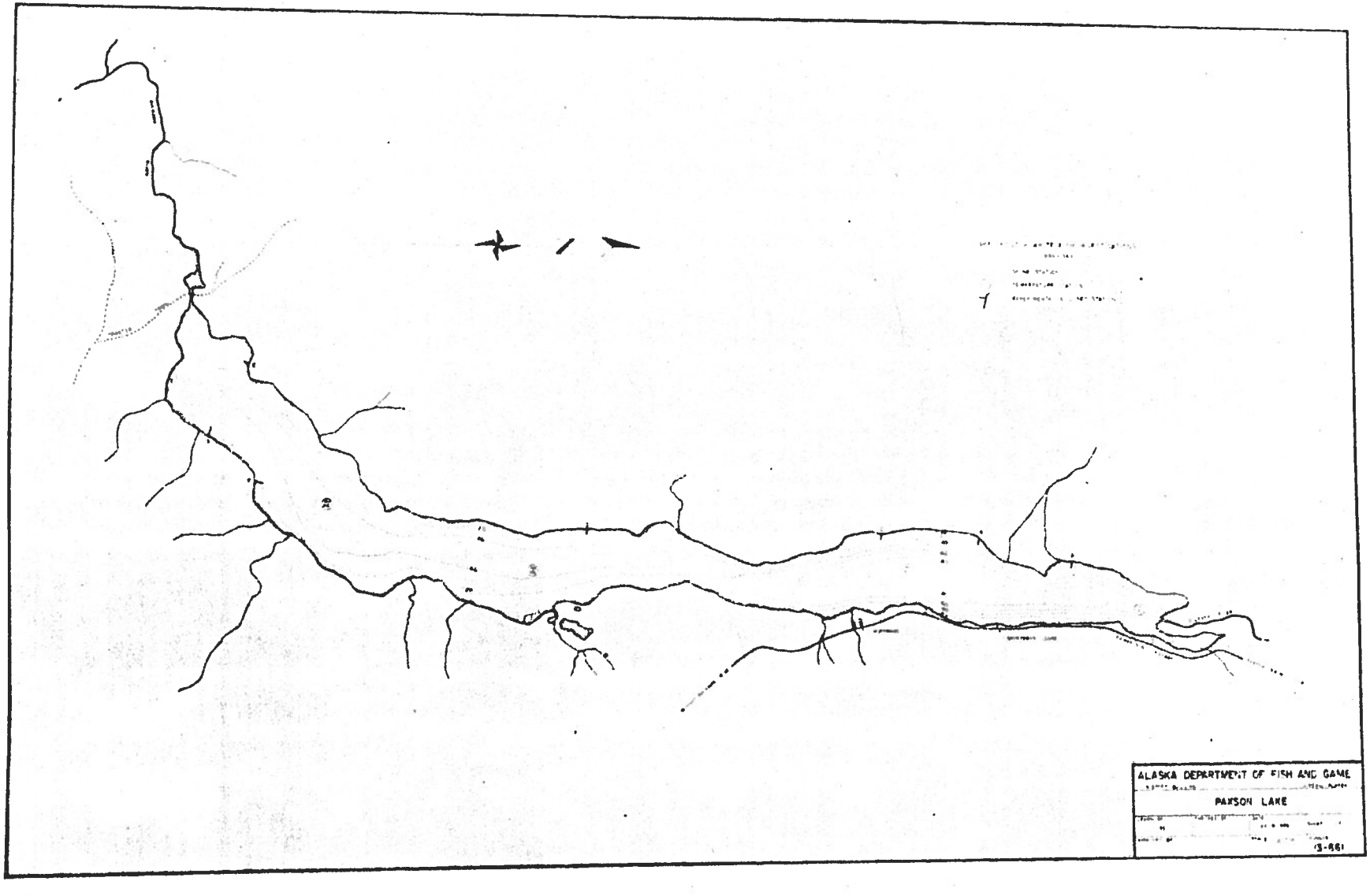


Figure 2. Paxson Lake contour map. Roman numerals indicate sampling stations.

The shore line of Paxson Lake is quite regular and consists of sedimentary rocks which, in many cases, have become metamorphosed. The substrate above 20 feet is composed principally of sedimentary rocks to 2 inches in diameter, interspersed with sand and some organic debris. Below 20 feet, the substrate is chiefly clay with traces of organic debris.

Morphometry of Summit Lake. Summit Lake has a surface area of 6.38 square miles, is 7.1 miles long, and has a maximum width of 1.1 miles. The maximum depth is 214 feet and the mean depth is 70 feet.

Summit Lake has both an irregular shoreline and very irregular bottom as shown in Figure 3. The total area between shore and the outer extreme of the 40-foot depth zone is 3.50 square miles or 55 percent of the total surface area. The greater part of the shoal areas are in the southern portion of the lake. Diversion of glacial streams in 1929, fed by the Gulkana glacier out of Gunn Creek, resulted in a clearing of the lake waters.

The drainage basin has a typical arctic continental weather regime with mild to warm summers and severe winters. The mean maximum temperature is 37.3° F, and the mean minimum is 16.6° F. The mean annual temperature is 27.2° F. Ice is usually present on both lakes from early November until early June and may obtain a thickness of 36 inches (U.S. Weather Bureau records). Mean annual precipitation is 11.7 inches and the mean annual snowfall is 48.6 inches. Seasonal variation in the amount of daylight varies from 20 hours in June to less than 5 hours in December, giving a general frost-free period of about 67 days. Paxson Lake, which is below tree line, possesses a brushy to wooded shoreline with alder and willow being the dominant brush forms and spruce and aspen being the dominant tree forms.

Summit Lake is above the tree line, which for this area is about the 3,000-foot elevation. The shoreline vegetation is restricted to willow and alder brush with tundra-type ground cover. Part of the east shore is formed by the Richardson Highway road bed and lacks vegetation entirely.

Most of the exposed shoreline is composed of rocks ranging in size from 2 inches to 2 feet in diameter. The substrate above 20 feet is chiefly composed of larger rubble. Some sand and rocks to 2 inches in diameter are present. Organic material is present in only small quantities in the very shallow waters of the north and southeast ends. Generally, the substrate below 20 feet is rock or clay deposited by glacial outwash.

As shown in Table 1, Summit and Paxson Lakes are very similar, the

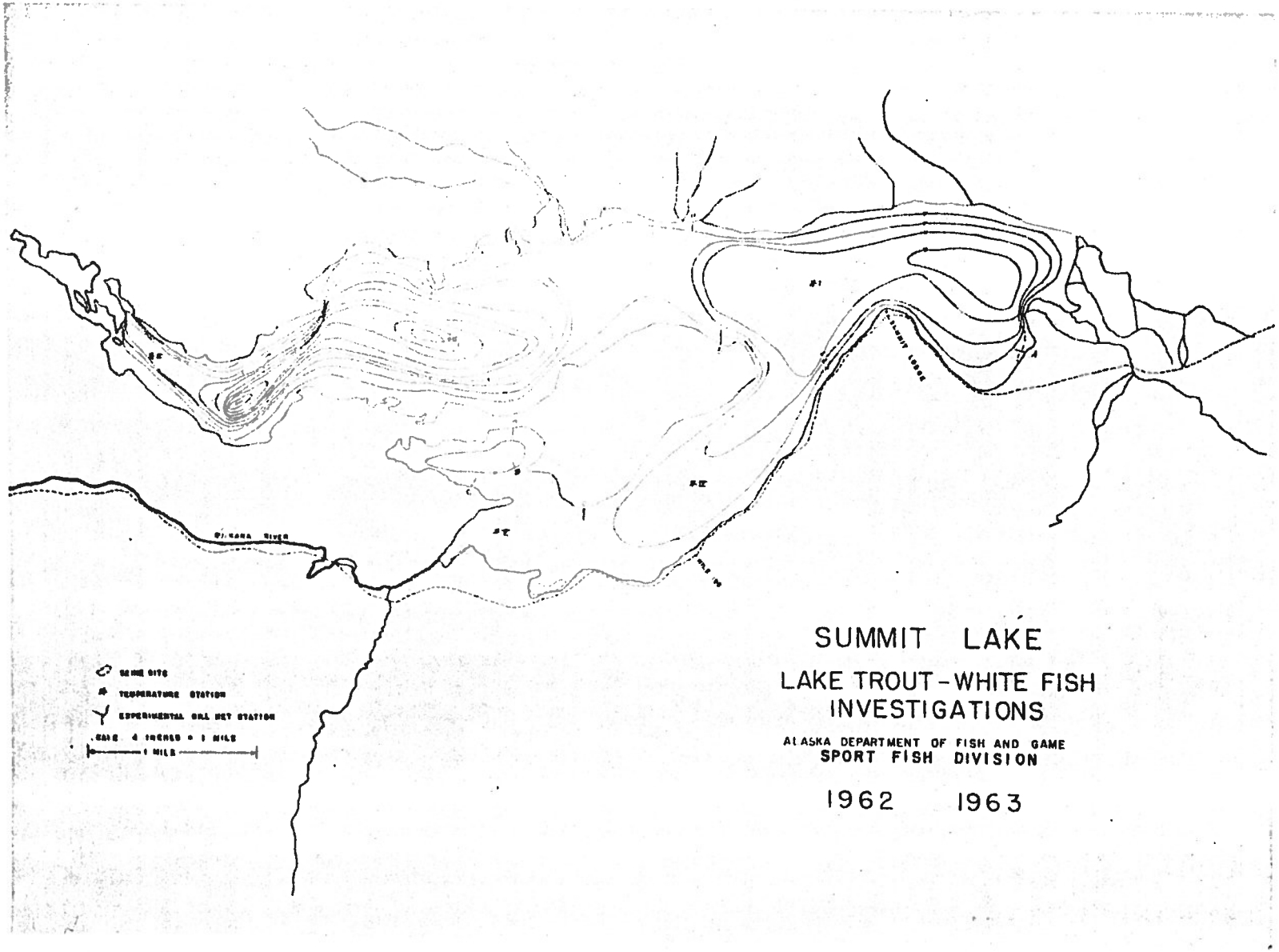


Figure 3. Summit Lake contour map. Roman numerals indicate sampling stations.

TABLE 1. LAKE MORPHOMETRY DATA, PAXSON AND SUMMIT LAKES.

