THE UNIVERSITY OF MANITOBA

THE EFFECTS OF PLANKTIVOROUS FISH PREDATION, LAKE MORPHOMETRY, AND LAKE PRODUCTIVITY ON THE LIMNETIC ZOOPLANKTON OF YUKON LAKES

by

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Abstract

Thirty-eight lakes in Yukon Territory and northern British Columbia were studied in the summer of 1975. Six lakes, exhibiting a broad range of planktivorous fish predation, were sampled three times each (early, mid-, and late summer); the remaining 32 lakes were sampled once each, in approximately midsummer.

The total amount of zooplankton ranged from 0.33 to 10.6 mg wet weight/cm^2 and appeared to be determined primarily by lake productivity, being most strongly correlated with total dissolved solids. The limnetic crustacean community was extremely simple; a total of 21 species was found with an average of 6 per lake and a range of 2 to 11 per lake. The most common species were: *Cyclops scutifer*, *Diaptomus pribilofensis*, *Heterocope septentrionalis*, *Daphnia longiremis*, *Eubosmina longispina*, and *Daphnia middendorffiana*, with the first two species being the usual dominants. *C. scutifer* was most abundant in large, deep, cool lakes, whereas daphnids as a group preferred small, warm lakes.

Indices of fish predation were calculated on the basis of fish species caught and their stomach contents. Intensity of predation had little effect on either the total amount of zooplankton or the relative abundances of daphnids, cyclopoids and diaptomids. The species composition of cladocerans was significantly affected by fish predation,

while that of copepods was essentially unaffected. Large *Daphnia* (*D. middendorffiana*) dominated the cladocerans in the absence of planktivorous fish, while small *Daphnia* (*D. longiremis*) and bosminids dominated in their presence. Body size of *D. middendorffiana* at first reproduction was inversely related to the intensity of fish predation, and the body size of *Heterocope*, the largest copepod, was smallest in high predation lakes.

Cluster analysis delineated two crustacean communities: (I) in lakes of low-moderate intensities of fish predation and dominated by *C. scutifer*, *Diaptomus pribilofensis*, *Heterocope*, and *Daphnia middendorffiana*; (II) in lakes of moderate-high predation intensities and dominated by *C. scutifer*, *Diaptomus pribilofensis*, *Daphnia longiremis*, and *Eubosmina longispina.* Thus the variation in crustacean species composition is a reflection of variation in the intensity of planktivorous fish predation. This conclusion is consistent with findings elsewhere, primarily from lakes and ponds of the temperate zone more influenced by man than the subarctic lakes in the present study.

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INTRODUCTION

In recent years, a great deal of work has been done concerning the effects of planktivorous fish predation on freshwater zooplankton communities (Brooks 1968; Hillbricht - Ilkowska and Weglenska 1973; Northcote and Clarotto 1975). The results are quite consistent--small zooplankton species generally replace large ones with increasing fish predation. In lakes with low intensities of predation, large species usually dominate, either because they are more efficient at food collection and utilization (Brooks and Dodson 1965) or because of size-selective invertebrate predation on small zooplankton species (Dodson 1974). In lakes with high predation intensities, small zooplankters dominate since fish predation is concentrated on larger forms.

Although the evidence presented to date is convincing, almost all of the studies done in this field compare zooplankton communities in lakes or ponds stocked with different numbers of fish, or compare communities in one lake (pond) before and after fish stocking, accidental fish introductions, or addition of fish poisons. The results of such disturbed conditions may not be applicable to natural situations. Questions arise such as: how do fish poisons affect zooplankton communities? how soon after fish introductions do conditions within the lake stabilize, and how similar are they to pre-introduction conditions? are predation levels in heavily stocked lakes comparable to those existing naturally? The undisturbed lakes studied by Northcote and Clarotto (1975) and Brooks and Dodson (1965) show essentially the same trends as the "disturbed" lakes, but both studies involved few lakes (eight in each case) in relatively small geographic areas of the temperate zone. To better understand the extent to which fish affect zooplankton communities in the natural situation, more lakes should be studied on a broader geographic scale.

The purpose of this study was to investigate whether or not planktivorous fish predation affects the species composition and body size of zooplankton in undisturbed northern lakes to the same extent that it does in lakes and ponds of the temperate zone more disturbed by man's activities. To this end, 38 lakes in the Yukon Territory and northern British Columbia exhibiting a broad range of fish predation were studied during the summer of 1975. These lakes also differed greatly with respect to morphometry (lake area and depth) and water chemistry (total dissolved solids, chlorophyll-a, and other rough measures of lake productivity). Therefore, the effects of lake morphometry and lake productivity on zooplankton communities, which are rarely taken into account in fish-zooplankton studies, were also examined.

MATERIALS AND METHODS

I. Field Work

Within the available time, it was possible to visit six of the lakes three times each (early, mid-, and late summer); the remaining 32 lakes were visited only once. The six lakes (Table 1), representing different levels of fish predation, were chosen from 62 Yukon lakes for which preliminary fish data were available (C.C. Lindsey unpublished data). The 32 lakes visited once were chosen and sampled essentially at random--accessibility of the lake and available time being the main deciding factors.

The 38 lakes are located in three major drainage systems (Fig. 1), and range from 0.5 to 409.5 km^2 in area and from 2 to more than 100 m in maximum depth (Table 1). All lake names are according to the Gazetteer of Canada (Yukon, 1973; British Columbia, 1966) except Lower Snafu, Pygmy, Smart, Wheeler, and Jackfish lakes which were named by local residents, C.C. Lindsey, or myself. All of the lakes lie within the Interior System of the Canadian Cordillera between 59° 41' N and 66° 11' N, at altitudes of approximately 380 m to 991 m.

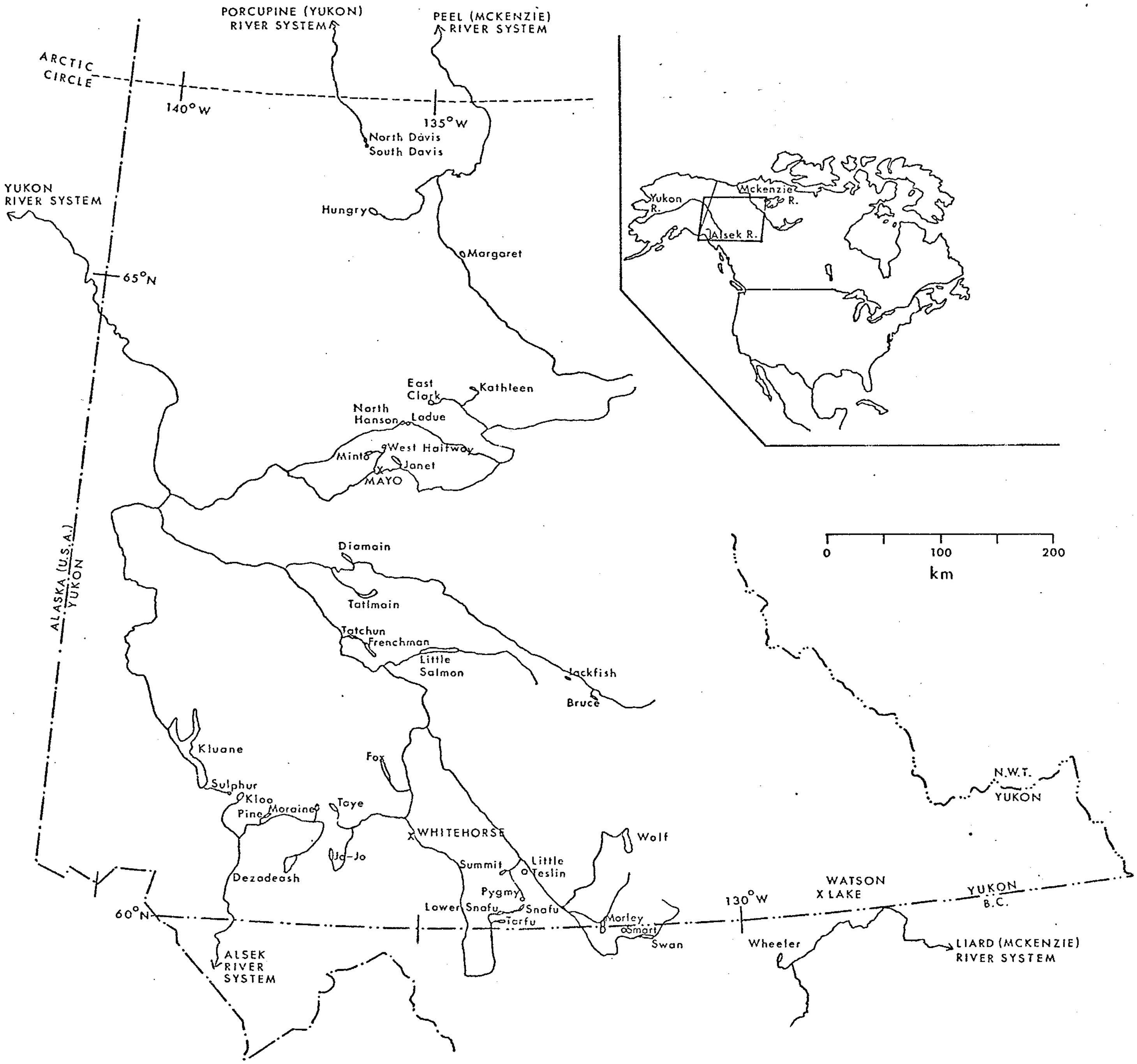
Yukon winters are long and cold; the summers short and cool. Freeze-up usually occurs in late October-early November; break-up in late May-early June. Mean July temperature varies from 15°C at Mayo (central Yukon) to 13.9°C at Whitehorse (southern Yukon) and 12.8°C at Kluane Lake (southwestern Yukon). Annual precipitation is light, between 200 and 400 mm.

Before nets were set in each lake, two or three zig-zag sounding transects were made with a Furuno FG-11/200 Mark-3 echo sounder. This

Table 1. Morphometric data, indices of planktivorous fish predation, and crustacean community types for 38 Yukon lakes. L, M, and H refer to "low", "moderate", and "high" intensities of fish predation, respectively; predation indices and community types defined in text. The six lakes visited three times are presented first.

Lake	Area (km2)	Maximum known depth (m)	Quantitative estimate of fish predation	Qualitative estimate of fish predation	Crustacean community type
Diamain	18.8	25	0	L	I
Pine	4.7	27	0 - 825	M	IIb
Minto	4.3	31	55 - 633	M	II
Fox	16.0	48	25 - 720	M	IIb
Swan	8.9	65	418 - 938	H	II
Lower Snafu	3.5	37	2791 - 8189	H	II
North Hanson	1.6	19	0	L	I
West Halfway	0.9	4.7	0	L	I
Janet	17.2	103	0	L	II
Sulphur	1.2	2	0	L	I
Taye	8.1	3	0	L	I
Hungry	6.6	4	0	L	I
Summit	1.9	13	1753	M	I
Ladue	2.4	24	372	M	I
Kathleen	2.6	60	32	M	I
Kluane	409.5	82	1480	M	I
Kloo	12.5	12	11770	M	II
Jo-Jo	6.6	52	4145	M	IIb
Moraine	4.2	32	25	M	I
Snafu	4.7	29	1691	M	II
Pygmy	0.5	18	12075	M	II
Wolf	74.4	66	0	M	I
Margaret	4.5	26	0	M	II
Tarfu	3.3	33	1553	M	I
Wheeler	2.8	30	565	M	II
Frenchman	14.1	39	337	M	II
Jackfish	1.7	17	2177	M	I
Tatlmain	33.2	42	5295	M	I
Little Teslin	2.8	20	15591	H	II
Tatchun	6.6	53	320	H	IIa
East Clark	1.6	23	2130	H	II
Dezadeash	77.2	7.6	17800	H	II
North Davis	1.2	23	1536	H	IIa
South Davis	1.6	27	1536	H	IIa
Morley	13.2	34	1100	H	II
Smart	1.4	6	8205	H	I
Little Salmon	62.6	96	5290	H	II
Bruce	2.5	35	4290	H	II

Figure 1. The locations and drainage patterns of the 38 lakes sampled in Yukon Territory and northern British Columbia. Major towns (X) are also indicated.