	Paxson Lake	Summit Lake
Elevation	2,600 ft.	3,300 ft.
Area	6.08 sq. mi.	6.38 sq.mi.
Maximum width	0.9 mi.	1.1 mi.
Maximum length	10.3 mi.	7.1 mi.
Maximum depth	89 ft.	214 ft.
Mean depth	35 ft.	70 ft.
Percent bottom area less than:		
20 ft. depth	29%	32%
40 ft. depth	60%	55%
60 ft. depth	86%	64%
80 ft. depth	92%	85%
100 ft. depth	--	91%
120 ft. depth	--	94%
140 ft. depth	--	97%
160 ft. depth	--	98%
180 ft. depth	--	99%
200 ft. depth	--	99%

main differences being in total volume of water and depths, Summit Lake being the greater of the two. Summit Lake has a mean depth of twice that of Paxson Lake, but the percent of shoal areas is practically the same.

Temperature - Paxson Lake. Two temperature stations were maintained in 1963. Data were collected six times between June 30 and August 9, 1963. Temperature profiles are shown in Figures 4 and 5. The data indicated that this lake does not distinctly stratify during the summer months. However, on July 4, a distinguishable thermocline was present at Station II, but not at Station I. This thermocline disappeared three days later and may reflect a temporary abatement of prevailing winds. The absence of stratification at Station I on July 4 may be due to the proximity of this station to the Gulkana River inlet. Warmer temperatures penetrated to greater depths later in the summer.

Paxson Lake, due to its location, shape and orientation to prevailing winds, is subject to continual turnover during its ice-free period. Based on observations by local residents, ice forms about the first of November and the break-up occurs during the first or second week of June. In 1962, freeze-up occurred between November 4 and 9. The date of freeze-up in 1963 is not known.

Temperature - Summit Lake. Two temperature stations were maintained in 1963. Data were collected five times between July 2 and August 13. Temperature profiles are shown in Figures 6 and 7. Data collected on July 2 immediately following spring break-up implied the presence of inverse stratification. The data are insufficient to be conclusive and no winter temperature data were collected to support this implication. However, it is quite probable, based on studies of lakes at this and other latitudes with similar climatic conditions, that both Paxson and Summit Lakes experience some degree of inverse stratification during their periods of ice cover. A weak thermocline was evident on July 9 at Station II. This thermocline disappeared prior to July 21.

Prevailing winds blow along the long axis of Summit Lake. Although its fetch is less than that of Paxson Lake, Summit Lake is located above the tree line and is more exposed; therefore, it should experience vertical mixing of at least the magnitude found in Paxson Lake.

Transparency. Light penetration was measured with the standard Secchi disc and was made in conjunction with plankton sampling. Readings in Paxson