PORCUPINE (YUKON) RIVER SYSTEM
PEEL (MCKENZIE) RIVER SYSTEM
ARCTIC CIRCLE
140° W
135° W
North Davis
South Davis
YUKON RIVER SYSTEM
Hungry
Margaret
65° N
East Clark
Kathleen
North Hanson
Ladue
West Halfway
Minto
Janet
MAYO
ALASKA (U.S.A.)
YUKON
Diamain
Tatlmain
Tatchun
Frenchman
Little Salmon
Jackfish
Bruce
Kluane
Fox
Sulphur
Kloo
Pine
Moraine
Taye
WHITEHORSE
Jo-Jo
Dezadeash
Summit
Little Teslin
Wolf
Pygmy
Lower Snafu
Snafu
Tarfu
Morley
Smart
Swan
60° N
ALSEK RIVER SYSTEM
130° W
WATSON X LAKE
Wheeler
YUKON
B.C.
LIARD (MCKENZIE) RIVER SYSTEM
N.W.T.
YUKON
0
100
200
km
Yukon R.
Mckenzie R.
Alsek R.

provided information about lake basin shape and maximum depth. Since it was not possible to sound a significant portion of the very large lakes, such as Kluane and Wolf, the estimated maximum depth for these lakes may be considerably less than the actual maximum depth.

At each visit to each lake, five experimental gill nets were set overnight for an average of 14 hours--one net in shallow water near shore, plus two floating and two on the bottom at the deepest part of the lake. For lakes deeper than 50 m, the deep nets were set at a more convenient depth, usually between 30 and 40 m. Each net measured 2.1 m x 38.1 m and had five equal panels of stretched mesh sizes 2.54, 3.81, 5.08, 6.35, and 7.62 cm. A 2.1 m x 7.6 m section of 1.9 cm stretched mesh net was added to both the floating and deep nets after unusually small ciscoes (*Coregonus sardinella*) were found in South Davis Lake (sampled August 9) which were nearly all caught by this small mesh size (see Results section).

The number of each fish species caught in each net was recorded, and fork length measurements were usually taken from a subsample of individuals of each species. Subsample size varied from less than 10% to 100% of the individuals of a species. Stomachs were taken from these same individuals and preserved in 4% formaldehyde.

Limnological measurements were made in mid-afternoon at one station over the deepest part of the lake, which was generally mid-lake. Two additional stations, one toward either end of the lake, were sampled in the six lakes visited three times.

Water transparency was measured with a black-and-white, 20 cm Secchi disc, and temperature profiles were taken with a YSI telethermometer. The temperature readings were corrected at each lake by taking the temperature of the surface water with a mercury thermometer (average correction factor was +0.4°C). Water samples for oxygen determination were taken from various depths with a 3-liter van Dorn bottle. A 300 ml BOD bottle was rinsed and filled to overflowing with water from the van Dorn sampler, and the oxygen content was measured with a YSI Model 54 oxygen meter. Although the meter was generally calibrated before use with air-saturated water of known temperature, altitude was not taken into account and this introduced an error in the oxygen readings of 1% for every 100 m change in elevation (6% error between most extreme lakes). This, plus the fact that the meter was calibrated on most but not all sampling days, means that between-lake oxygen comparisons are probably less reliable (estimated error of 10-15%) than within-lake (within-profile) comparisons.

A van Dorn sample from 1 m depth was taken for water chemistry analysis. Samples were treated according to Stainton et al. (1974) for subsequent analysis of cations (calcium, magnesium, sodium, potassium), anions (chloride, sulphate), silicon, total dissolved solids (TDS), and chlorophyll-a (uncorrected for phaeophytin). Necessary filtrations were done in the field through a Gelman glass fiber filter (pore size 0.3 μ) using a Falcon 7102 filter apparatus and a hand vacuum pump for suction. Sample storage conditions were also according to Stainton et al. (1974), except that samples for silicon, anions, and TDS were stored at air temperature (approx. 14°C) rather than at the recommended 5°C. This difference probably did not significantly affect the results as the recommended storage procedures are not strict rules, but only rough guidelines (M.P. Stainton pers. comm.). Samples taken before August 10 were air-shipped to the Freshwater Institute laboratory in Winnipeg on

August 14, and samples from the rest of the summer arrived at the laboratory on September 19.

In each of the six lakes visited three times, chemistry sampling was done only during the midsummer visit, at two of the three stations. Each van Dorn sample from 1 m depth was treated as described above, with the additional collection of samples for particulate phosphorus and total dissolved phosphorus analyses. The sum of these two is total phosphorus, a variable which is roughly related to lake productivity (Vollenweider 1968). Again, sample treatments and storage were according to Stainton et al. (1974) except that the total dissolved phosphorus sample was preserved by adding two drops of 36N sulfuric acid and not by treating with ultraviolet light. Although this preservation method has not been thoroughly tested, it was expected to give satisfactory results (M.P. Stainton pers. comm.).

Quantitative zooplankton samples were taken with a 26-liter Schindler-Patalas trap (Schindler 1969) fitted with a filtering net of 73-µ mesh. Equally spaced samples were taken every 2 or 3 m in the epilimnion, and every 3-10 m in the hypolimnion, depending on the depth. Samples from each zone were combined, but the zones were kept separate resulting in two samples per station. In shallow lakes with no thermal stratification, one combined sample was taken from the water column. All samples were preserved in 4% formaldehyde.

A Wisconsin net (mouth diameter 25 cm, mesh size 73 µ) was used instead of the trap in four lakes (Hungry, Margaret, North Davis, South Davis); the efficiency of the Wisconsin net is about 63% relative to the trap (Patalas 1975). Single vertical hauls from near the lake bottom to the surface were taken at each station with a pulling speed of about 1 m/sec. In Little Salmon Lake, trap samples were taken only from the epilimnion, and a total vertical Wisconsin net haul was also made.

II. Laboratory Analyses

Physical and Chemical Measurements

Water chemistry analyses were done at the Freshwater Institute, Environment Canada, Winnipeg, according to their standard analytical procedures (see Stainton et al. 1974). To account for possible leaching of materials from the filter or filter apparatus, two distilled water blanks were run through the filter apparatus while in the field and treated exactly as the lake water samples. All chemical values reported herein represent the average of these two blanks subtracted from the lake water values. The results of the chemical analyses of the blanks are presented in Appendix A.

Vertical oxygen profiles can provide information about lake productivity, although they are also influenced by lake morphometry (Hutchinson 1957). The difference in oxygen concentration between the epilimnion (surface sample) and lower hypolimnion (sample from lower half of hypolimnion, usually close to lake bottom) was calculated and used as a very rough measure of lake productivity (greater difference with greater productivity in lakes of comparable morphometry).

Lake areas were approximated by using an Ott planimeter on the lake outlines on 1:250,000 topographic maps (Department of Mines and Technical Surveys, Ottawa). Epilimnetic temperature was defined as the average temperature of the top 4 m of the water column.

Indices of Fish Predation

Fish stomachs were examined to determine the contribution of zooplankton to the diets of various species. Stomach contents were placed in a petri dish and examined under a dissecting microscope. The proportional volume contribution of zooplankton to the total food was estimated by eye. This diet information was used together with the results of the net sets to calculate both a quantitative and a qualitative index of the intensity of planktivorous fish predation in each lake.

To calculate the quantitative index of fish predation, fish caught in shore nets were ignored since any zooplankton eaten by these fish were probably littoral, and such zooplankton were not considered in this study. Fish species moving onshore at night were probably underrepresented in the floating and deep net catches, but this should roughly reflect the fact that such fish spend less time feeding in the open water zone. For fish caught in the floating and deep nets, numbers were converted to biomass using fork length measurements and length-weight curves for the different species taken from the literature (Appendix B). The resulting biomass estimate of each species caught was multiplied by the average proportion of zooplankton in the diet for that species. Summing these "fish biomass X proportion of zooplankton in stomachs" figures over all species caught in a lake results in a number which represents the biomass of fish caught per standard net set (excluding shore net) that were eating only zooplankton. This was taken as a quantitative index of fish predation on zooplankton, and a sample calculation is shown in Appendix C.

To calculate the qualitative index of fish predation, the diet information was used to divide the fish species into three broad categories: 1. fish eating essentially no zooplankton (<0.01 by proportional volume of stomach contents); 2. fish eating some zooplankton (≥ 0.01, <0.9); 3. fish eating mostly zooplankton (≥ 0.9). Lakes were classified as having low, moderate, or high intensities of fish predation according to the fish species caught in all nets (including shore net): "low predation" lakes had either no fish or only fish of category 1; "moderate predation" lakes had fish of category 2, perhaps also of 1, but none of category 3; "high predation" lakes had fish of category 3, and perhaps also of categories 1 and 2.

Zooplankton Samples

Zooplankton samples were reduced to a volume of 40 or 20 ml, depending on the concentration of zooplankton, by siphoning off excess preservative through a tube covered with 45-μ netting. One ml subsamples were taken by mixing the sample in all directions with a pipette and then immediately withdrawing the subsample from the middle of the sample. A variance-to-mean ratio test showed that this subsampling technique was random for all zooplankton species except large Daphnia (D. middendorffiana) and large calanoid copepods (Heterocope, Senecella). These species were usually rare, and so were counted from the whole sample (see later). The subsample was then placed in a Sedgwick-Rafter cell and counted in its entirety under a compound microscope.

Adult calanoid copepods were identified to species according to Wilson (1959), and adult cyclopoid copepods according to Yeatman

(1959). Copepodid stages were identified to genus only, and nauplii were classified as either calanoid or cyclopoid. When more than one species per genus was found in a sample, immature individuals were proportioned between the species according to the adult ratio. Although the species ratio is not always the same for mature and immature individuals, this error is reduced here because most of the lakes (29 of the 38) did not have more than one species per copepod genus. Rotifers were counted, but not identified. Immature and mature cladocerans were identified to species according to Brooks (1957, 1959). Very little work has been done on *Daphnia* taxonomy in northwestern North America and this group presented the most trouble taxonomically. Two subspecies, *Daphnia galeata galeata* and *D. longispina hyalina microcephala* (?), are not discussed by Brooks, but are quite common in this part of North America (K. Patalas unpublished results). The taxonomic status of the latter subspecies is not clear (K. Patalas pers. comm.). More detailed taxonomic work will probably result in species such as *D. middendorffiana* and *D. longiremis* being subdivided further (see Results section).

Rotifers and copepod nauplii were counted until a minimum of 100 individuals in all had been counted. Cyclopoids were identified and counted until at least 64 had been counted; diaptomids were treated similarly. Identification and enumeration of cladocerans continued until a minimum count of 64 daphnids was reached. Counting at least 100 individuals sets the 95% confidence limits for the count at a maximum of $\pm$ 20%; counting at least 64 individuals sets the limits at a maximum of $\pm$ 25% (Elliott 1971, p. 84). For the six lakes visited three times, adults of cyclopoids, diaptomids, and daphnids were measured with an ocular micrometer from the anterior margin of the head (antennae excluded) to the base of the caudal setae for cyclopoids and diaptomids, and to the base of the caudal spine for daphnids. For the 32 lakes visited once, only Daphnia adults were measured as they were the only group to show between-lake size differences in the six lakes visited three times. For all lakes, immature individuals were measured approximately and classified as "large" or "small", the division point being the average size of the largest and smallest immature individuals seen of that species. All immature forms were accurately measured for the midsummer visit of the lakes visited three times, and these data were used to derive the division points which are presented in Appendix D. After subsampling, the rest of the sample was examined under a dissecting microscope for rare and/or large species, with any large individuals found being measured. Appropriate multiplications were carried out to calculate the total number of each species in the sample.

The number of zooplankton per liter of both epilimnion and hypolimnion was calculated in lakes with more than one station by averaging the station values, weighting each according to the depth ("thickness") of the zone at that station. Open lake averages for the entire water column were calculated by averaging epilimnion and hypolimnion values, weighting each zone according to its "thickness."

The number of zooplankton beneath 1 square centimeter of lake surface was calculated from the number per liter (average for entire water column) simply by taking into account the total depth at the sampling station. For lakes sampled with the Wisconsin net, the number of zooplankton per square centimeter was obtained directly from the area of the mouth of the net ($\pi (25/2)^2$ cm^2) and the efficiency of the net (63%). This was converted to number per liter for the entire water column, but epilimnetic and hypolimnetic densities could not be separated.

Biomass was favoured over numbers as a measure of the total amount of zooplankton since using numbers considers very small and very large individuals to be equal. Biomass of zooplankton (mg wet weight per liter, and per cm^2) was calculated using the total number, the size distribution, and the length-weight curve for each species. Length-weight curves for copepods and Daphnia were obtained from Klekowski and Shushkina (1966, cited from Edmondson 1971) and Pechen (1965, cited from Edmondson 1971), respectively; Appendix E presents a sample calculation of biomass from numbers. The adult size distribution of each copepod species in the 32 lakes visited once was assumed to be equal to the average adult size distribution of that species in the six lakes visited three times. For rotifers, nauplii, and cladocerans other than Daphnia, average size distributions were obtained by taking a few size measurements from one or two lakes. Average weights were calculated from these size distributions by assuming unit density for rotifers and nauplii, using the length-weight curve given by Pechen (1965, cited from Edmondson 1971) for Bosmina, and by using available length-weight curves (Pechen 1965; Sherbakov 1952--both cited from Edmondson 1971) of similarly shaped cladocerans for the remainder of the species for which no length-weight data could be found. For example, the Bosmina curve was used for Eubosmina, Alona, and Chydorus. The errors involved here are probably great, but are of little concern as these species are very minor components of the zooplankton in most Yukon lakes; species other than copepods and Daphnia generally comprised less than 10% of the total zooplankton biomass.

Zooplankton parameters were generally expressed per unit area rather than per unit volume. This is probably the best basis of comparison between lakes of different depths since the solar energy driving the lake ecosystem enters the lake through its surface (Brylinsky and Mann 1973), as does the mixing action of wind which is responsible for circulation of materials and thermal stratification, two very important processes in lakes (Patalas 1960).

Statistical Analyses

Simple correlation coefficients were used to detect significant relationships between lake parameters. Partial correlation coefficients, which account for more of the interrelationships between variables, were also calculated to more precisely determine factors influencing the following selected parameters: average *Daphnia* size, total zooplankton abundance, and the relative abundance of both cyclopoids and daphnids. First and second order partial coefficients, however, gave essentially the same results as the simple coefficients, and so are not presented. Higher order partial coefficients gave increasingly unreliable results, probably because the sample size and degree of replication were not great enough (B.D. Macpherson pers. comm.).

All parameters involved in correlation analysis were tested for normality using the Kolmogorov-Smirnov statistic, and suitable transformations were applied to parameters that deviated significantly from normality at the 5% level. Logarithmic transformations were used, except for percentage data where arc sine or square root transformations were applied (Appendix F).

Analysis of variance was used to test for differences in various zooplankton parameters between the three qualitative levels of planktivorous fish predation. Zooplankton data were transformed according to Appendix F.

A packaged computer program (CLUSTAN, prepared by D. Wishart, University College, London) was used to perform a cluster analysis on the zooplankton data, with the actual clustering done by the "mode" method. This method produces "natural" groupings and will not resolve more than one group if the samples are all from a unimodal swarm (Wishart 1969). This contrasts with the more usual minimum-variance methods where the samples are divided into a specified number of groups with the sole purpose of minimizing within-group variance. Natural groupings are not easily obtained by these methods as the number of groups obtained is determined by the investigator.

The clustering procedure required that similarity coefficients between samples be calculated, and this was done using Sorenson's quotient of similarity (Sorenson 1948, cited in Southwood 1966) which measures the average proportion of species common to two communities:

$$QS = 2j/(a+b)$$

where a = the number of species in the first community; b = the number of species in the second community; j = the number of species common to both communities.

RESULTS

I. General Limnology

Little is known about the limnology of Yukon lakes. Although a few of the larger lakes have been studied in some detail (Aishihik Lake, Kussat 1973; Atlin and Tagish lakes, Withler 1956; Teslin Lake, Clemens et al. 1968), most of the available information is of a cursory nature (Brown et al. 1976; Hooper 1947; C.C. Lindsey and K. Patalas unpublished results; Livingstone 1963). The present study examined a wide variety of limnological parameters in lakes scattered over central and southern parts of the Yukon, and provides an extensive overview of the limnology of this part of Canada.

Limnological data for the 38 lakes are presented in Appendix G. Parameters known to vary significantly over time, such as temperature, can only properly be compared between lakes sampled at similar times. However, since all but three of the lakes were sampled in midsummer (July or August), different sampling times should not pose a serious problem. Results from the three lakes, Tatchun, Summit (both sampled in June), and Tatlmain (sampled in September), should be compared with results from the other lakes with caution.

Table 2 presents correlation coefficients for various pairs of lake parameters. Large lakes tended to be of greater maximum depth and have lower epilimnetic temperatures and chlorophyll-a concentrations than small lakes. The cooler epilimnia of large lakes is due to the strong winds generally prevalent on such lakes transporting heat to greater depths. Epilimnion depth was positively correlated with lake area. Large lakes also showed little difference in oxygen concentration

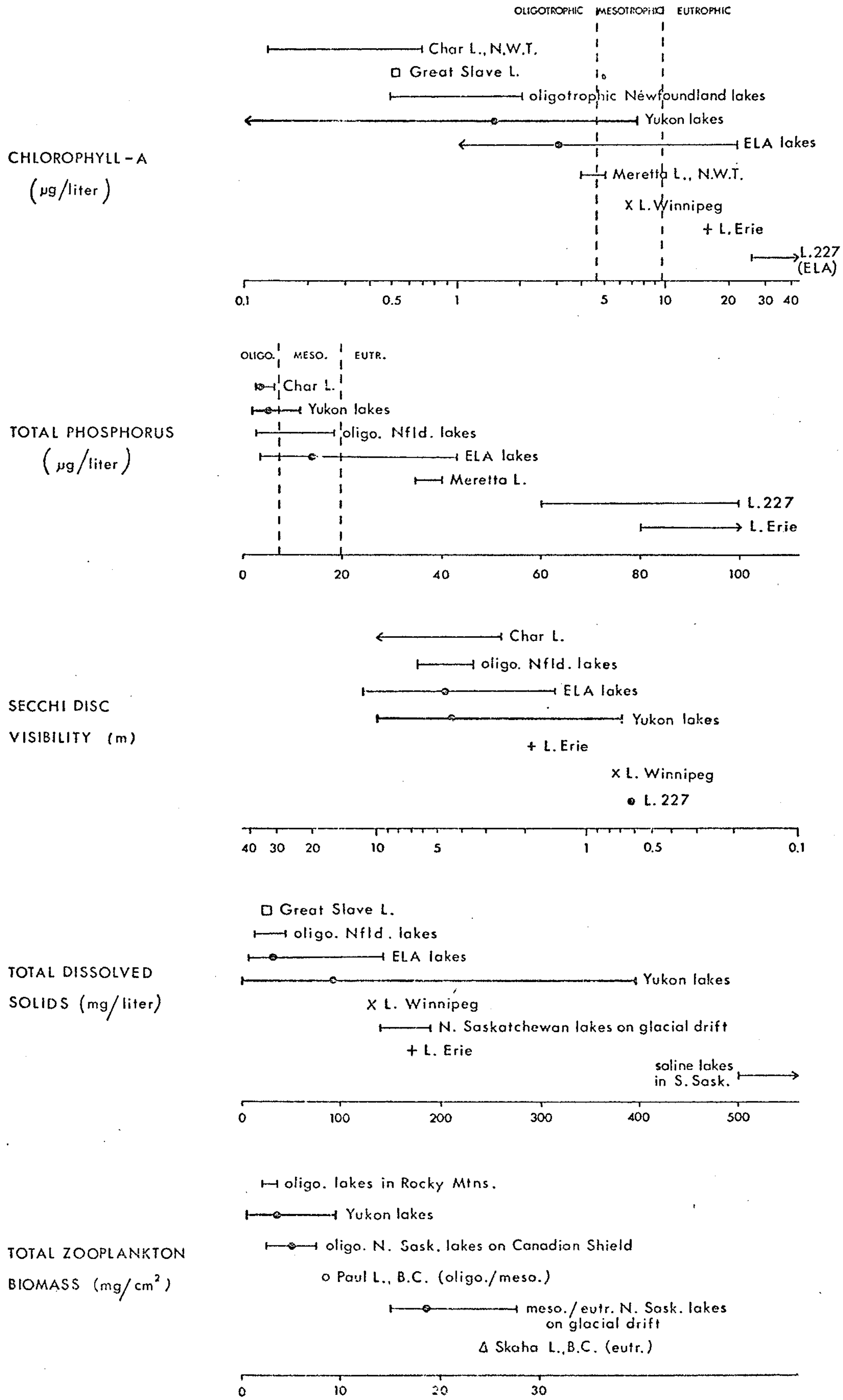
Table 2. Correlation of various lake parameters among themselves. In each square, the simple correlation coefficient (r) is presented above, and the degrees of freedom (n-2) below. Significant correlations at the 5% level are underlined with a broken line, at the 1% level with a solid line. All data transformed according to Appendix F.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Area (km^2)		0.42 36	-0.47 35	0.24 31	-0.34 32	-0.02 32	-0.58 4	0.03 32	-0.19 32	0.08 32	-0.02 32	0.57 21	-0.56 26
2. Max depth (m)			-0.30 35	0.44 31	-0.57 32	0.15 32	-0.03 4	0.21 32	0.17 32	0.10 32	0.17 32	0.23 21	-0.29 26
3. Epilimnion temperature (°C)				-0.05 31	0.02 32	0.26 32	0.16 4	0.30 32	0.23 32	0.08 32	0.26 32	-0.08 21	0.18 26
4. Secchi disc visibility (m)					-0.55 30	0.36 30	-0.50 4	0.36 30	0.38 30	0.37 30	-0.01 30	0.46 19	-0.28 25
5. Chlorophyll-a (μg/liter)						-0.14 32	0.86 4	-0.14 32	-0.10 32	-0.02 32	-0.15 32	-0.03 20	0.47 26
6. TDS (mg/liter)							0.11 4	0.94 32	0.87 32	0.73 32	0.81 32	0.33 20	0.44 26
7. Total phosphorus (μg/liter)								0.34 4	-0.08 4	-0.06 4	0.32 4	-0.51 3	0.47 4
8. Ca^{++} (mg/liter)									0.87 32	0.64 32	0.76 32	0.36 20	0.37 26
9. Mg^{++} (mg/liter)										0.51 32	0.63 32	0.32 20	0.38 26
10. Na^{+} (mg/liter)											0.60 32	0.49 20	0.41 26
11. $SO_4^{=}$ (mg/liter)												0.20 20	0.29 26
12. Epilimnion depth (m)													-0.15 17
13. Oxygen concentration difference between epilimnion and lower hypolimnion (mg/liter)													

between the epilimnion and lower hypolimnion. (Hereafter, this shall be referred to as the epilimnion-lower hypolimnion oxygen difference). Secchi disc visibility and chlorophyll-a concentration were inversely related, no doubt because chlorophyll-a concentration is a reasonable measure of phytoplankton standing crop (Winberg 1963). The concentrations of the major ions (Ca^{++}, Mg^{++}, $SO_4^{=}$, Na^{+}) were strongly correlated with each other. Significant positive correlations were also found between total phosphorus and chlorophyll-a, and between the epilimnion-lower hypolimnion oxygen difference and both TDS and chlorophyll-a. Dillon and Rigler (1974) and Sakamoto (1966) observed a close relationship between total phosphorus at spring overturn and midsummer chlorophyll-a concentration in a wide variety of lakes. The Yukon data fits Sakamoto's regression line well despite the fact that total phosphorus was measured in midsummer.

In order to place Yukon lakes in a more general perspective, they were compared to other North American lakes representing a broad range of trophic status (Fig. 2). The five parameters compared between lakes are known to be roughly related to lake productivity (for example, see Northcote and Larkin 1956; Winberg 1963; Dobson et al. 1974). Both the average chlorophyll content and total phosphorus concentration of Yukon lakes are characteristic of oligotrophic lakes, with conditions in the richer lakes approaching mesotrophy. Secchi disc visibilities are poor indicators of productivity in highly coloured or silty lakes. The lower Secchi disc visibilities of Yukon lakes were generally not caused by algal blooms, but by highly coloured water (Tatchun Lake, 1.8 m Secchi) or very silty water (North Palmer Lake, 1.2 m; South Palmer Lake, 0.7 m). The low Secchi visibility in Hungry Lake (0.9 m), however,

Figure 2. Five parameters of Yukon lakes compared with other North American lakes. Ranges (⊢——⊣) and/or means (—•—, x, +, etc.) of midsummer values presented; epilimnion values used for chemical parameters. Great Slave L. represented by McLeod Bay; L. Erie by its western basin. ELA stands for Exp'tal Lakes Area, northwestern Ontario. Dotted vertical lines represent approximate trophic boundaries from Dobson et al. (1974). Data taken from: Armstrong and Schindler (1971); Cleugh and Hauser (1971); Gachter et al. (1974); Kerekes (1974); Patalas (1972, 1975); Patalas and Salki (1973); Rawson (1942, 1951, 1960); Schindler (1972); Schindler et al. (1973, 1974, 1974).