FIGURE 4. WATER TEMPERATURES IN PAXSON LAKE, 1963

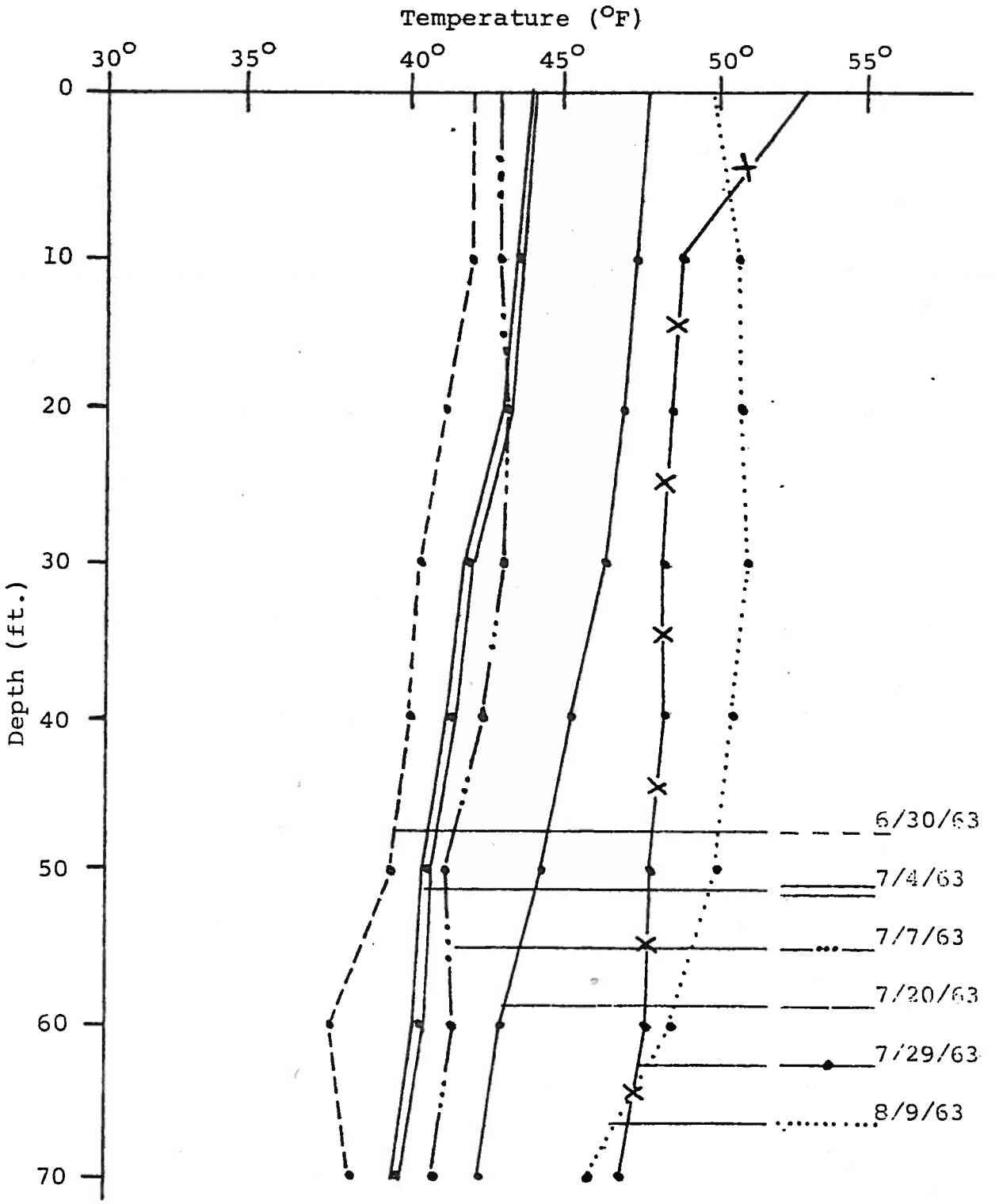


FIGURE 5. WATER TEMPERATURES IN PAXSON LAKE, 1963

Station II

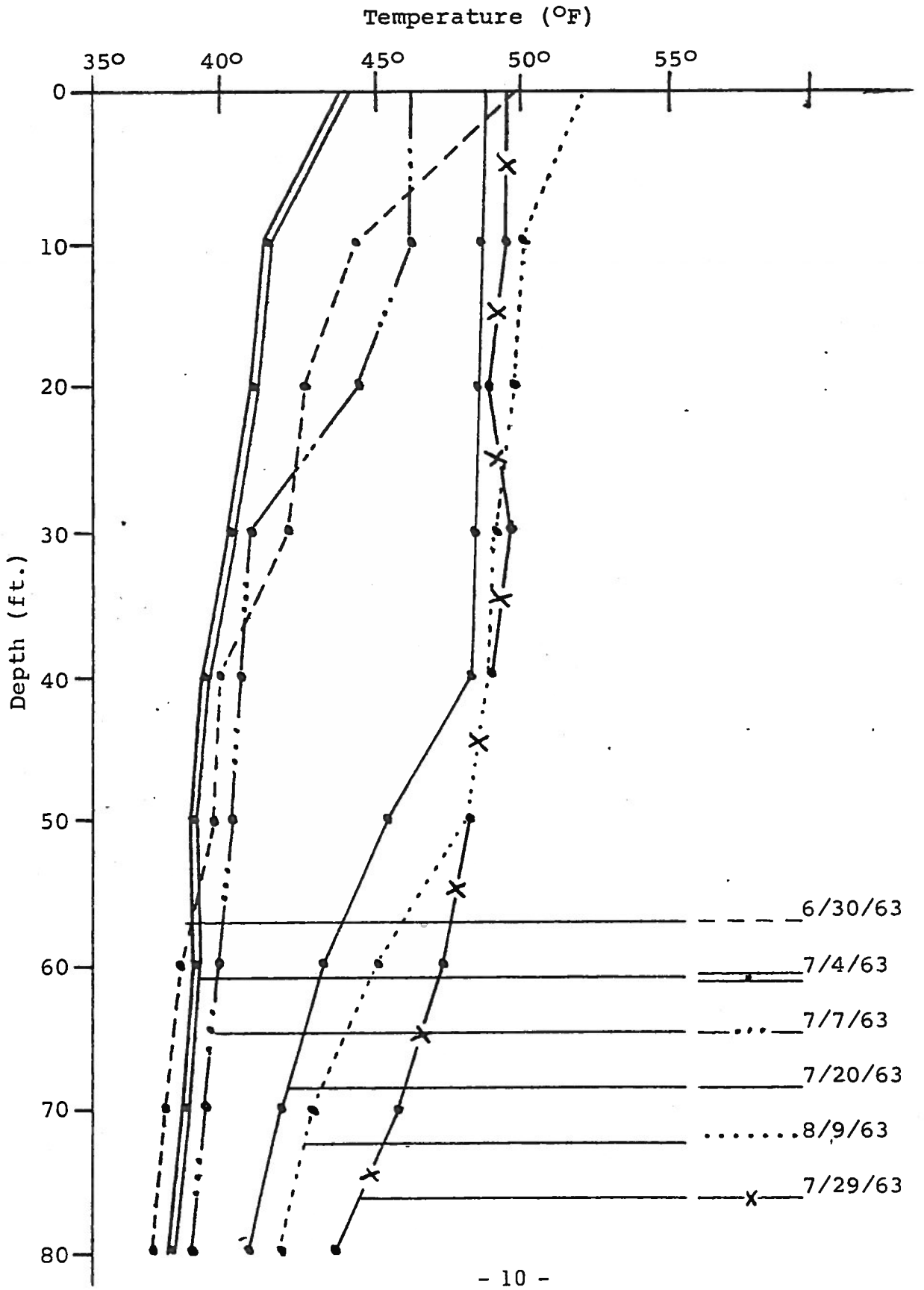


FIGURE 6. WATER TEMPERATURES IN SUMMIT LAKE, 1963

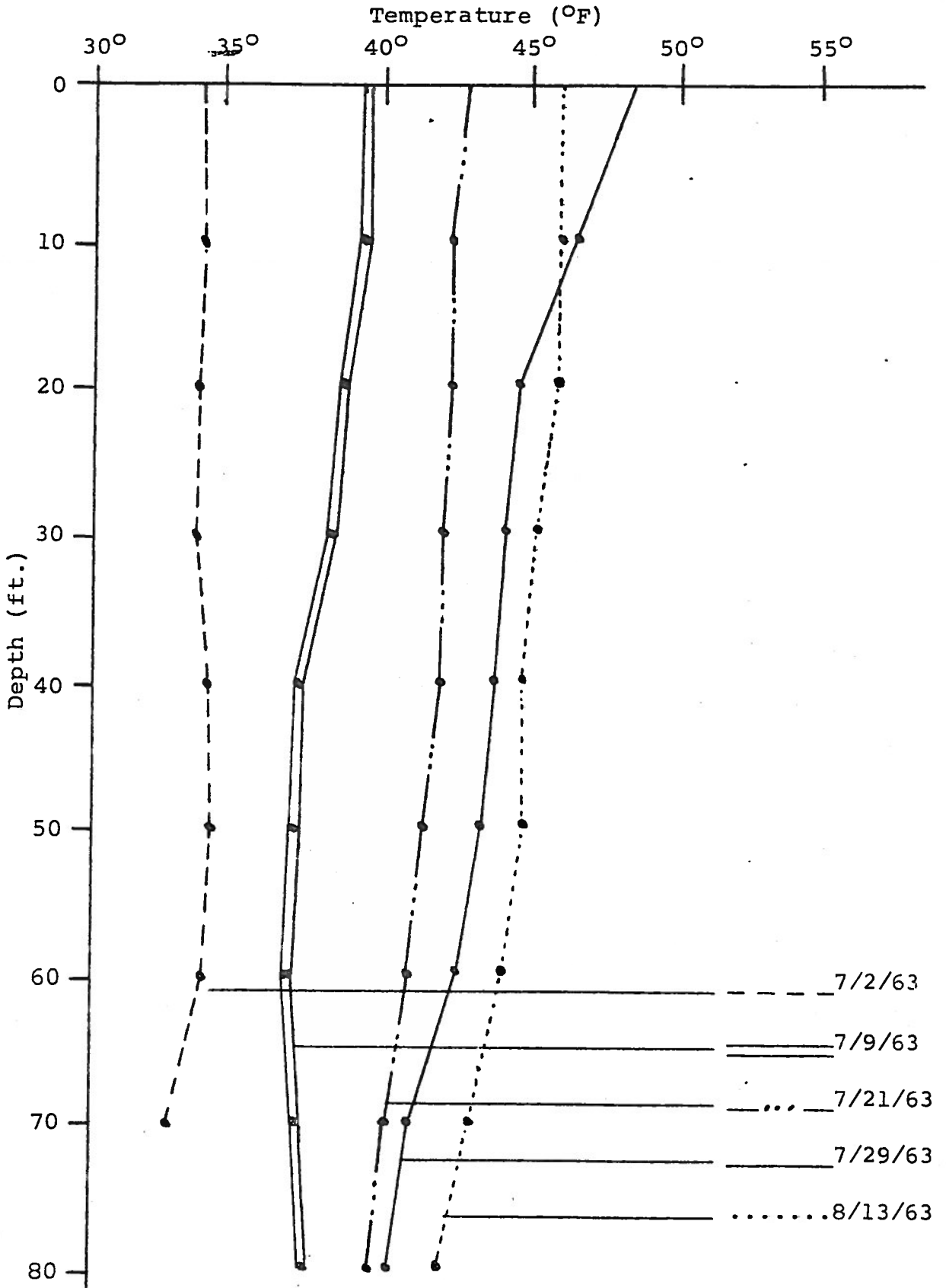
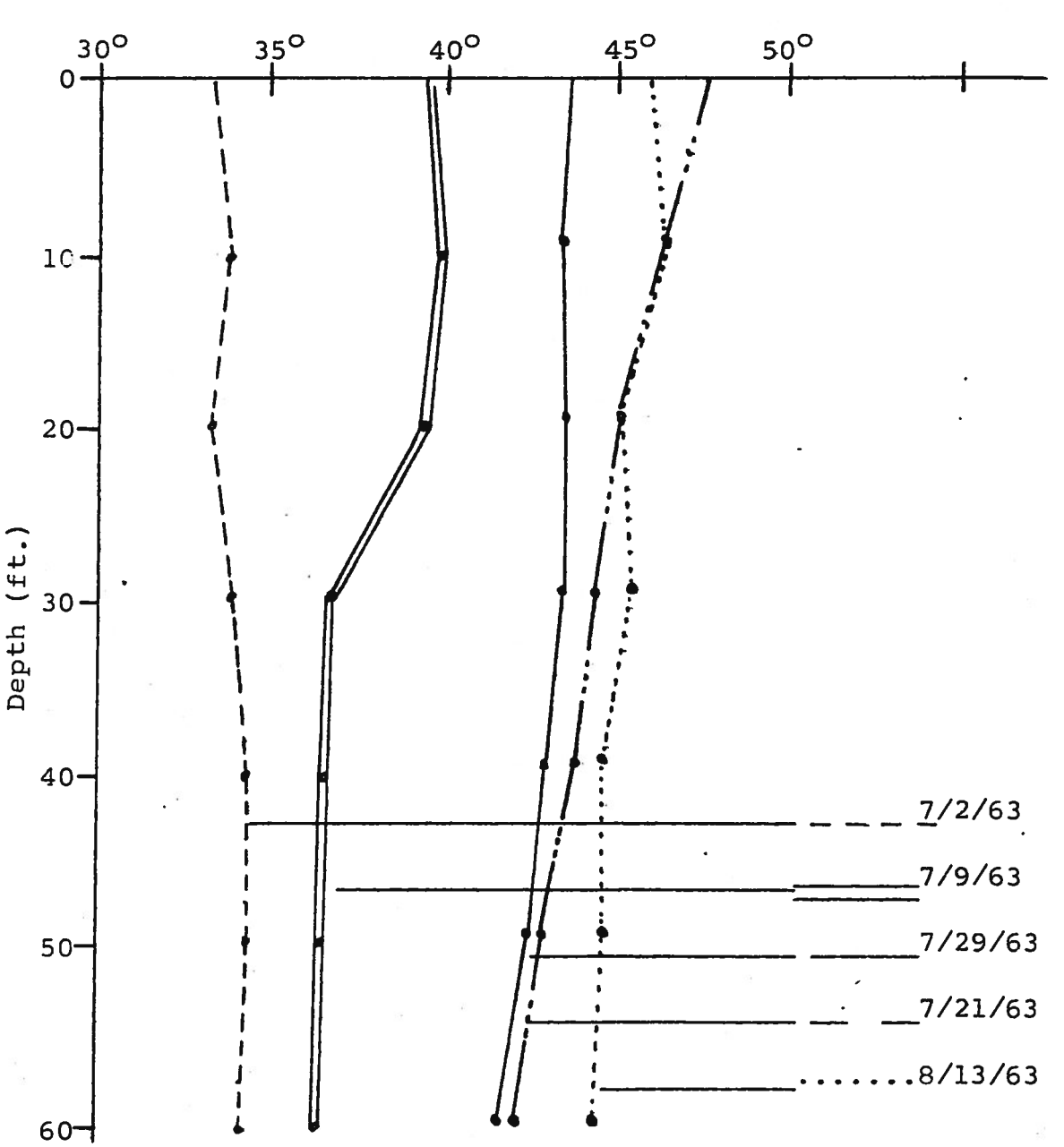


FIGURE 7. WATER TEMPERATURES IN SUMMIT LAKE, 1963

Station II



Lake ranged from 10 to 14 feet. Summit Lake was more variable, with readings ranging from 5 to 18 feet. Decreased transparency resulted from turbidity fluctuations, as no correlation was observed between Secchi disc values and the quantity of plankton collected. The highest turbidity in Summit Lake was observed following a period of high winds which could have produced sufficient mixing to bring up the fine bottom sediments. In addition, Gunn Creek, the principal inlet, brings variable amounts of melt water from Gulkana Glacier into Summit Lake.

Chemical Characteristics

To obtain a quantitative chemical analysis of Paxson and Summit Lake waters, samples were sent to the University of Alaska for analysis. Samples were collected at the five-foot depth in the center of both lakes on October 23, 1963 and at that time, it was believed both lakes had experienced complete mixing. Therefore, the data as shown in Table 2 should be representative of the entire lake.

The chemical characteristics indicated that both lakes are soft water lakes; both experiencing slow buffering. The lack of sufficient carbonate in Paxson Lake is the probable cause of the high CO_2 content which may have been a temporary condition due to the fact that the pH was alkaline. Both lakes exhibited the high bicarbonate content which is characteristic of soft water lakes.

Biological Characteristics

Plankton. Table 3 presents the results of plankton sampling conducted in both Paxson and Summit Lakes during the summer of 1963. Plankton was collected in 40-foot vertical hauls, using a Wisconsin type plankton net with Number 25 silk bolting cloth mesh. Plankton collections were made in conjunction with temperature data collections in both lakes. The specific location of sampling stations are noted in Figures 2 and 3. The mean settled volume of plankton per samples from Paxson Lake was twice that of those examined from Summit Lake.

Two types of phytoplankton, Ceratium and Dinobryon, were found in Paxson Lake, but not in Summit Lake. The zooplankter Polyarthra was poorly represented in the Paxson Lake samples and was not found in samples from Summit Lake. It was observed that each organism present in both lakes was represented by a larger number of individuals in Paxson Lake.

TABLE 2. WATER ANALYSIS OF PAXSON AND SUMMIT LAKES, OCTOBER, 1963

	Summit	Paxson
O_2	9.4 ppm	8.1 ppm
CO_2	0.0 ppm	5.5 ppm
pH-th alkalinity	9.0 ppm	0.0 ppm
M.O.	50.0 ppm	64.0 ppm
Total alkalinity	59.0 ppm	64.0 ppm
pH	7.8	7.4
NH_4 Nitrogen	0.07 ppm	0.07 ppm
NO_2 + NO_3 Nitrogen	0.00 ppm	0.02 ppm
PO_4	0.12 ppm	0.10 ppm
Fe	0.00 ppm	0.46 ppm
SO_4	3.00 ppm	0.09 ppm
Tannin	0.10 ppm	0.00 ppm
Turbidity	0.00 ppm	2.00 ppm

TABLE 3. PLANKTON SAMPLE ANALYSIS, PAXSON AND SUMMIT LAKES, 1963[1]

PAXSON LAKE				SUMMIT LAKE			
Date	Station	Mean Settled Volume (cc)	Forms Present	Date	Station	Mean Settled Volume (cc)	Forms Present
7/7	IV	1.48	Phytoplankton	7/8	V	0.40	Phytoplankton
7/20	III	0.95	Asterionella*	7/21	II	0.20	Asterionella*
7/20	II	0.73	Ulothrix*	7/21	V	0.15	Ulothrix*
7/29	III	0.53	Coelosphaerium	7/29	V	0.45	Microcystis*
7/29	II	0.45	Microcystis	7/29	II	0.70	Coelosphaerium
8/9	III	0.30	Ceratium	8/13	V	0.17	Anabaena
8/9	II	0.45	Dinobryon	8/13	II	0.35	Actinastrum
			Aphanizomenon				Zooplankton
	TOTAL	4.89	Anabaena		TOTAL	2.42	Keratella
			Zooplankton				Kellicottia
			Copepoda*				Copepoda*
			Nauplius larvae*				Nauplius larvae
			Polyarthra				
			Kellicottia				
			Keratella				

1 Each sample based on two, 40-foot vertical hauls.

* Most abundant forms.