OLIGOTROPHIC
MESOTROPHIC
EUTROPHIC
Char L., N.W.T.
Great Slave L.
oligotrophic Newfoundland lakes
Yukon lakes
ELA lakes
CHLOROPHYLL-A
(μg/liter)
Meretta L., N.W.T.
X L. Winnipeg
+ L. Erie
L.227 (ELA)
0.1
0.5
1
5
10
20
30
40
OLIGO.
MESO.
EUTR.
Char L.
Yukon lakes
TOTAL PHOSPHORUS
(μg/liter)
oligo. Nfld. lakes
ELA lakes
Meretta L.
L.227
L. Erie
0
20
40
60
80
100
Char L.
oligo. Nfld. lakes
ELA lakes
SECCHI DISC
VISIBILITY (m)
Yukon lakes
+ L. Erie
X L. Winnipeg
L. 227
40
30
20
10
5
1
0.5
0.1
Great Slave L.
oligo. Nfld. lakes
ELA lakes
TOTAL DISSOLVED
SOLIDS (mg/liter)
Yukon lakes
X L. Winnipeg
N. Saskatchewan lakes on glacial drift
+ L. Erie
saline lakes in S. Sask.
0
100
200
300
400
500
oligo. lakes in Rocky Mtns.
Yukon lakes
TOTAL ZOOPLANKTON
BIOMASS (mg/cm²)
oligo. N. Sask. lakes on Canadian Shield
o Paul L., B.C. (oligo./meso.)
meso./eutr. N. Sask. lakes on glacial drift
Δ Skaha L., B.C. (eutr.)
0
10
20
30

was apparently due to a relatively high standing crop of algae (7.21 µg/liter chlorophyll-a). The average TDS value of Yukon lakes was slighly higher than that of oligotrophic lakes on the Canadian Shield, but was lower than the average of mesotrophic/eutrophic northern Saskatchewan lakes situated on glacial drift. Zooplankton biomass per unit area was comparable to values obtained elsewhere for oligotrophic and oligotrophic/mesotrophic lakes.

II. Fish

Fish caught in each of the three different nets set per lake are shown in Appendix H. A total of 12 species were found with a maximum of 7 occurring in any one lake. The main planktivorous fish was the least cisco (*Coregonus sardinella*). The contribution of zooplankton to the diets of the more common fish species is shown in Table 3.

Quantitative indices of fish predation for the 38 lakes range from 0 to 17,800 (Table 1). Note that although the fish caught in North and South Davis lakes were not identical, the quantitative indices of fish predation for these two lakes are identical. This is because the ciscoes in South Davis Lake were unusually small (c. 9 cm fork length) and were nearly all caught in net of 1.9 cm mesh, a size not set in North Davis Lake (see Materials and Methods). The absence of ciscoes from the floating-net catch in North Davis Lake was probably due to the absence of 1.9 cm mesh net since the two lakes are only 1 km apart and are joined by a stream which appears easily navigable to fish (C.C. Lindsey pers. comm.). Also, one larger cisco was caught in the shore net in North Davis Lake.

After the Davis lakes sampling experience, 1.9 cm mesh net was included in the standard floating and deep net sets. Of the 15 lakes sampled in this fashion (lakes sampled from August 9 on--see Appendix G), this small mesh net caught fish (small lake whitefish and ciscoes) in 7 of them. In none of these lakes did the 1.9 cm mesh catch species that were not also caught by the other mesh sizes. Therefore, inclusion of this small mesh size did not affect the total number of fish species caught. Also, since the additional fish caught by this mesh size were so small, inclusion or exclusion of it probably did not significantly alter the quantitative index of fish predation.

Classifying the 38 lakes according to the qualitative index of fish predation resulted in 7 "low predation" lakes, 19 "moderate predation" lakes and 12 "high predation" lakes (Table 1). Values for the quantitative index of fish predation were averaged across lakes within each of the three qualitative categories of predation, and, as expected, lakes in the "high" category had the highest quantitative average while lakes in the "low" category had the lowest average (5614 for "high" predation" lakes, 2329 for "moderate", and 0 for "low").

Two lakes, Tatchun and Bruce, were put in the "high predation" category although planktivorous fish, fish of category 3 (Table 3), were not caught in either lake. This is because ciscoes had been previously caught in Tatchun Lake (C.C. Lindsey unpublished data 1970) and were assumed to be present but not caught in 1975. Grayling in Bruce Lake were exceptional as in no other lake were so many caught in the floating net. In lakes, grayling are generally found close to shore (McPhail and Lindsey 1970), and in this study were most commonly caught in shore nets. This cisco-like behaviour of Bruce Lake grayling was further

Table 3. Average proportion of zooplankton by volume in the diets (stomach contents) of the more common fish species in Yukon lakes. Within-species diet differences between individuals caught in different nets or of different size are indicated where noticed. Diet categories are: 1 - fish eating essentially no zooplankton (< 0.01); 2 - fish eating some zooplankton (≥0.01, < 0.9); 3 - fish eating mostly zooplankton (≥0.9).

Fish species	Net of capture (floating or deep) and body size (fork length, cm)	Average proportion of zooplankton in stomach contents	Diet Category	Source of Information
Esox lucius	both nets; all sizes	<0.01	1	Present study-These data generally confirmed by diet information given in McPhail and Lindsey (1970) & Scott and Crossman (1973).
Lota lota	both nets; all sizes	<0.01	1	
Catostomus catostomus	both nets; all sizes	<0.01	1	
Prosopium cylindraceum	deep net; all sizes	0.07	2	
P. cylindraceum	floating net; all sizes	0.5		
Salvelinus namaycush	both nets; ≥35 cm	0	2	
S. namaycush	both nets; <35 cm	0.5		
Thymallus arcticus (all lakes except Bruce)	both nets; all sizes	0.28	2	
T. arcticus (Bruce Lake only)	both nets; all sizes	0.97		
Coregonus clupeaformis (low gill raker form)*	deep net; ≥23 cm <23 cm	0.07 0.48	2	Present study; R. A. Bodaly unpubl. data; Lindsey 1963
C. clupeaformis (low gill raker form)*	floating net; all sizes	0.5		
C. clupeaformis (high gill raker form)*	both nets; all sizes	0.93	3	
C. sardinella	both nets; all sizes	0.96	3	

*see Lindsey 1963

exemplified by the fact that these individuals were eating mostly zooplankton (two stomachs contained 95 and 100% zooplankton by volume). Grayling caught in floating nets in three other lakes (Jackfish, Moraine, Tarfu) were eating mostly terrestrial insects (five stomachs examined--four contained no zooplankton and one contained 5% zooplankton). Classifying Tatchun and Bruce lakes as "high predation" lakes utilizes the available information to the greatest extent.

Due to sampling inadequacies, neither index of fish predation is fully reliable. Used together, however, these two indices should give reasonable approximations of the relative levels of planktivorous fish predation in the 38 lakes.

III. Zooplankton

General Observations

The total amount of zooplankton (crustacean zooplankton plus rotifers) and the numerical abundance of crustacean zooplankton species for all 38 lakes are shown in Appendices I and J. Counts for *Chaoborus* larvae and amphipods are also included. Note that pelagic amphipods were caught only in "low predation" lakes. The lakes in both appendices are grouped according to the qualitative categories of fish predation.

A total of 32 crustacean species were found, of which 21 can be considered as pelagic and 11 as littoral species (see Appendices I and J). It should be noted that some of the *Daphnia middendorffiana* populations showed features indicating *D. pulex* admixture, particularly in Pine Lake. Also, two allopatric "forms" of *D. longiremis* were found--a relatively small form (average adult size 1.12 mm) with moderately large helmets (plate 36B, p. 107, Brooks 1957), and a larger form (average adult size 1.58 mm) with greatly extended helmets (plate 36E, p. 107, Brooks 1957). All D. longiremis in Appendices I and J were of the small form, except where noted.

From 2 to 11 species of crustacean zooplankton were found in a single lake, the average being 6 species. Number of species was inversely related to altitude of the lake (r = -0.43, 36 degrees of freedom, $p < 0.01$). Frequency of occurrence of pelagic zooplankton species is shown in Table 4, with the species arranged from most to least common. The number of lakes in which a single species contributed more than 10% of the total number of crustaceans is also indicated. Such species were termed "dominants" after Patalas (1971). Cyclops scutifer was the most common species--it occurred in all lakes and was a "dominant" in all lakes but one. The next most common species, Diaptomus pribilofensis, was found in 89% of the lakes and was a "dominant" in 53% of the lakes. Heterocope septentrionalis occurred in 66% of the lakes, and none of the remaining species were found in more than 50% of the lakes. The most common cladocerans were Daphnia longiremis, Eubosmina longispina, and D. middendorffiana. Although they rarely were numerical dominants, cladocerans (particularly Daphnia) were often important in terms of biomass.

The sampling program in the six lakes visited three times accounted at least partially for both spatial and temporal variation of zooplankton populations, although the sample size was small (six lakes). The sampling of the 32 lakes visited once did not account for spatial or temporal variation, but did constitute a reasonable sample size. Therefore, relationships which are evident in both sets of lakes are probably not

Table 4. Frequency of occurrence of pelagic species of crustacean zooplankton in 38 Yukon lakes. Asterisks denote species abundant enough to be used in the calculation of community similarity coefficients.

Species	Number of Lakes			
	in which the species occurs	%	in which the species is "dominant" (comprises more than 10% of total number of crustaceans)	%
* Cyclops scutifer	38	100	37	97
* Diaptomus pribilofensis	34	89	20	53
* Heterocope septentrionalis	25	66	0	0
* Daphnia longiremis	18	47	2	5
* Eubosmina longispina	17	45	1	3
* Daphnia middendorffiana	16	42	0	0
* Diaptomus sicilis	13	34	7	18
* Daphnia galeata galeata	8	21	0	0
Chydorus sphaericus	7	18	0	0
* Daphnia longispina hyalina microcephala(?)	7	18	0	0
Cyclops capillatus	6	16	0	0
Leptodora kindtii	6	16	0	0
* Bosmina longirostris	4	11	0	0
Holopedium gibberum	3	8	0	0
* Daphnia galeata mendotae	2	5	0	0
* Acanthodiaptomus denticornis	1	3	1	3
* Cyclops bicuspidatus thomasi	1	3	0	0
Cyclops vernalis	1	3	0	0
* Daphnia pulex (x schoedleri)?	1	3	1	3
* Daphnia schoedleri (x pulex)?	1	3	0	0
* Senecella calanoides	1	3	0	0

artifacts and may be taken as being well supported. Results from both sets of lakes will be discussed separately, beginning with the lakes visited three times.

Factors Affecting Zooplankton Communities - Lakes visited three times

The six lakes visited three times represented all three qualitative levels of fish predation: "low" (Diamain), "moderate" (Pine, Minto, Fox), and "high" (Swan, Lower Snafu). The bathymetric map for Lower Snafu Lake could not be reasonably completed with only three transects due to the extreme irregularity of the lake bottom (Fig. 3).

The relative numerical abundance of *Cyclops scutifer*, the dominant cyclopoid, remained high throughout the summer, while the relative abundance of diaptomids decreased (Fig. 4). Daphnids were least abundant in early summer. Results from different sampling dates were not radically different with respect to species composition or relative abundance, and the differences that did exist generally involved the early summer sampling date, the mid- and late summer dates being quite similar.

Total zooplankton biomass was lowest in early summer, and increased roughly two-fold to reach a maximum in mid- or late summer (Fig. 5).

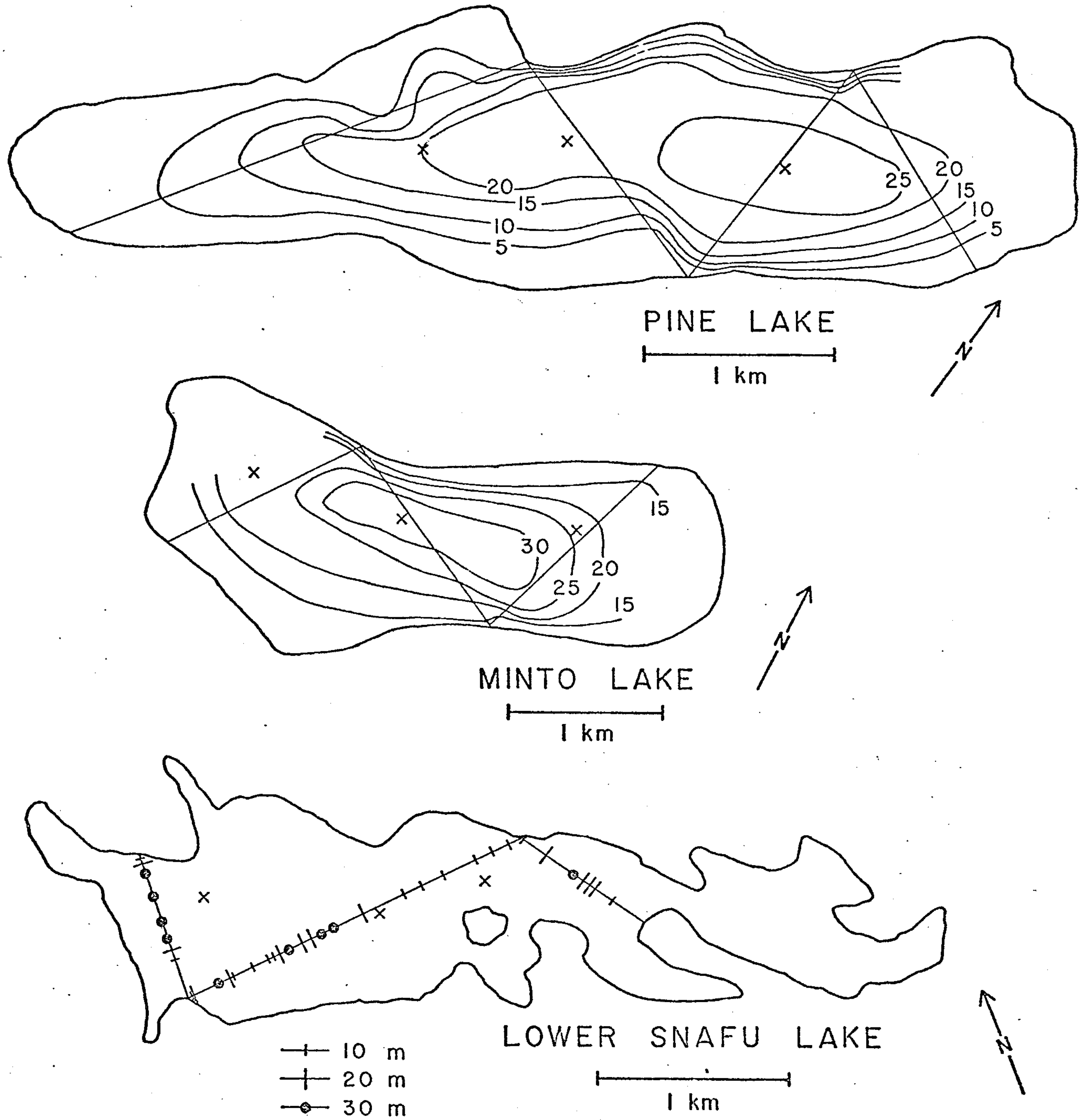
Relationships between certain lake parameters and various aspects of the zooplankton community were investigated with simple correlation analysis, after appropriate transformations (Table 5). The relationships between these aspects of the zooplankton community and the qualitative index of fish predation were also examined (Fig. 6). Of the physical and chemical parameters, the seasonal average of zooplankton

Table 5. Simple correlation between various lake parameters and certain aspects of the zooplankton community of the six Yukon lakes visited three times. Values used for zooplankton data were averaged over all samples taken per lake. Significant correlations denoted as in Table 2; four degrees of freedom for all correlations. Data transformed according to Appendix F.

		Area	Max depth	Epilimnion temperature	Secchi disc visibility	Total phosphorus	Chlorophyll-a	TDS	Oxygen difference between epilimnion and lower hypolimnion	Quantitative index of fish predation
Total zooplankton abundance (mg/cm^2)		-0.37	0.00	0.23	0.52	0.20	-0.17	0.89	0.52	0.63
Relative abundance (percent of total zooplankton biomass) of...	cyclopoids	-0.10	0.85	-0.54	-0.48	0.27	0.47	-0.35	0.03	0.53
	diaptomids	0.48	-0.50	0.04	0.36	-0.41	-0.49	0.41	-0.48	-0.61
	daphnids	-0.91	-0.42	0.83	0.05	0.57	0.32	0.05	0.96	0.50
	bosminids	-0.04	0.91	-0.64	-0.23	-0.12	0.19	-0.42	0.49	-0.19
Average adult *Daphnia* size		0.58	-0.70	0.28	0.34	-0.49	-0.60	-0.07	-0.30	-0.93

Figure 3 (a, b).

Approximate bathymetric maps for the six Yukon lakes visited three times. Sampling stations (X) and sounding transects (——) are also indicated.


20
15
10
5
25
20
15
10
5
PINE LAKE
1 km
N
15
30
20
25
15
MINTO LAKE
1 km
N
10 m
20 m
30 m
LOWER SNAFU LAKE
1 km
N

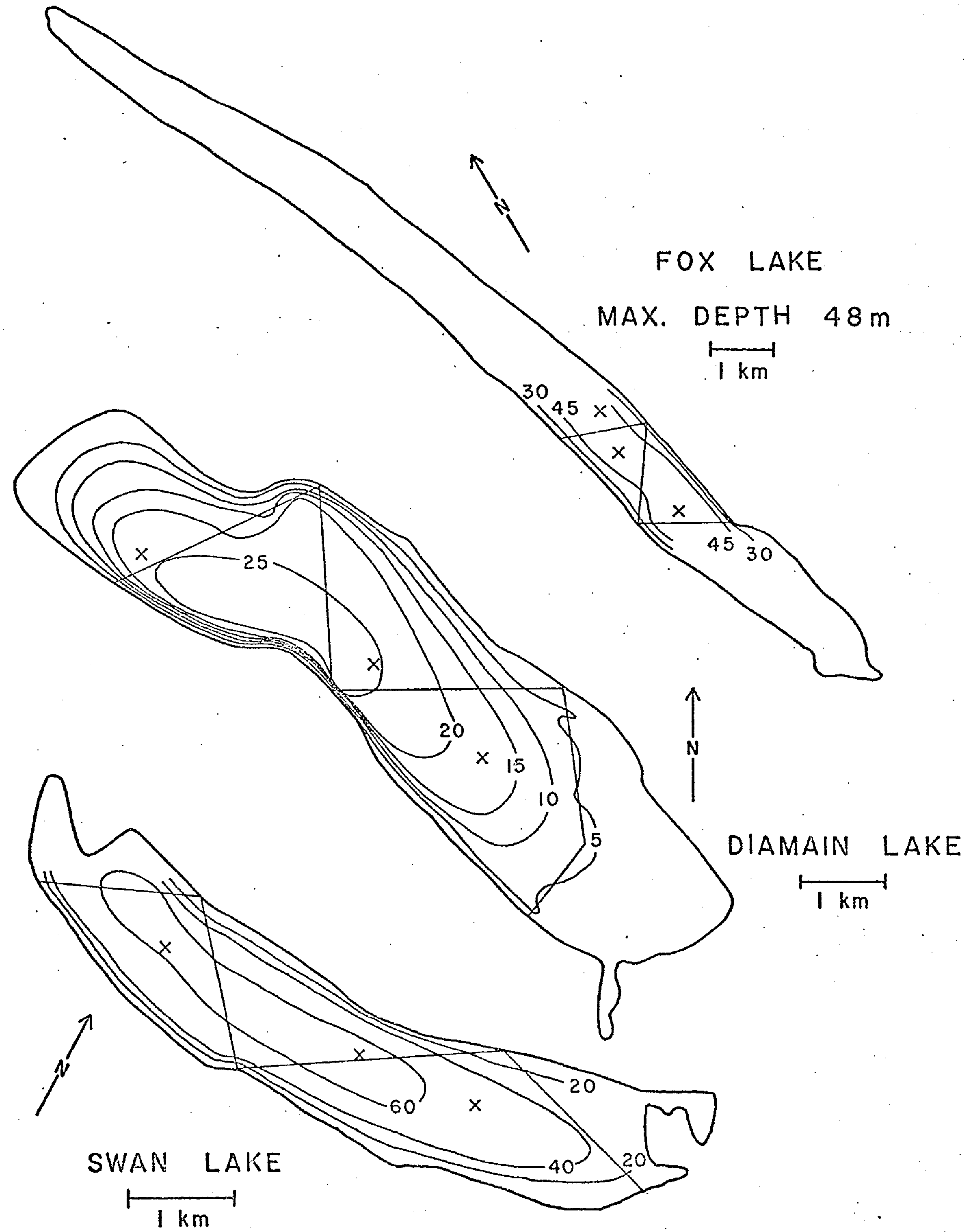

FOX LAKE
MAX. DEPTH 48m
1 km
N
30
45
45
30
DIAMAIN LAKE
1 km
N
25
20
15
10
5
SWAN LAKE
1 km
N
60
40
20
20

Figure 4. Numerical percentage composition of crustacean zooplankton by species for each of the six lakes visited three times. Percentages are averages over all samples taken in a lake at each visit; sampling dates refer to 1975.