Benthic Fauna. A total of 40 bottom samples was taken in the two lakes using an Ekman dredge 22.8 cm by 22.8 cm in cross section. Samples were obtained from various depths in the north, east, and west portions of Summit Lake and the north, south, and east portions of Paxson Lake. Table 4 and 5 present results of the dredgings in the two lakes.

Chironomidae larvae were the most abundant forms in both lakes. In Summit Lake, Trichoptera and a clam, Pisidium sp., were also abundant. In Paxson Lake, other abundant forms were various oligochaetes, the gastropod Gyralus sp., and Pisidium sp.

Compared to Summit Lake, the benthic fauna of Paxson Lake was richer in numbers and types of organisms. The only exception was the relative abundance of Trichoptera in Summit Lake. The greater abundance of oligochaeta and the presence of hirudinea and amphipods in Paxson Lake reflected the more organic nature of its substrate, as opposed to the fine clay in Summit Lake.

Although not confirmed by measurement, individual organisms were observed to be larger in Paxson Lake than in Summit Lake. This difference in size was best illustrated by the mollusks where shells of Paxson Lake mollusks were heavier than those in Summit, indicating a greater supply of carbonates.

Except for Chironomidae larvae in Paxson Lake, the majority of organisms occurred at depths of 20 feet or less. Chironomidae larvae in Paxson Lake were most abundant at 60 feet, while maximum abundance in Summit Lake occurred at 10 feet. In both temperature and substrate type, the sixty-foot depth in Paxson Lake was similar to the ten-foot depth in Summit Lake.

Rooted Aquatic Vegetation. Potamogeton is the major plant type in both lakes, being represented by a number of different species. Rooted aquatic plants are very scarce in Summit Lake and are restricted to the north and southeast shoal areas. Rooted vegetation is so sparse in Summit Lake that it should have almost no affect on the environment.

Paxson Lake has abundant aquatic vegetation on every shoal except those which are subjected to severe wave action. Potamogeton and Myriophyllum are the most abundant forms, providing a distinct habitat type.

Although no measurements of plant growth were made, early summer growth was extremely slow. Apparently a temperature threshold was reached in late summer after which plant growth proceeded rapidly. Accelerated growth

TABLE 4. BOTTOM FAUNA, PAXSON LAKE, AUGUST 1963
GIVING ORGANISM TYPE AND AVERAGED FREQUENCY OF OCCURRENCE

Average Number of Organisms Per Square Meter

pth t.)	Chironomidae	Oligochaeta	Amphipoda	Hirudinea	Diptera (Adult)	Trichoptera	Ostracoda	Lymnea sp.	Gyralus sp.	Pisidium sp.	Total Per (depth
1	153	77	--	3	3	23	17	21	330	303	930
10	30	197	57	17	-	60	--	60	247	153	821
	157	221	--	--	-	51	--	3	17	47	496
	40	80	--	--	-	--	--	10	---	---	130
	790	80	--	--	-	--	--	--	10	10	890
TALS	1170	655	57	20	3	134	17	94	604	513	3267
RCENT	35.8	20.0	1.7	0.6	0.1	4.1	0.5	2.9	18.5	15.7	

TABLE 5. BOTTOM FAUNA, SUMMIT LAKE, AUGUST 1963
GIVING ORGANISM TYPE AND AVERAGED FREQUENCY OF OCCURRENCE

Average Number of Organisms Per Square Meter

Depth (ft.)	Chironomidae	Oligochaeta	Diptera	Trichoptera	*Lymnea sp.*	*Gyralus sp.*	*Pisidium sp.*	Total Per Depth
2-5	3	41	3 adult	20	3	3	33	106
7-10	605	40	---	90	45	65	205	1050
20	220	--	5 pupae	125	45	70	85	550
40	---	--	30 pupae	170	--	--	---	200
60	20	--	20 pupae	100	--	--	---	140
TOTALS	648	81	58	505	93	138	323	2046
PERCENT	41.4	4.0	2.8	24.7	4.5	6.7	15.8	

was observed during the last week in July, 1963. At that time, water temperatures in the shoal areas ranged from 48.5° to 52.5° F.

Fish

Sampling Methods. Fish populations were sampled by variable mesh gill nets and by bag seine. The variable mesh gill nets were 125 feet long and 6 feet deep, consisting of 5 panels 25 feet in length, with mesh size varying from 1 to 3.5 inches stretch measure.

In an effort to reduce sampling bias, net sets were made along the shorelines at predetermined locations with the small mesh toward shore. As a result of differences in bottom contour, the larger mesh sampled at various depths. The bag seine was 50 feet long and 6 feet deep with one-half inch bar mesh. Sampling was done throughout the season to collect the young-of-the-year fish.

Because sampling was intensive, 787 hours in Paxson Lake and 677 hours in Summit Lake, it was doubtful that any species in the two lakes were not represented in the catch.

Relative Abundance. Red salmon (Oncorhynchus nerka) spawn in the east fork of the Gulkana River and in tributaries above and below Paxson Lake. There is also limited red salmon spawning in Gunn Creek, the inlet of Summit Lake. Adult salmon first appear in the two lakes soon after the ice cover disappears. In 1962, spawning continued into October. Adult red salmon were taken incidentally in the variable mesh gill net catches and were much more numerous in Paxson Lake than in Summit Lake.

Both Paxson and Summit Lakes have a year-round population of juvenile red salmon. These fish were abundant and comprised the majority of the bag seine catches during August and September. Apparently most of the salmon fry were too small to be captured in the seine until August.

The slimy sculpin (Cottus cognatus) was found to be equally numerous in both lakes. Although it was larger and darker in Paxson Lake, none longer than 100 mm were observed in either lake. This species inhabits shallow waters and was readily captured with the bag seine.

A single long-nosed sucker (Catostomus catostomus) was captured in Paxson Lake. The resident population of this species was very sparse.

Both lakes have small populations of burbot (Lota lota). Only small individuals were taken, as the gear was unsuitable for taking the larger individuals.

A few grayling (Thymallus arcticus) were taken from the shallower waters of both lakes. In Paxson Lake, the catch was restricted to the south end and near the outlet. In Summit Lake, the catch was more widespread.

The lake whitefish (Coregonus clupeaformis) was not found in Summit Lake, but was abundant in Paxson Lake. The rapid fall of the Gulkana River between the two lakes may be a factor preventing the easy entry of lake whitefish into Summit Lake. The young-of-the-lake whitefish were taken in the bag seine only during the early part of July. Later that month they completely disappeared from the catch. This disappearance was apparently due to a migration to deeper water and may be correlated to a rise in surface water temperature. Larger individuals were taken throughout the summer in gill nets. This species is taken occasionally on hook and line and supports a small, local, subsistence net fishery during the late fall and early winter.

The round whitefish (Prosopium cylindraceum) was found in both lakes. Young of the round whitefish were taken by bag seine throughout the summer with the largest catches being made at night. Individuals of age 4 or older were taken in gill nets throughout the summer. This species is also taken occasionally by hook and line, and supports a small, local, subsistence net fishery when they move into the streams in the late fall to spawn.

The lake trout (Salvelinus namaycush) was present in both lakes. This species supports a relatively intense fishery during the summer months. Paxson Lake receives heavier fishing pressure due to its good reputation and available boat facilities. No lake trout were taken by bag seine.

Relative population data were collected for lake trout, two species of whitefish, grayling, and burbot on a catch per unit effort basis. Table 6 and 7 indicate a summary of gill net sampling in both lakes. To reduce fouling of the variable mesh gill nets by adult red salmon, no gill net sampling was conducted in Summit Lake before August 20, or in Paxson Lake before September 6. By these dates, adult red salmon were no longer present in the lakes in any appreciable numbers.

The data indicated that lake trout populations in these lakes constituted a very similar percentage of each lake's fish population. Catch per unit effort for lake trout in Summit Lake was slightly greater than in Paxson Lake and a greater catch per unit effort was achieved for grayling in Paxson Lake than in

TABLE 6. CATCH SUMMARY - PAXSON LAKE, 1962

Unit of gear: Variable mesh gill net 125' x 6'
Mesh: 1" - 3-1/2" stretch mesh

Total hours fished: 787

Total fish caught: 1,084

Total catch/unit effort: 1.377

Species	Number Taken	Catch/Unit Effort	% Comp.
Lake Whitefish (Coregonus clupeaformis)	527	0.670	48.6
Round Whitefish (Prosopium cylindraceum)	405	0.515	37.4
Lake Trout (Salvelinus namaycush)	101	0.128	9.3
Grayling (Thymallus arcticus)	45	0.057	4.2
Burbot (Lota lota)	6	0.008	0.6

One longnose sucker (Catostomus catostomus) was taken on September 20, 1962, in Paxson Lake, but not in the above series of net sets.

Red salmon (Oncorhynchus nerka) and slimy sculpin (Cottus cognatus) have been omitted from both the table and the catch per unit effort computation.

NOTE: Catch per unit effort defined as number of fish taken per hour of fishing with above defined unit of gear.

TABLE 7. CATCH SUMMARY - SUMMIT LAKE, 1962

Unit of gear: Variable mesh gill net 125' x 6'
Mesh: 1" - 3-1/2" stretch mesh

Total hours fished: 677.5

Total fish caught: 995

Total catch/unit effort: 1.469

Species	Number Taken	Catch/Unit Effort	% Comp.
Round Whitefish (*Prosopium cylindraceum*)	880	1.318	88.4
Lake Trout (*Salvelinus namaycush*)	106	0.156	10.7
Grayling (*Thymallus arcticus*)	5	0.007	0.5
Burbot (*Lota lota*)	4	0.006	0.4

Red salmon (*Oncorhynchus nerka*) and slimy sculpin (*Cottus cognatus*) have been omitted from both the table and the catch per unit effort computation.

NOTE: Catch per unit effort defined as number of fish taken per hour of fishing with above defined unit of gear.