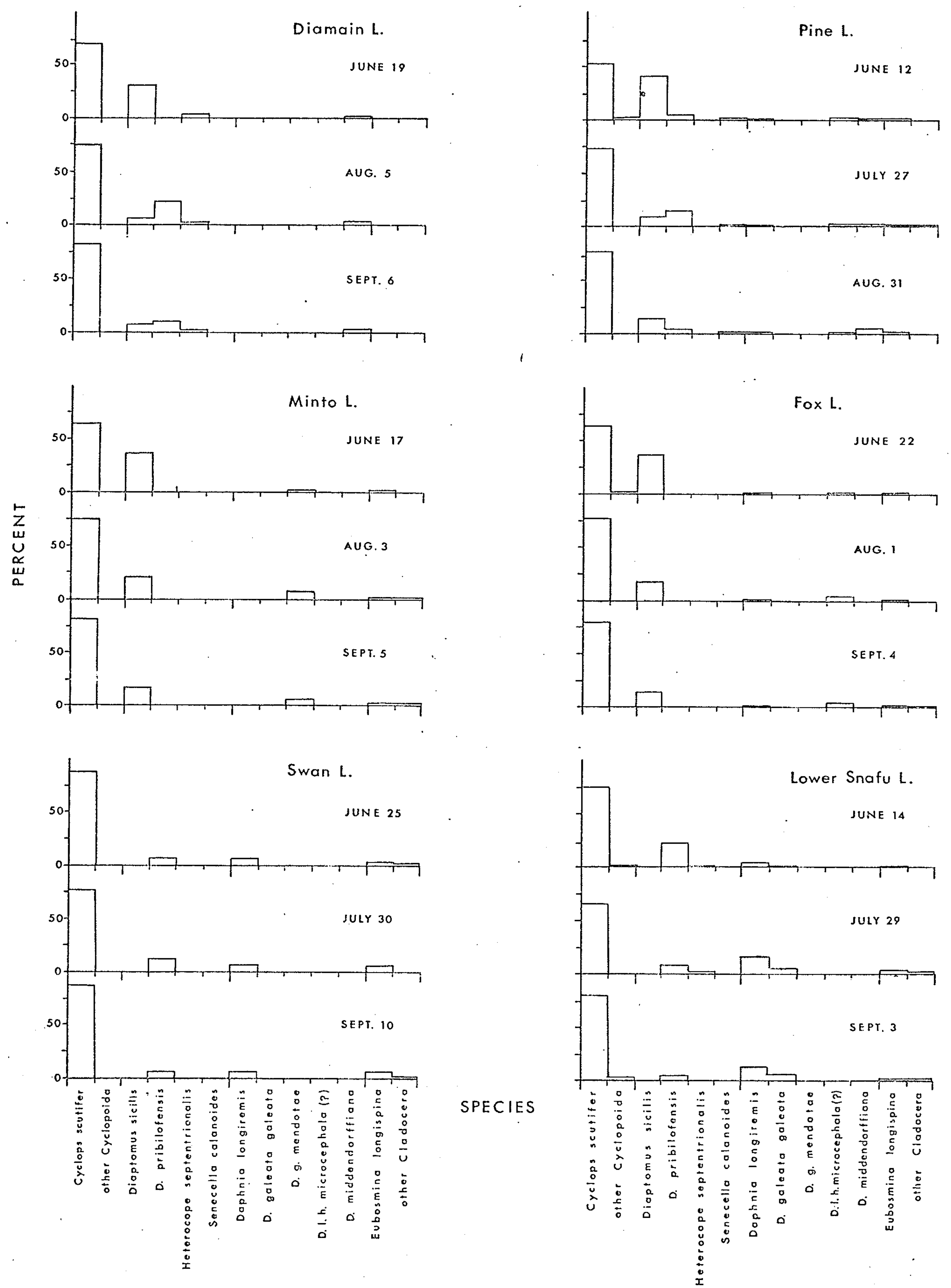
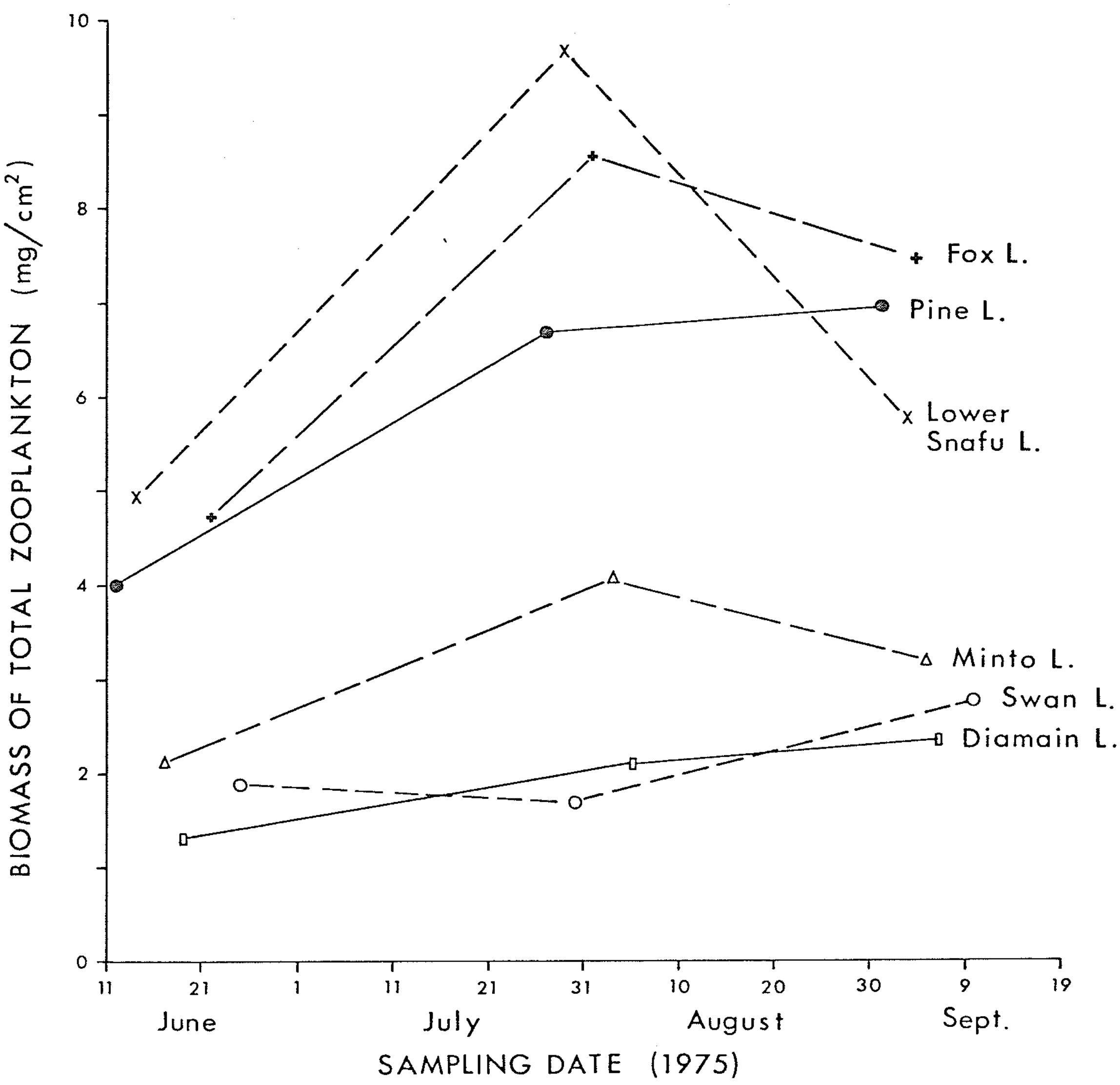
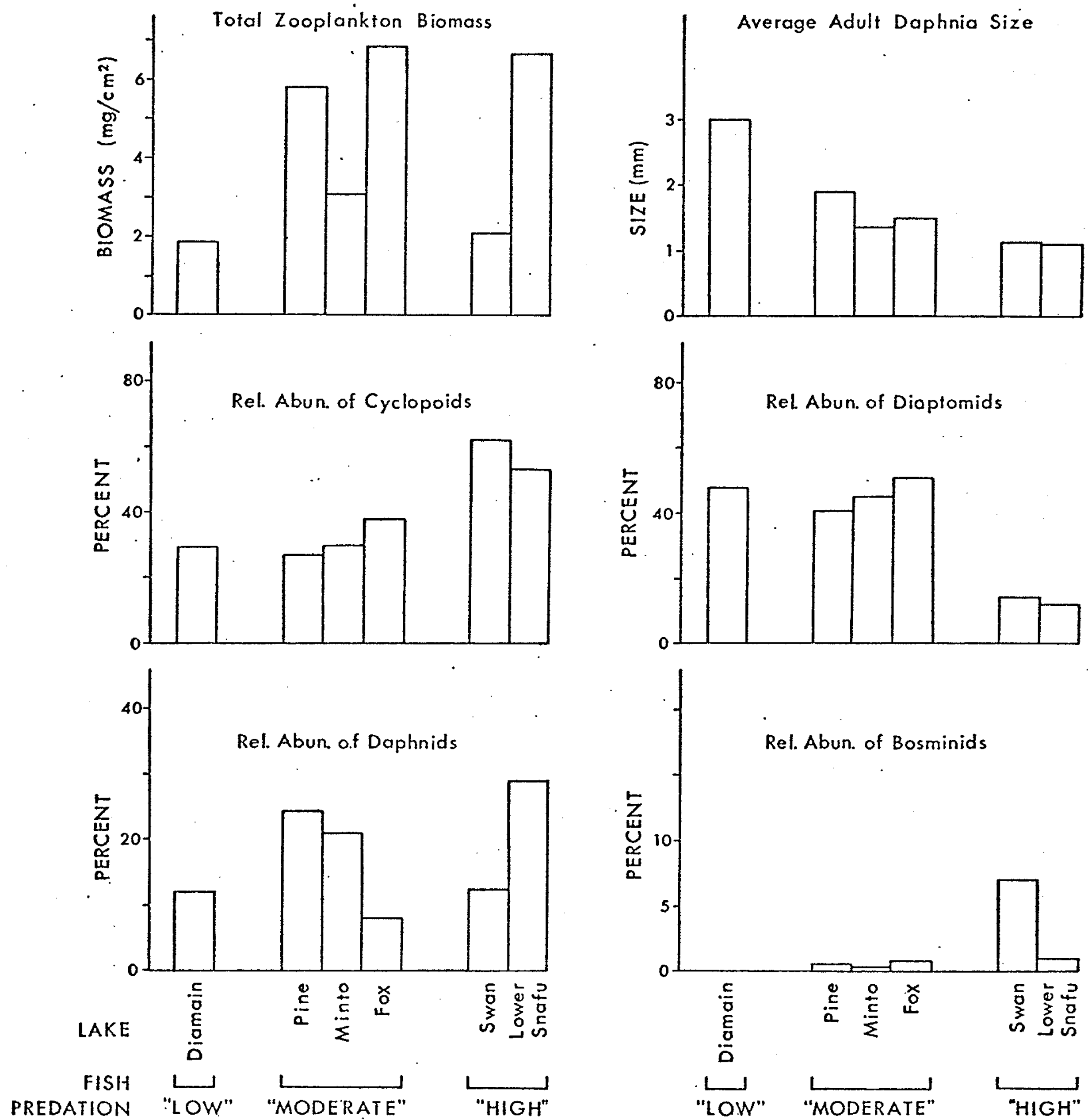

Diamain L.
JUNE 19
AUG. 5
SEPT. 6
Pine L.
JUNE 12
JULY 27
AUG. 31
Minto L.
JUNE 17
AUG. 3
SEPT. 5
Fox L.
JUNE 22
AUG. 1
SEPT. 4
Swan L.
JUNE 25
JULY 30
SEPT. 10
Lower Snafu L.
JUNE 14
JULY 29
SEPT. 3
PERCENT
50
0
SPECIES
Cyclops scutifer
other Cyclopoida
Diaptomus sicilis
D. pribilofensis
Heterocope septentrionalis
Senecella calanoides
Daphnia longiremis
D. galeata galeata
D. g. mendotae
D. l. h. microcephala (?)
D. middendorffiana
Eubosmina longispina
other Cladocera

Figure 5. Total zooplankton biomass (crustacean zooplankton plus rotifers) versus time for the six lakes visited three times. Values plotted are averages over three stations per lake.



10
8
6
4
2
0
BIOMASS OF TOTAL ZOOPLANKTON (mg/cm²)
Fox L.
Pine L.
Lower
Snafu L.
Minto L.
Swan L.
Diamain L.
11
21
1
11
21
31
10
20
30
9
19
June
July
August
Sept.
SAMPLING DATE (1975)

Figure 6. Certain aspects of the zooplankton communities of the six lakes visited three times (seasonal averages) versus the qualitative categories of planktivorous fish predation. Rel. abun. is relative abundance based on biomass units.


Total Zooplankton Biomass
BIOMASS (mg/cm²)
Average Adult Daphnia Size
SIZE (mm)
Rel. Abun. of Cyclopoids
PERCENT
Rel. Abun. of Diaptomids
PERCENT
Rel. Abun. of Daphnids
PERCENT
Rel. Abun. of Bosminids
PERCENT
LAKE
Diamain
Pine
Minto
Fox
Swan
Lower Snafu
FISH PREDATION
"LOW"
"MODERATE"
"HIGH"

biomass was related only to TDS. Zooplankton biomass was not related to either quantitative or qualitative indices of fish predation.

The relative abundance (percentage of total zooplankton biomass) of cyclopoids was greater in lakes of greater maximum depth, and was not related to the quantitative index of fish predation (Table 5). Lakes with "high" fish predation, however, appeared to have more cyclopoids than "moderate" or "low" lakes (Fig. 6). The relative abundance of diaptomids was not significantly correlated with any of the parameters in Table 5, but was low in "high predation" lakes. Daphnids were most abundant in smaller lakes with warm epilimnia and reduced oxygen levels in the hypolimnion. Daphnid abundance was not related to the intensity of fish predation. Bosminids appeared to be more abundant in deep, "high predation" lakes (Table 5, Fig. 6).

Body size of *Cyclops scutifer* was not different between lakes (Fig. 7). Two diaptomid species (*Diaptomus pribilofensis*, *D. sicilis*) were found in these six lakes, and their adult sizes showed no appreciable differences between species or between lakes (Fig. 8). Five species of *Daphnia* were found: *Daphnia middendorffiana*, *D. galeata mendotae*, *D. g. galeata*, *D. longispina hyalina microcephala* (?), and *D. longiremis*. Small *Daphnia* species were dominant in "high predation" lakes, while large species were dominant in "low predation" lakes (Fig. 9). The average size of adult *Daphnia* was strongly inversely correlated with the quantitative index of fish predation (Table 5), and was also strongly correlated with the qualitative index (Fig. 6). No other parameters were significantly correlated with average *Daphnia* size.

Two species of large calanoid copepods were present in three of the six lakes; *Heterocope septentrionalis* (adult size range 2.7 - 3.8

Figure 7. Size distributions of adult *Cyclops scutifer* in the six lakes visited three times. Size measurements from all visits and stations pooled.

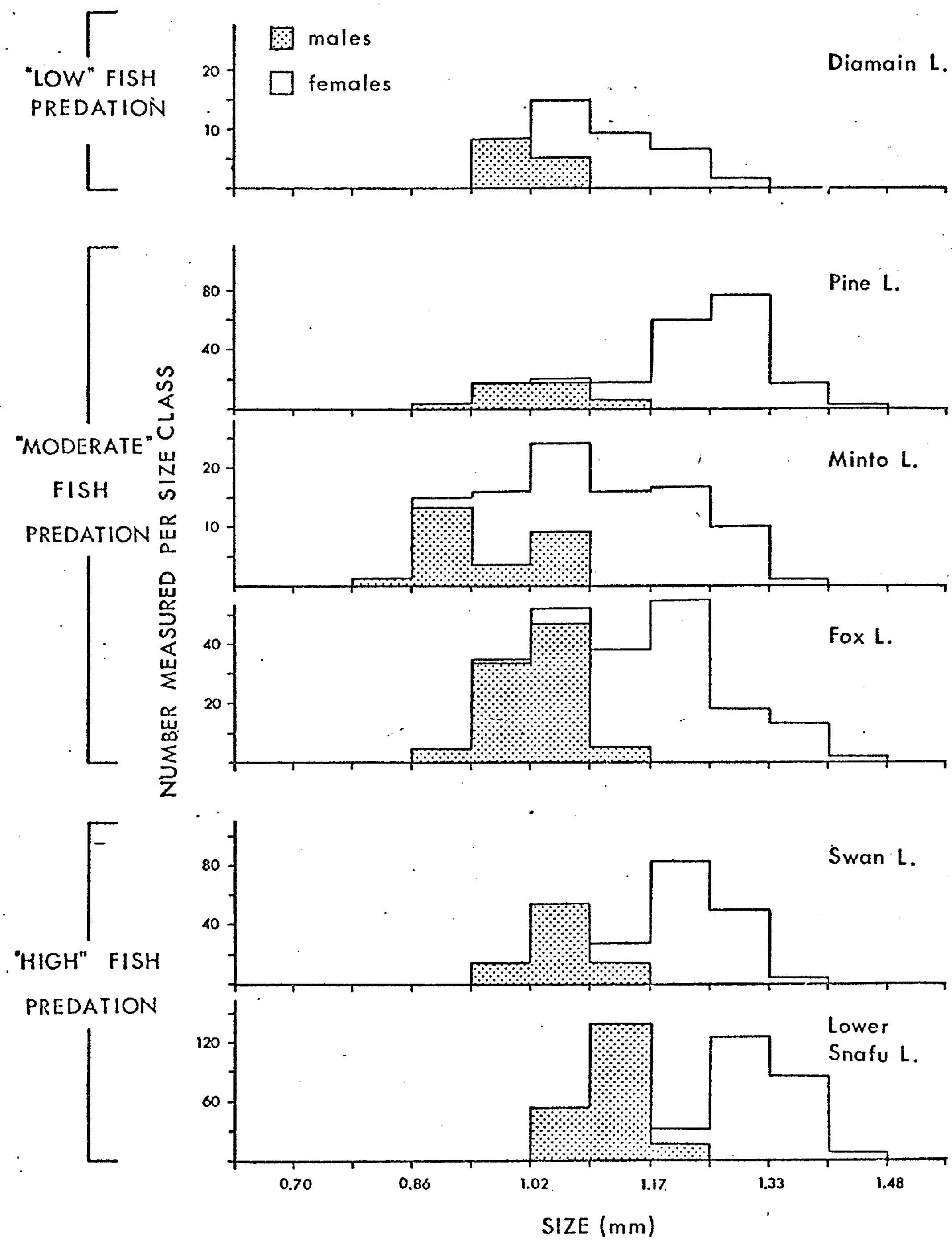
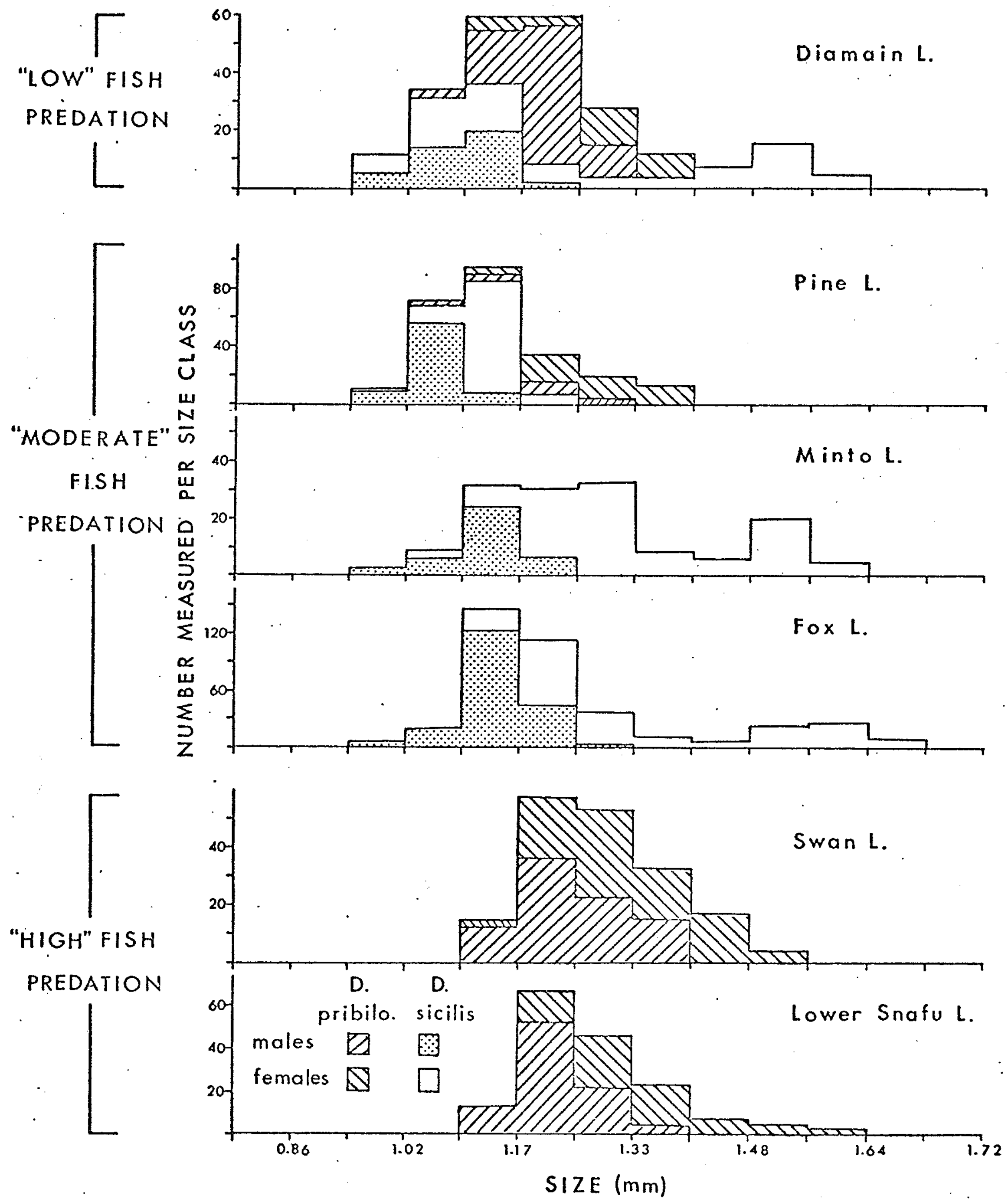
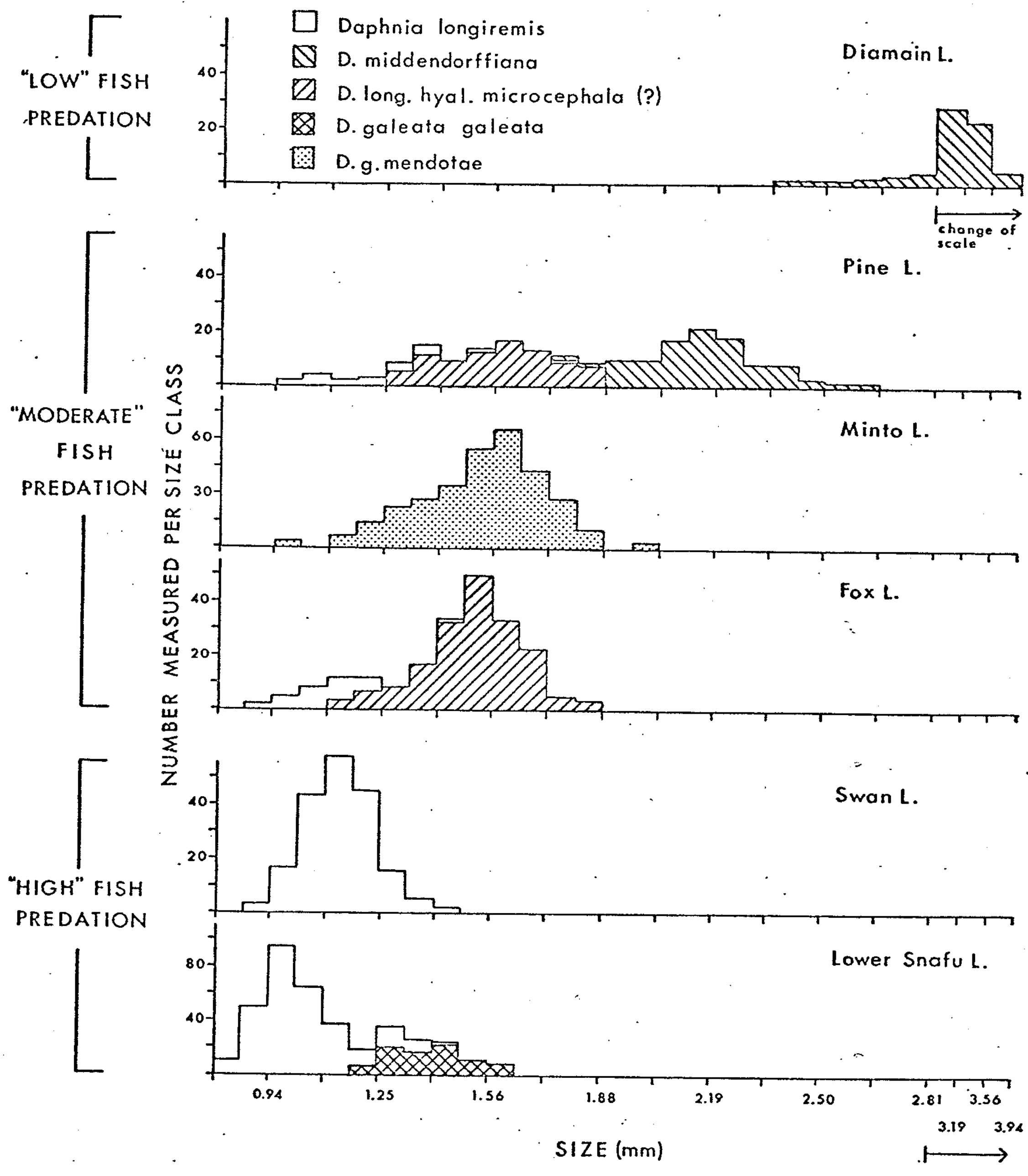

"LOW" FISH PREDATION
"MODERATE" FISH PREDATION
"HIGH" FISH PREDATION
males
females
Diamain L.
Pine L.
Minto L.
Fox L.
Swan L.
Lower Snafu L.
NUMBER MEASURED PER SIZE CLASS
20
10
80
40
20
10
40
20
80
40
120
60
0.70
0.86
1.02
1.17
1.33
1.48
SIZE (mm)

Figure 8. Size distributions of adult *Diaptomus sicilis* and *Diaptomus pribilofensis* in the six lakes visited three times. Size measurements from all visits and stations pooled.



"LOW" FISH PREDATION
"MODERATE" FISH PREDATION
"HIGH" FISH PREDATION
NUMBER MEASURED PER SIZE CLASS
Diamain L.
Pine L.
Minto L.
Fox L.
Swan L.
Lower Snafu L.
D. pribilo.
D. sicilis
males
females
0.86
1.02
1.17
1.33
1.48
1.64
1.72
SIZE (mm)

Figure 9. Size distributions of adult *Daphnia* in the six lakes visited three times. Size measurements from all visits and stations pooled. Note the change of scale at the extreme right edge of the horizontal axis.


Daphnia longiremis
D. middendorffiana
D. long. hyal. microcephala (?)
D. galeata galeata
D. g. mendotae
Diamain L.
"LOW" FISH PREDATION
change of scale
Pine L.
Minto L.
Fox L.
"MODERATE" FISH PREDATION
NUMBER MEASURED PER SIZE CLASS
Swan L.
Lower Snafu L.
"HIGH" FISH PREDATION
0.94
1.25
1.56
1.88
2.19
2.50
2.81
3.19
3.56
3.94
SIZE (mm)

mm) in Lower Snafu and Diamain lakes, and Senecella calanoides (1.8 - 2.7 mm) in Pine Lake. Since these three lakes represent each of the three qualitative fish predation categories, the presence or absence of large calanoids does not appear related to fish predation. However, the average relative abundance of large calanoids in Lower Snafu Lake, the "high predation" lake, was the lowest of the three lakes (0.23% of total zooplankton biomass compared with 5.1% for Pine Lake and 8.6% for Diamain Lake). Fish predation, therefore, may influence the abundance of large calanoids, and this will be examined in more detail when all the lakes are considered.

Factors Affecting Zooplankton Communities - Lakes visited once

To increase sample size, midsummer results from the six lakes visited three times were added to the 32 lakes visited once. Comparisons between these 38 lakes were made difficult by the fact that they were sampled at different times. At these latitudes, however, this problem is not severe because changes in species composition with time are not pronounced (Fig. 4). Samples from early summer were the most different, primarily due to the scarcity of Daphnia, and this would affect only Tatchun Lake (sampled June 21) and perhaps Summit Lake (sampled June 28). All other lakes were sampled in midsummer (July-August) except Tatlmain which was sampled in late summer (September 7), a time which was not radically different from midsummer (Fig. 4). Therefore, single samples from roughly midsummer can be taken as probably being representative. Patalas (1971) reached the same conclusion by studying lakes much further south (50°N) where temporal variability is likely to be more pronounced due to warmer temperatures and a longer growing season.

The fact that spatial variation was also not taken into account in most lakes will make the more subtle relationships between variables difficult to detect. However, this additional variation should not be enough to obscure the more significant relationships as many other authors have obtained reasonable results based on lakes sampled at one station each (for example, see Nilsson and Pejler 1973; Northcote and Larkin 1956; Patalas 1971).