Summit Lake. The catch per unit effort of burbot was approximately the same for both lakes, but sample sizes were too small to afford meaningful comparisons.

The round whitefish population of Summit Lake was more than twice that of Paxson Lake. This difference is perhaps a result of competition in Paxson Lake between the two species of whitefish for food, space, or other resources. The round whitefish population of Summit Lake was approximately equal to both species of whitefish in Paxson Lake.

ECOLOGY OF LAKE TROUT AND WHITEFISH

Age Determination

Methods. Age and growth determinations were completed on lake trout and round whitefish from both Paxson and Summit Lakes, and lake whitefish from Paxson Lake.

All captured lake trout were used for age determinations. Sample sizes totaled 106 specimens from Summit Lake and 101 specimens from Paxson Lake. Due to manpower and budgetary limitations, it was decided to limit the study sample of lake whitefish to the first 150 specimens captured. Age determinations were completed on 597 round whitefish from Summit Lake and 412 from Paxson Lake. Larger samples of round whitefish than lake whitefish were used as data were also being prepared for a Masters thesis on the age and growth of round whitefish. Scales used in the growth analysis were taken midway between the lateral line and the origin of the dorsal fin on the left side of the body. Plastic impressions of whitefish scales were made using a cold-press technique. Plastic impressions of lake trout scales were made using both hot-press and cold-press techniques. Optimum results were obtained using the cold-press technique.

Four scales from each fish were used as a sample. Of the four, two scales of uniform shape and characteristics were chosen. Measurements were made on both scales and the results were averaged.

Age determinations were made on a Bausch and Lomb model 42-63-58 micro-projector. A 2.7x lens was used for the whitefish scales and a 12x lens was used for the lake trout scales.

Growth was calculated by the formula $L_n = (Lt/St)\ S_n$, where

L_n = fork length of fish at nth year of life

L_t = fork length of fish at time of capture

S_t = distance from scale focus to posterior margin

S_n = distance from scale focus to nth annulus.

The use of this direct proportion formula is justified by the straight-line relationship which was found to exist between the average fork length and the average scale radius for each age group. Some deviation from this relationship was observed in older age groups of lake trout, but this deviation included only about 10 percent of the fish in the samples.

Year Class Composition. Figures 8, 9, and 10 present a summary of year class composition for lake trout and both species of whitefish. The selectivity of the gear is illustrated by the low frequency of the younger age groups of all species.

It is interesting that the frequency of round whitefish of Age-class VI was sharply reduced in both lakes (Figure 10). Since the bulk of the samples was composed of individuals from ages IV-IX, gear selectivity can be disregarded. Therefore, age class VI may reflect a spawning year of unusually poor survival.

Growth in Length

The increment of yearly growth for lake trout in Summit and Paxson Lakes is tabulated in Tables 8 and 9. In addition, a comparison of lake trout growth is shown in Figure 11. As shown, growth was generally slower in Summit Lake than in Paxson Lake. To age V, growth rates were similar, though slightly slower in Summit Lake. During these years, the young lake trout feed primarily on insects and mollusks. The small difference in growth, to age V, may be correlated with the more abundant invertebrate fauna in Paxson Lake.

From ages V through IX, growth was much more rapid in Paxson Lake. This difference in growth, after the lake trout have shifted to a fish diet, is probably correlated to the greater number of small fish in Paxson Lake. As noted in the food habits section presented later, red salmon fry were utilized extensively by Paxson Lake lake trout; while in Summit Lake, where red salmon fry were much

FIGURE 8. AGE COMPOSITION OF LAKE TROUT IN PAXSON AND SUMMIT LAKES, 1962, AS CALCULATED FROM GILL NETTING

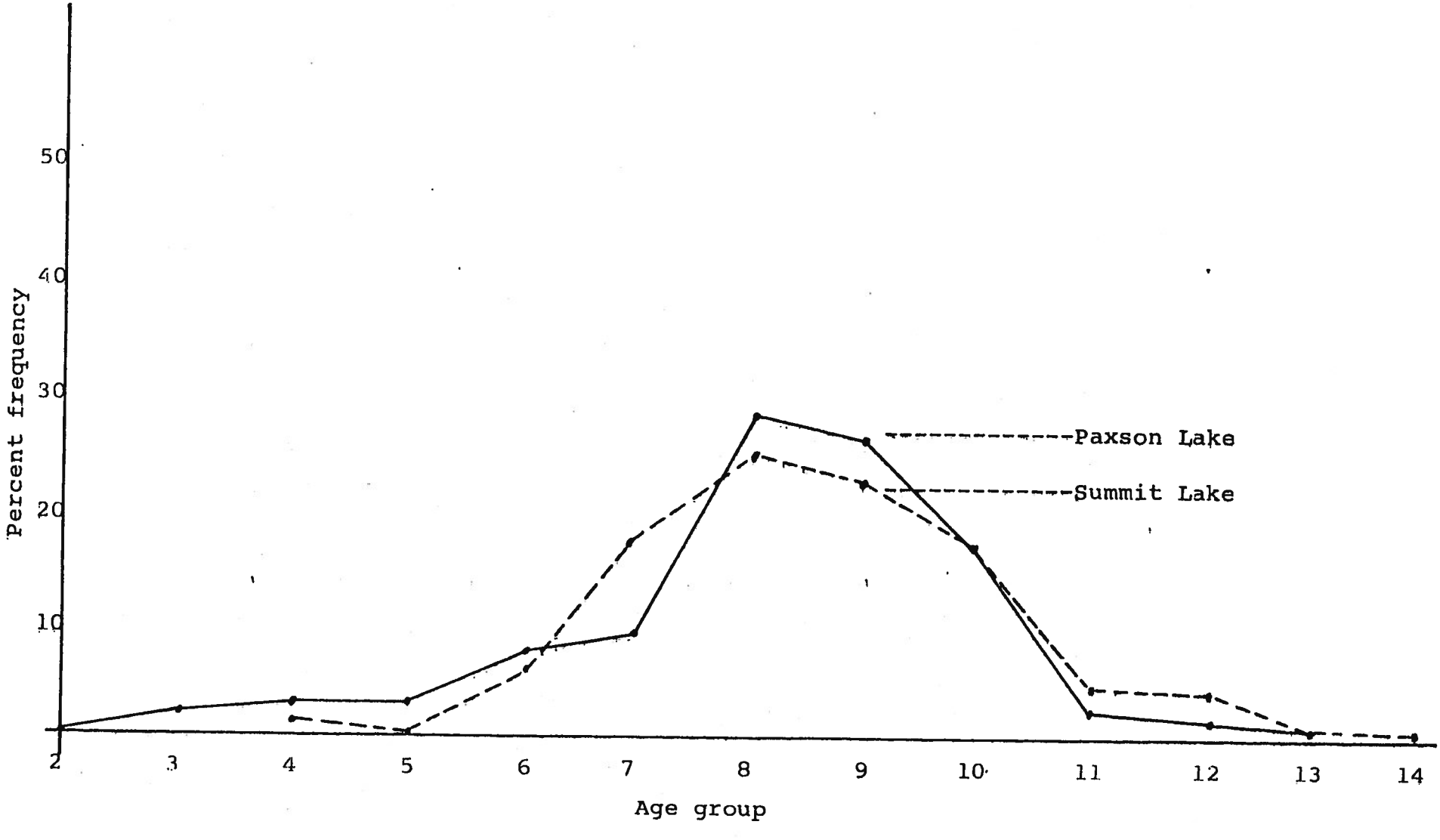


FIGURE 9. AGE COMPOSITION OF LAKE WHITEFISH IN PAXSON, 1962, AS CALCULATED FROM GILL NET SAMPLING

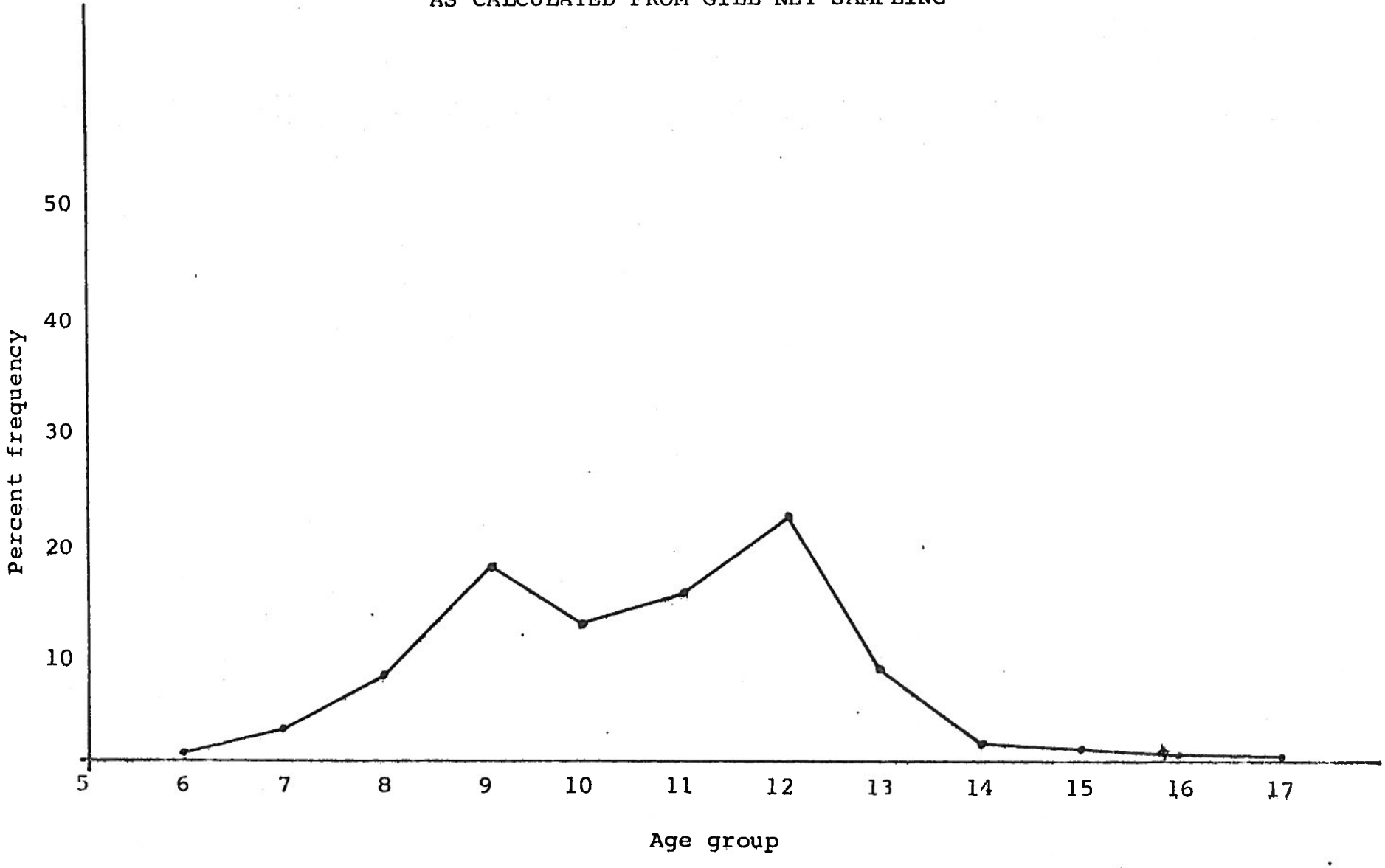


FIGURE 10. AGE COMPOSITION OF ROUND WHITEFISH IN PAXSON AND SUMMIT LAKES, 1962, AS CALCULATED FROM GILL NET SAMPLE

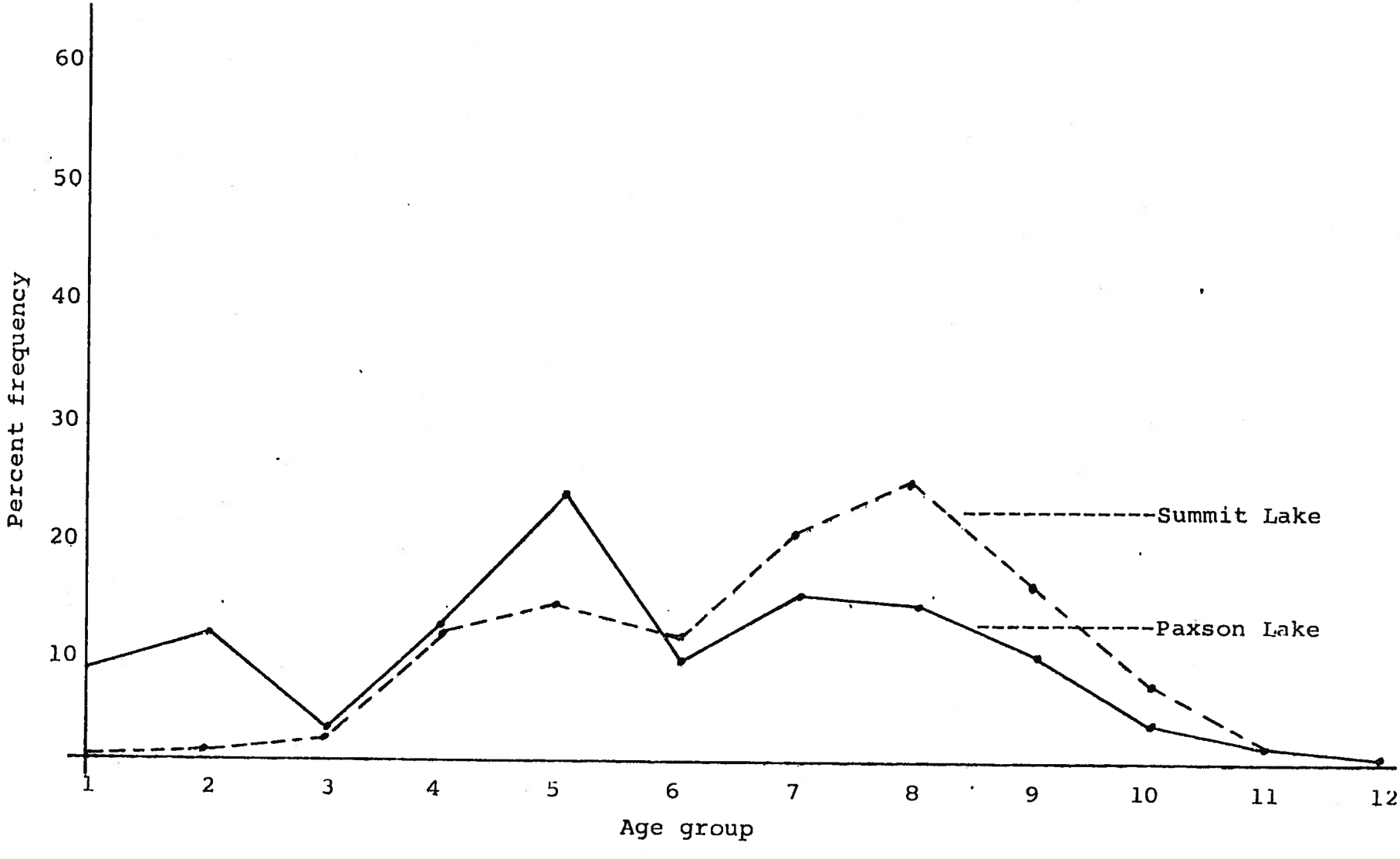


TABLE 8. CALCULATED GROWTH IN FORK LENGTH (cm.) OF LAKE TROUT TAKEN FROM SUMMIT LAKE, 1962

AVERAGE LENGTH CALCULATED FROM EACH AGE GROUP AT END OF YEAR OF LIFE

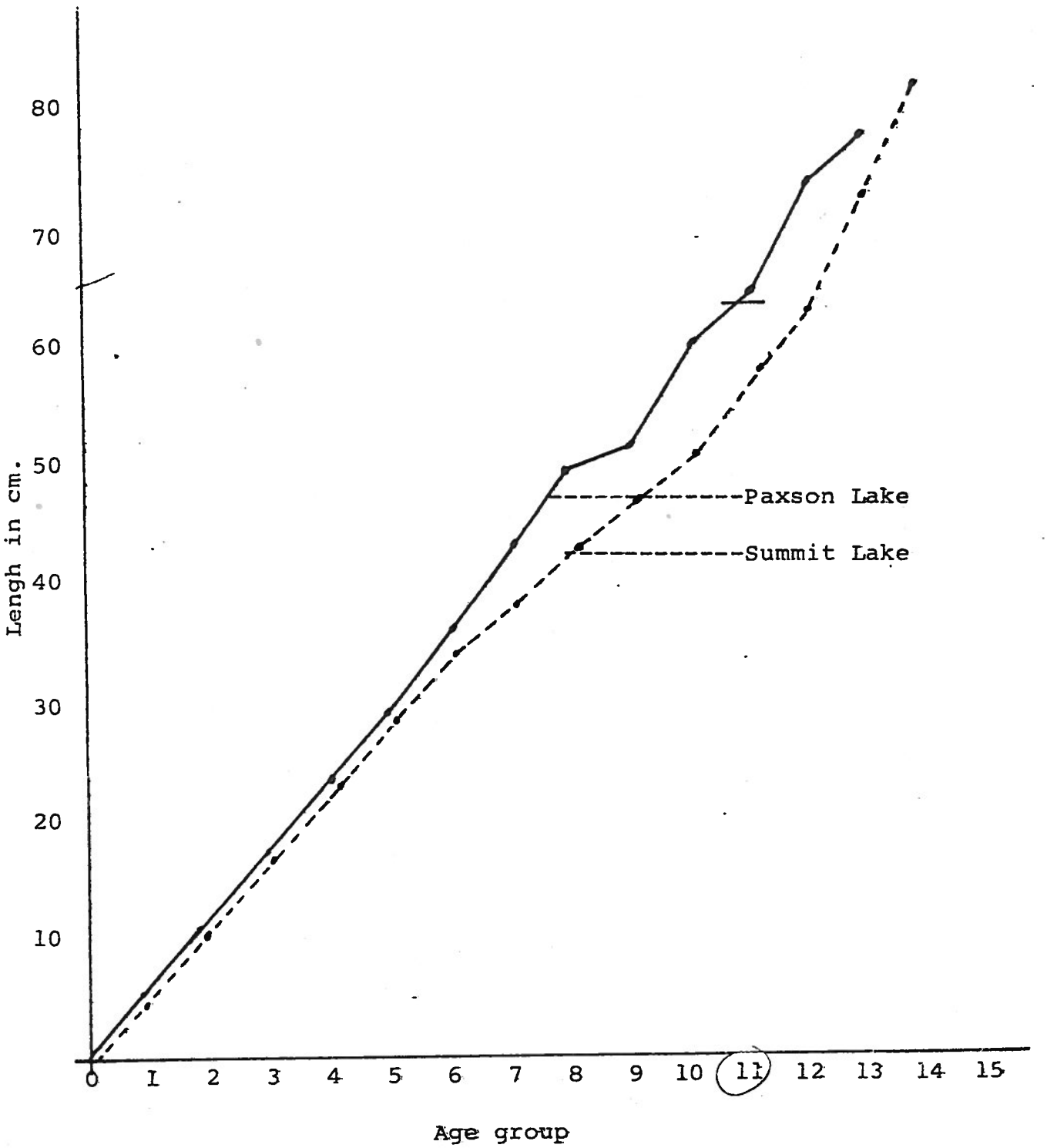
Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
2	5,7	10.6	20,5	28.8										
1	6.3	11,9	18,2	23,9	30.2									
6	6,0	11.3	17.3	24.3	30,7	37.1								
19	6.0	10.5	16.6	23.2	28,4	34,7	40.2							
27	5,7	10,3	15.8	21.2	26,8	32.3	37,5	42.2						
24	5.3	10,0	14.8	19.8	25.6	31,4	36.2	41.3	46.2					
17	5.1	9,7	14.8	19.5	24.4	29.4	34.3	39.6	44.3	48.3				
4	5,3	9.8	13.7	18.4	24.4	29.8	34.8	39.5	44.2	48.8	52.6			
4	5,6	10.7	15.8	20.9	25.8	31.2	35.8	41.1	46.5	50.9	55.6	59.8		
1	7,4	11.4	16.1	22.8	26.8	32.2	36.8	40.2	45,6	50.2	54,9	61,0	67.0	
1	6.6	10.8	15,8	20.8	27.4	32.3	38.2	43.2	49.8	56,4	60.6	66,4	74.7	81.3
Weighted Average	5.6	10.2	15.5	21.3	26,7	32.0	37.1	41,1	45,5	49.0	54.9	61.2	70.9	81.3

TABLE 9. CALCULATED GROWTH IN FORK LENGTH (cm.) OF LAKE TROUT TAKEN FROM PAXSON LAKE, 1962

AVERAGE LENGTH CALCULATED FROM EACH AGE GROUP AT END OF YEAR OF LIFE

Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII
1	6.1	14.3											
3	6.0	10.8	18.0	21.7									
3	5.7	10.2	14.7	19.1	24.5								
8	6.0	11.0	16.1	20.7	25.9	31.4							
9	6.2	11.5	16.8	22.8	28.4	34.1	40.0						
29	6.9	12.7	18.9	25.3	31.5	38.3	44.8	50.9					
26	6.4	12.0	17.9	24.0	30.3	36.6	42.5	48.2	53.0				
16	6.7	11.9	17.5	23.2	29.1	35.7	41.8	48.6	54.2	59.6			
3	6.3	11.4	17.2	22.3	27.3	32.7	38.2	43.7	48.1	53.1	58.0		
2	7.2	15.8	21.2	25.1	34.1	41.0	48.0	53.8	60.2	64.4	69.4	74.2	
1	8.3	15.8	20.8	26.6	32.4	38.2	44.0	48.1	53.1	61.4	67.2	73.0	78.0
Weighted Average	6.4	12.2	18.0	23.6	29.0	36.3	42.9	49.3	51.1	59.4	63.5	73.7	78.0

FIGURE 11. GROWTH OF THE LAKE TROUT (Salvelinus namaycush) OF SUMMIT AND PAXSON LAKES BASED ON AVERAGE CALCULATED FORK LENGTH FOR EACH AGE GROUP



less numerous, lake trout were forced to feed on the slimy sculpin. Therefore, after age V, production and growth of lake trout in these two lakes may well be keyed to the continued availability of red salmon fry. Beyond age X the number of fish from both lakes representing each age group was too small to be of any use in depicting an accurate increment of growth. Growth of the lake trout in Summit Lake may also have been retarded somewhat by low water temperatures.

Comparing the growth of fish in these two lakes with other lakes involves consideration of many variables. Generally, growth was slower in Paxson and Summit Lakes than in lakes of lower latitudes. Growth comparison for large Alaskan lakes are frequently made with Great Slave Lake and Great Bear Lake in Canada, although these lakes are extremely large.

Great Slave Lake, located between latitude 61° and 63° north and longitudes 109° to 117° east, contains 10,500 square miles of surface and has a northern continental climate with a mean annual temperature of approximately 23° F. (Rawson, 1950). This temperature is slightly below the 27.2° annual mean temperature in the locality of Summit and Paxson Lake areas. Kennedy (1954) investigated population dynamics of lake trout in Great Slave Lake and reported a growth rate that was intermediate between that of Paxson and Summit Lakes.

Miller and Kennedy (1943) also investigated the lake trout in Great Bear Lake, a vast lake of 11,800 square miles located at latitude 64° - 67° north and longitude 119° - 123° west. This lake is subjected to severe climatic conditions with ice floes on the lake until late July. In Great Bear Lake, the lake trout growth reported by Miller and Kennedy (1948) was exceedingly slow when compared to Summit or Paxson Lakes. Age group XV, from Great Bear Lake, compared favorably with age group X in Summit Lake and age group VIII in Paxson Lake.

Growth of the lake whitefish in Paxson Lake is shown in Table 10, and is also graphed for clarity in Figure 12. The annual increment of growth was nearly constant until age X. From age X through age XIII, a reduction in growth rate was evident. After age XIII, the sample was too small to afford meaningful conclusions.

In comparison, the growth rate for lake whitefish in Great Slave Lake (Kennedy, 1953) was somewhat above that of Paxson Lake.

Growth of the round whitefish is depicted in Figure 13. Since growth of this species in Paxson and Summit Lakes is the subject of a Masters thesis

TABLE 10. CALCULATED GROWTH IN FORK LENGTH (cm.) OF LAKE WHITEFISH TAKEN FROM PAXSON LAKE, 1962

AVERAGE LENGTH CALCULATED FROM EACH AGE GROUP AT END OF YEAR OF LIFE

Number of Fish	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
2	3.6	6.4	11.8	18.1	23.0	27.7											
5	3.7	7.8	11.5	15.8	20.2	25.2	29.2										
11	3.9	7.9	12.9	16.9	20.6	24.3	27.5	30.8									
23	3.3	6.7	10.6	14.9	19.0	22.8	26.6	30.0	33.2								
17	3.9	7.6	11.5	15.1	18.9	22.7	26.7	30.3	33.3	35.8							
20	3.6	6.7	10.0	13.5	17.2	20.6	24.0	27.8	30.8	33.3	35.6						
28	3.8	6.8	9.8	13.1	16.6	20.0	23.5	26.8	30.0	32.9	35.4	37.6					
11	3.9	6.8	8.1	12.5	15.5	18.4	21.6	24.9	27.6	30.4	33.4	35.7	37.8				
3	4.9	7.9	10.6	14.9	18.5	21.6	24.9	27.9	30.6	33.0	35.4	37.7	39.5	41.2			
2	2.8	4.9	7.8	10.8	13.9	16.4	20.0	22.2	26.5	29.7	32.0	35.0	36.9	38.9	40.4		
1	4.6	7.1	10.0	12.9	16.1	18.9	22.8	25.0	28.2	30.0	32.1	34.3	36.1	38.2	39.6	40.7	
1	2.9	6.2	9.1	11.7	14.0	17.6	21.5	24.8	28.7	30.6	32.6	34.6	37.2	40.1	42.7	44.3	46.3
Weighted Average	3.6	6.9	10.4	14.2	18.0	21.6	24.9	28.2	31.0	33.3	34.8	37.6	37.8	39.9	41.1	42.4	46.3

FIGURE 12. GROWTH OF THE LAKE WHITEFISH (Coregonus clupeaformis) IN PAXSON LAKE BASED ON AVERAGE CALCULATED FORK LENGTH FOR EACH AGE GROUP

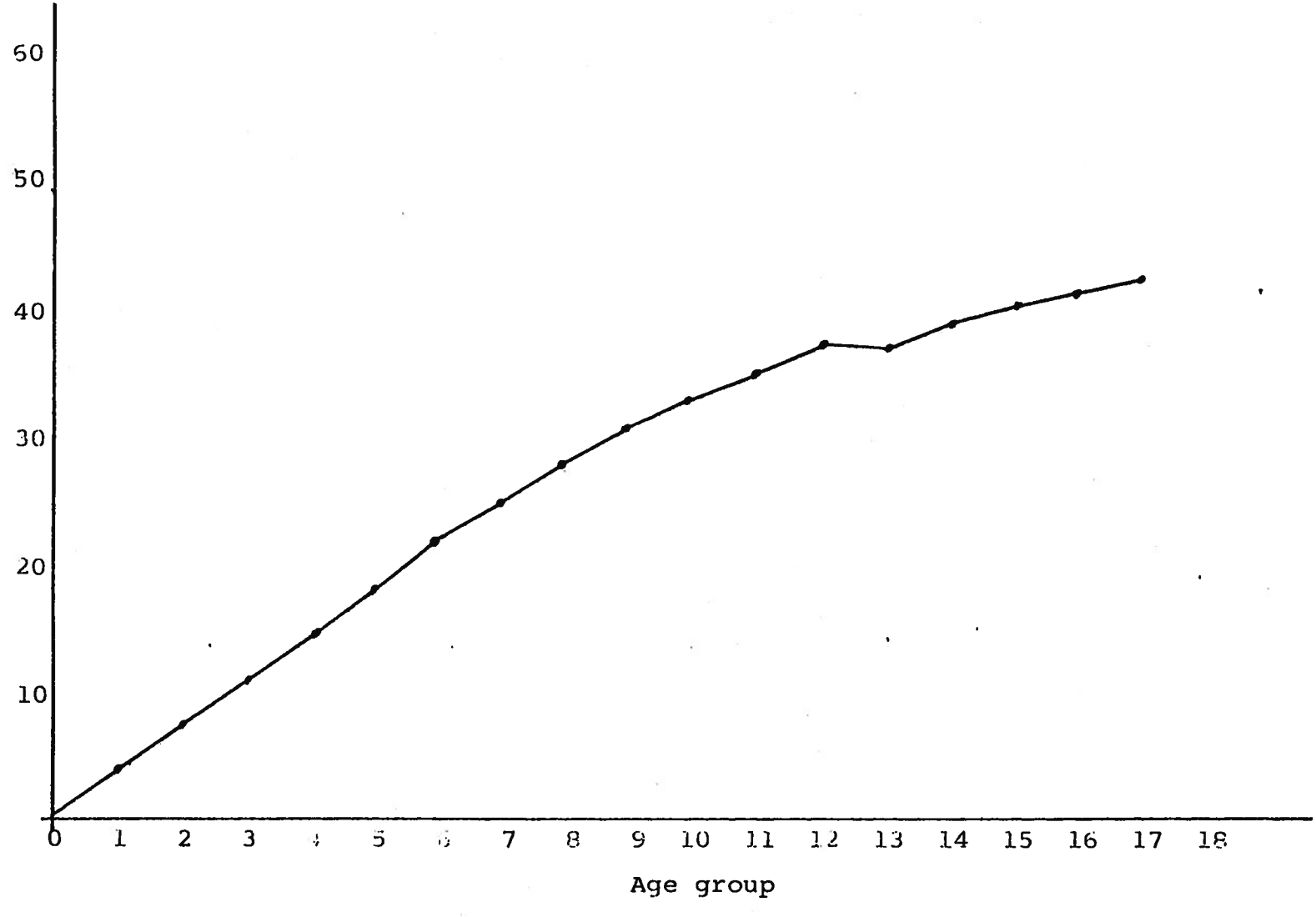
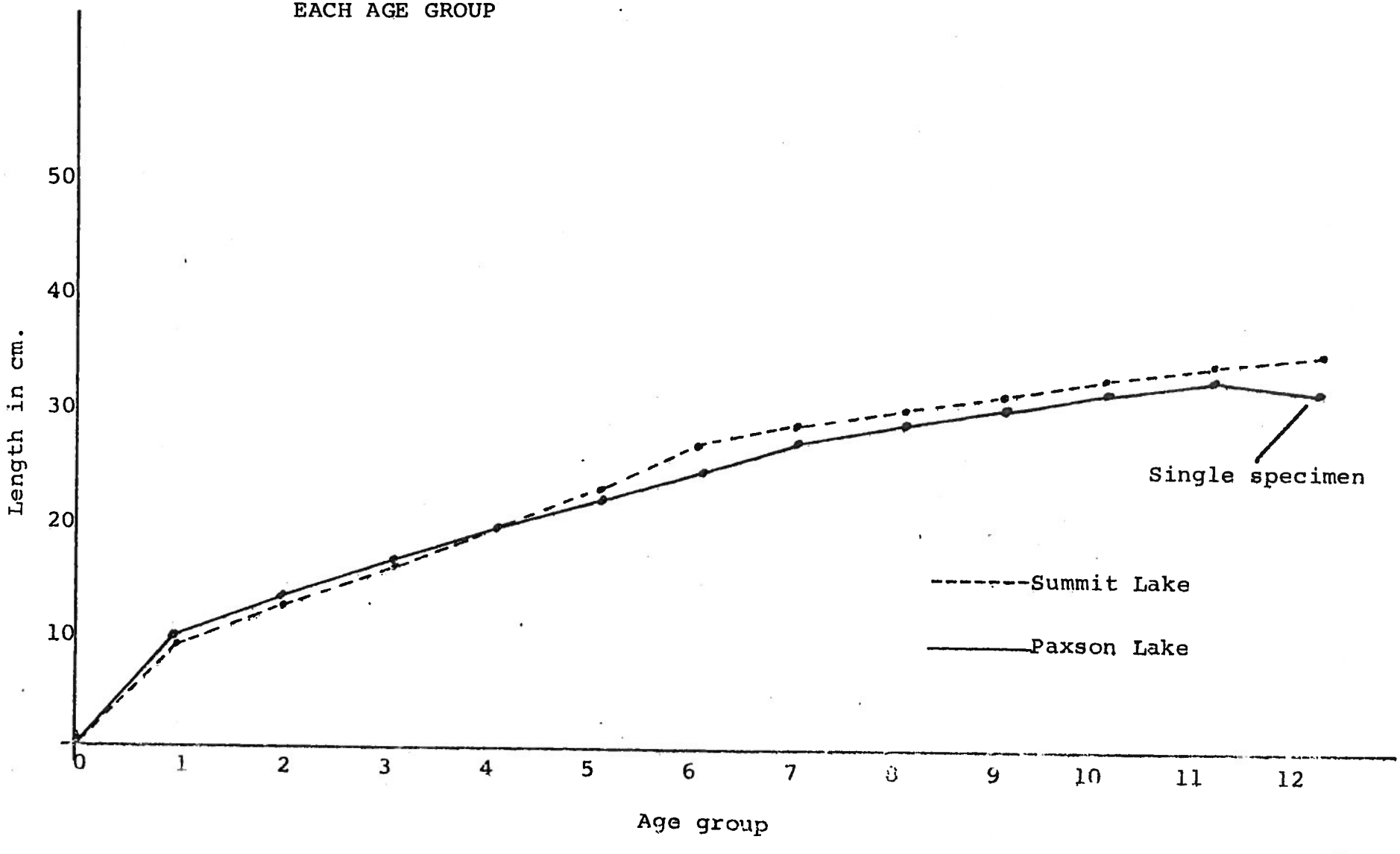


FIGURE 13. CALCULATED GROWTH OF THE ROUND WHITEFISH (Prosopium cylindraceum) IN PAXSON AND SUMMIT LAKES BASED ON AVERAGE CALCULATED FORK LENGTH FOR EACH AGE GROUP



by the junior author, discussion of round whitefish growth is only briefly mentioned in this paper. Figure 13 is based on sample sizes of 470 specimens from Paxson Lake, and 572 specimens from Summit Lake. However, below age IV and above age X, sample sizes were too small to provide accurate comparisons of growth.

Sex Ratio

In Paxson Lake samples, the overall female:male ratio for lake trout was 48:52. Among the lake trout samples, males exceeded females only in age classes IV-VII. Older age classes contained a majority of females.

In Summit Lake, the female:male ratio of lake trout taken was 67:33. Females dominated all age classes. Among the lake whitefish, males slightly dominated all age classes. The female:male ratio of round whitefish was exactly the same as in Paxson Lake, 56:44. Females dominated all age classes except age IV.

The Paxson Lake female:male ratio of the round whitefish was 56:44. Males dominated age classes III-VI; but older age classes consisted predominately of females.

Size and Age at Maturity

Most lake trout in Paxson Lake mature at ages VII-VIII. Almost all lake trout in Paxson Lake were mature when reaching 45 cm in length. Maturity is defined here as either having gonads developed to such an extent that spawning will take place within the same summer, or in that gonads show evidence of prior spawning. By gross examination, female lake trout were divided quite easily into fish containing large eggs that were held loosely in the ovaries and were about to spawn, and fish containing much smaller ova still held tightly in the ovaries. Males could not be definitely separated into spawning males and mature males which would not spawn in the current year. It is unfortunate that data was not compiled on the ratio of mature lake trout spawning each year.

Data similar to that obtained in Paxson Lake were collected in Summit Lake, except that most lake trout matured between ages VIII-X instead of VII-VIII. Numerous individuals were immature at 50 cm, but all were mature at 55 cm.

Gonad development indicated that spawning in Summit Lake would commence in mid-September and approximately 10 days later in Paxson Lake.

The above results compared favorably with age and size at maturity of lake trout in Great Slave Lake. In this lake, Kennedy (1954) found that the first fish matured at age VII and 43 cm in length. All fish were mature by age XI and 57 cm in length. Kennedy also reported that Great Slave Lake trout apparently spawned once every two years after becoming mature.

In contrast, Miller and Kennedy (1948) reported that in Great Bear Lake the first lake trout matured at age XIII at 42 cm in length, and all lake trout matured by age XVII at approximately 55 cm in length. These authors reported that Great Bear Lake trout spawned once every three years after becoming mature.

All lake whitefish from age VII were judged to be sexually mature. Not all individuals appear to spawn each year, however, no data concerning the ratio of ripe spawners to unripe mature fish was compiled. Therefore, the frequency of lake whitefish spawning in Paxson Lake is unknown. All individuals were mature at 29 cm.

Kennedy (1953) reported that in Great Slave Lake the lake whitefish first matured between age VIII and 30 cm with all fish mature by age XIII and 45 cm. The same author reported lake whitefish in Great Slave Lake spawned once every two years after attaining maturity.

In both Paxson and Summit Lakes, all observed round whitefish shorter than 22 cm total length and younger than age IV were immature; whereas all fish were mature when longer than 29 cm and older than age VIII.

In Paxson Lake, more than 50 percent of the males sampled were mature at a smaller size (24 cm) than a comparable majority of females. However, in Summit Lake, the males attained 26 cm in length before more than 50 percent were mature, whereas the females were similar to those from Paxson Lake.

The round whitefish from both lakes had little difference in age at maturity, with more than 50 percent of both sexes maturing at age VI. A greater percentage of males than females matured at age IV and V. In Paxson Lake, a slightly higher percentage of fish younger than age V were mature at an earlier age and at a shorter length than for Summit Lake fish.

Food Habits

A qualitative survey of the summer food habits of the lake trout and round whitefish in Paxson and Summit Lakes, and lake whitefish in Paxson Lake

was conducted in conjunction with gill net sampling.

In both lakes, lake trout under 40 cm fed principally on insects and mollusks with some small fish being eaten by trout in the 30-40 cm range. Beyond 40 cm, the diet of lake trout was almost entirely fish. The slimy sculpin was common in stomachs of lake trout between 45 and 55 cm in Summit Lake. Sculpins were much less common in the stomachs of comparable sized Paxson Lake lake trout. Salmon fry were utilized by lake trout in Paxson Lake much more extensively than in Summit Lake. In both lakes, whitefish were intensively fed upon by large lake trout. In Paxson Lake, where both species of whitefish are present, fish remains were usually too badly digested to allow identification as to species.

Adult lake whitefish in Paxson Lake were observed feeding on salmon fry quite extensively during the spring and early summer. However, the predation ended as the fry grew too big for the whitefish. It was also observed that while some adult lake whitefish were feeding entirely on salmon fry, others in the same area would ignore the fry completely, feeding on the usual diet of mollusks and other invertebrates. Round whitefish fed almost entirely on invertebrates. The principal food items were Trichoptera, Diptera larvae, Lymnea sp., and Gyralus sp. No fish remains were found; but 40 salmon eggs were found in the stomach of one specimen from Paxson Lake.

Parasites

A total of 55 lake trout from both lakes were examined for parasites. Specimens were selected randomly as to age and sex and examined by the Department of Fish and Game parasitologist. The following parasites were found:

Eubothrium salvelini. This tapeworm is commonly found in many trouts and chars and was found in 36 of the 55 specimens. Nine individuals contained more than 30 of the parasites. Incidence was not correlated to age or sex. This parasite has a first larval stage (procercoid) in copepods and a second larval stage (pleroceroid) in prey fish and are not noted as significant pathogens.

Neoechinorhynchus rutili, an acanthocephalan, has a world-wide distribution and is commonly found in salmonoids, perches, and carps. Twenty-five of the 55 specimens contained this parasite, with 4 individuals carrying more than 30 of the parasites. Incidence was not correlated to age or sex. This parasite uses Ostracods or certain species of megalopteran insects as a host for the only larval stage. Heavy infestations of this parasite have been

reported to cause mortality in trout.

Crepidostomum farionis. This fluke is a parasite of salmonoids throughout Europe and North America. Only 3 of the 55 specimens examined were found to be infected; none having more than 30 of the parasite. The 3 infected specimens were females and all were in the 12 year age class. The larval stage of this parasite develops in snails and the aquatic larvae of some insects. Heavy infestation has been suggested as a source of trout mortality.

Proteocephalus sp. This tapeworm is found in a wide variety of freshwater fishes throughout the world. Copepods are the intermediate hosts for the only larval stage. Twenty-three of the 55 specimens were infected, with 8 of the specimens containing more than 30 of the parasite. Generally, older individuals were more heavily parasitized. Both sexes were equally infected.

All parasitic infestations of lake trout were relatively mild. In no case was the infestation judged to be of sufficient severity to appreciably impair the functions or performance of the infected individual.

SUMMARY

1. All limnological conditions, including water temperature, indicated Paxson Lake as a significantly more productive lake than Summit Lake. Factors such as elevation and surface-to-volume ratio were considered the main reasons for the difference in productivity.

2. All fish species present in Summit Lake were also present in Paxson Lake. However, Paxson Lake possessed one species, the lake whitefish, not found in Summit Lake.

3. The catch per unit effort of round whitefish in Summit Lake was more than twice that of Paxson Lake, and even exceeded the combined catch of both species of whitefish in Paxson Lake. No significant difference in catch per unit effort was found for lake trout in the two lakes.

4. Lake trout in Paxson Lake grew faster than those in Summit Lake. Difference in growth rates to age V was apparently correlated to the relatively greater invertebrate fauna in Paxson Lake. Differential growth rates were especially pronounced between age V and age X, and were likely a result of changes in diet from invertebrates to small fish.

The number of small fish suitable for lake trout food in Paxson Lake due chiefly to the larger numbers of salmon fry and smolts greatly exceeded those in Summit Lake. Colder water temperatures in Summit Lake during the ice-free period were also partly responsible for slower growth. After age X, the samples were considered too small to make valid conclusions.

Growth of lake whitefish appeared to be constant until age X; thereafter a decrease in the growth rate was evident.

ACKNOWLEDGEMENTS

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