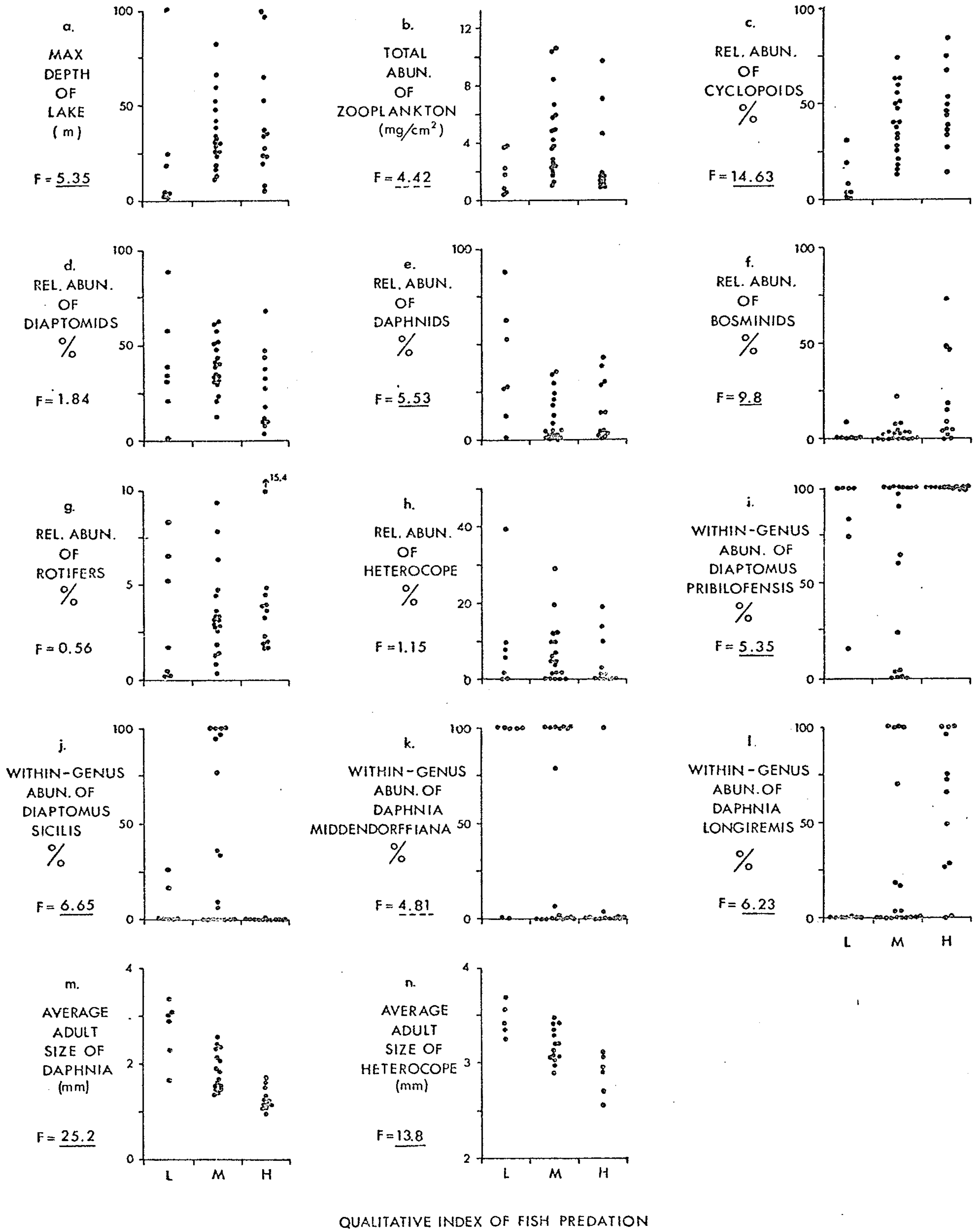
Total zooplankton abundance was positively correlated with both TDS and the epilimnion-lower hypolimnion oxygen difference (Table 6), two variables which are rough measures of lake productivity. Total abundance also increased with both increasing Secchi disc visibility and increasing maximum depth. Patalas (1971) observed a similar increase in the abundance (numbers) of plankton per unit area with increasing maximum depth, and explained it on the basis of the deeper epilimnia which are generally present in larger, deeper lakes. The epilimnion roughly coincides with the trophogenic zone (Patalas 1960) and so a deeper epilimnion means a larger volume available for zooplankton feeding and growth. Such an explanation possibly applies here too since the total abundance per unit area was also correlated with epilimnion depth (Table 6). Note, however, that some authors have observed a decrease in zooplankton abundance per unit area with increasing depth (Rawson 1955) while others have observed no clear relationship between the two (Northcote and Larkin 1956). Total abundance was not related to either quantitative or qualitative indices of fish predation (Table 6, Fig. 10b). Zooplankton abundance was greatest for lakes of "moderate" fish predation, but this was probably not due to predation differences since shallow depths were probably responsible for low abundances in "low predation" lakes (see

Table 6. Simple correlation between various lake parameters and certain aspects of the zooplankton community of 38 Yukon lakes. Correlation coefficients, degrees of freedom, and significance levels are presented as in Table 2. Data transformed according to Appendix F.

		Area	Max depth	Epilimnion depth	Epilimnion temperature	Secchi disc visibility	Chlorophyll-a	TDS	Oxygen difference between epilimnion & lower hypolimnion	Quantitative index of fish predation
Total zooplankton abundance (mg/cm^2)		0.01 36	0.41 36	0.46 21	0.11 35	0.54 31	-0.04 32	0.60 32	0.47 26	0.13 36
Relative abundance (percent of total zooplankton biomass) of...	cyclopoids	0.33 36	0.80 36	-0.05 21	-0.51 35	0.34 31	-0.42 32	0.05 32	-0.26 26	0.38 36
	diaptomids	-0.04 36	-0.28 36	0.23 21	0.12 35	-0.32 31	0.39 32	-0.10 32	0.19 26	-0.08 36
	daphnids	-0.33 36	-0.32 36	-0.03 21	0.38 35	0.18 31	-0.16 32	0.24 32	0.15 26	-0.31 36
	bosminids	0.12 36	0.20 36	-0.09 21	-0.10 35	0.12 31	-0.18 32	0.01 32	0.05 26	0.31 36
	Heterocope septentrionalis	-0.12 35	-0.45 35	-0.12 20	0.31 34	-0.33 30	0.37 31	-0.24 31	0.11 26	-0.02 35
	rotifers	0.04 36	0.15 36	0.06 21	-0.17 35	-0.28 31	0.15 32	0.06 32	0.00 26	0.27 36
Within-genus abundance (percent of total biomass of that genus) of...	*Diaptomus pribilofensis*	-0.27 35	-0.25 35	0.11 20	0.21 34	-0.05 30	0.16 31	0.03 31	0.09 25	0.16 35
	Diaptomus sicilis	0.30 36	0.39 36	0.06 21	-0.23 35	0.25 31	-0.35 32	0.11 32	-0.14 26	-0.11 36
	Daphnia middendorffiana	-0.19 36	-0.37 36	0.04 21	0.31 35	0.04 31	0.09 32	0.02 32	-0.09 26	-0.44 36
	*Daphnia middendorffiana**	-0.22 24	-0.33 24	-0.03 16	0.22 23	0.05 20	0.03 21	-0.08 21	-0.12 18	-0.35 24
	Daphnia longiremis	0.04 36	0.12 36	-0.16 21	-0.16 35	-0.26 31	0.10 32	-0.24 32	0.00 26	0.41 36
Average adult *Daphnia* size		-0.15 32	-0.50 32	0.03 20	0.51 31	0.08 27	0.02 28	0.10 28	-0.06 24	-0.60 32
Average adult *Daphnia middendorffiana* size		-0.05 11	-0.50 11	-0.09 6	0.44 10	-0.08 8	-0.10 9	-0.23 9	-0.51 9	-0.69 11
Average adult *Heterocope septentrionalis* size		-0.16 23	-0.10 23	0.20 13	0.35 22	0.02 19	0.01 21	0.29 21	-0.29 18	-0.68 23

*excluding "high predation" lakes

Figure 10. Average values for certain zooplankton parameters of the 38 Yukon lakes plotted for each of the qualitative levels of planktivorous fish predation. Each dot represents a lake; L, M, and H refer to "low", "moderate", and "high" predation intensities, respectively. Rel. Abun. is relative abundance based on biomass units. Significant F values at the 5% level are underlined with a broken line; at the 1% level with a solid line.


a.
MAX DEPTH OF LAKE (m)
F = 5.35
b.
TOTAL ABUN. OF ZOOPLANKTON (mg/cm²)
F = 4.42
c.
REL. ABUN. OF CYCLOPOIDS %
F = 14.63
d.
REL. ABUN. OF DIAPTOMIDS %
F = 1.84
e.
REL. ABUN. OF DAPHNIDS %
F = 5.53
f.
REL. ABUN. OF BOSMINIDS %
F = 9.8
g.
REL. ABUN. OF ROTIFERS %
F = 0.56
15.4
h.
REL. ABUN. OF HETEROCOPE %
F = 1.15
i.
WITHIN-GENUS ABUN. OF DIAPTOMUS PRIBILOFENSIS %
F = 5.35
j.
WITHIN-GENUS ABUN. OF DIAPTOMUS SICILIS %
F = 6.65
k.
WITHIN-GENUS ABUN. OF DAPHNIA MIDDENDORFFIANA %
F = 4.81
l.
WITHIN-GENUS ABUN. OF DAPHNIA LONGIREMIS %
F = 6.23
m.
AVERAGE ADULT SIZE OF DAPHNIA (mm)
F = 25.2
n.
AVERAGE ADULT SIZE OF HETEROCOPE (mm)
F = 13.8
L M H
QUALITATIVE INDEX OF FISH PREDATION

next paragraph), and low TDS values were probably responsible for low abundances in "high predation" lakes. (The average TDS value for the 9 "high predation" lakes clumped together in Fig. 10b is 39 mg/liter, while the average for the 3 "high" lakes with greater zooplankton abundances is 128 mg/liter).

Maximum depth was not independent of the qualitative index of fish predation (Fig. 10a). "High" and "moderate predation" lakes were not significantly different with respect to maximum depth, but both were deeper than "low predation" lakes. These shallow lakes (< 5 m maximum depth; West Halfway, Sulphur, Taye, Hungry) are inhabited only by pike, possibly because they are the only fish species able to survive the severe winter oxygen depletion generally present in such lakes. "Low predation" lakes, therefore, may be differet from "moderate" and "high predation" lakes with respect to some parameters simply because of this difference in maximum depth. Care must be exercised to differentiate effects of fish predation from effects of depth.

The relative abundance of cyclopoids was greatest in large, deep, cool lakes with low epilimnetic concentrations of chlorophyll-a (Table 6). Cyclopoid abundance was related to fish predation only in that "low predation" lakes had lower abundances (Fig. 10c), most likely due to the shallowness of such lakes. (Within the "low predation" lakes, the two deepest lakes, Janet and Diamain, had the most cyclopoids). The relative abundance of diaptomids was related only to chlorophyll-a, with more diaptomids occurring in lakes of higher chlorophyll-a concentrations. Daphnids were more abundant in small lakes with warm epilimnia, although the correlations were not highly significant (Table 6). "Low predation" lakes had significantly more daphnids than "moderate" or "high" lakes (Fig. 10e). Again, this is probably not due to differences in fish predation, but to differences in maximum depth, the "low predation" lakes being shallow and warm. The wide range of Daphnia abundance in "low predation" lakes (Fig. 10e) is largely explained by temperature--for example, the two lakes lowest in Daphnia abundance, Diamain and Hungry, had the coolest epilimnia. The relative abundance of bosminids increased with increasing fish predation. Rotifer abundance was not related to any of the measured parameters (Table 6, Fig. 10g).

The environmental preferences of the more common crustacean zooplankton species were also examined. In Table 6 and Fig. 10, within-genus abundance refers to the percentage of the total biomass of a genus that is comprised of a certain species. For example, a 20% within-genus abundance of Daphnia longiremis would mean that D. longiremis biomass contributes 20% to the total Daphnia biomass. In Fig. 11, each histogram is differentiated into three or four categories and represents a physical, chemical, or biological characteristic of the lakes under study.

Cyclops scutifer was the only abundant cyclopoid, and so its environmental preferences were the same as for cyclopoids as a group. Cyclops capillatus was found in six lakes of various characteristics.

The most common diaptomid was Diaptomus pribilofensis and it tended to be replaced by, or at least co-occur with, D. sicilis in deeper lakes with low chlorophyll-a concentrations. D. sicilis is known to prefer deeper layers in some lakes (Patalas 1969; Rigler and Langford 1967). Fish predation did not have a clear effect on the within-genus abundances of these two species. D. pribilofensis was most abundant in "high predation" lakes and least abundant in "moderate predation" lakes, while D. sicilis was just the reverse (Fig. 10i,j). D. sicilis was not abundant in "low predation" lakes probably due to their shallowness, and was absent from all "high predation" lakes possibly because of fish predation. Acanthodiaptomus denticornis was found only in Hungry Lake.

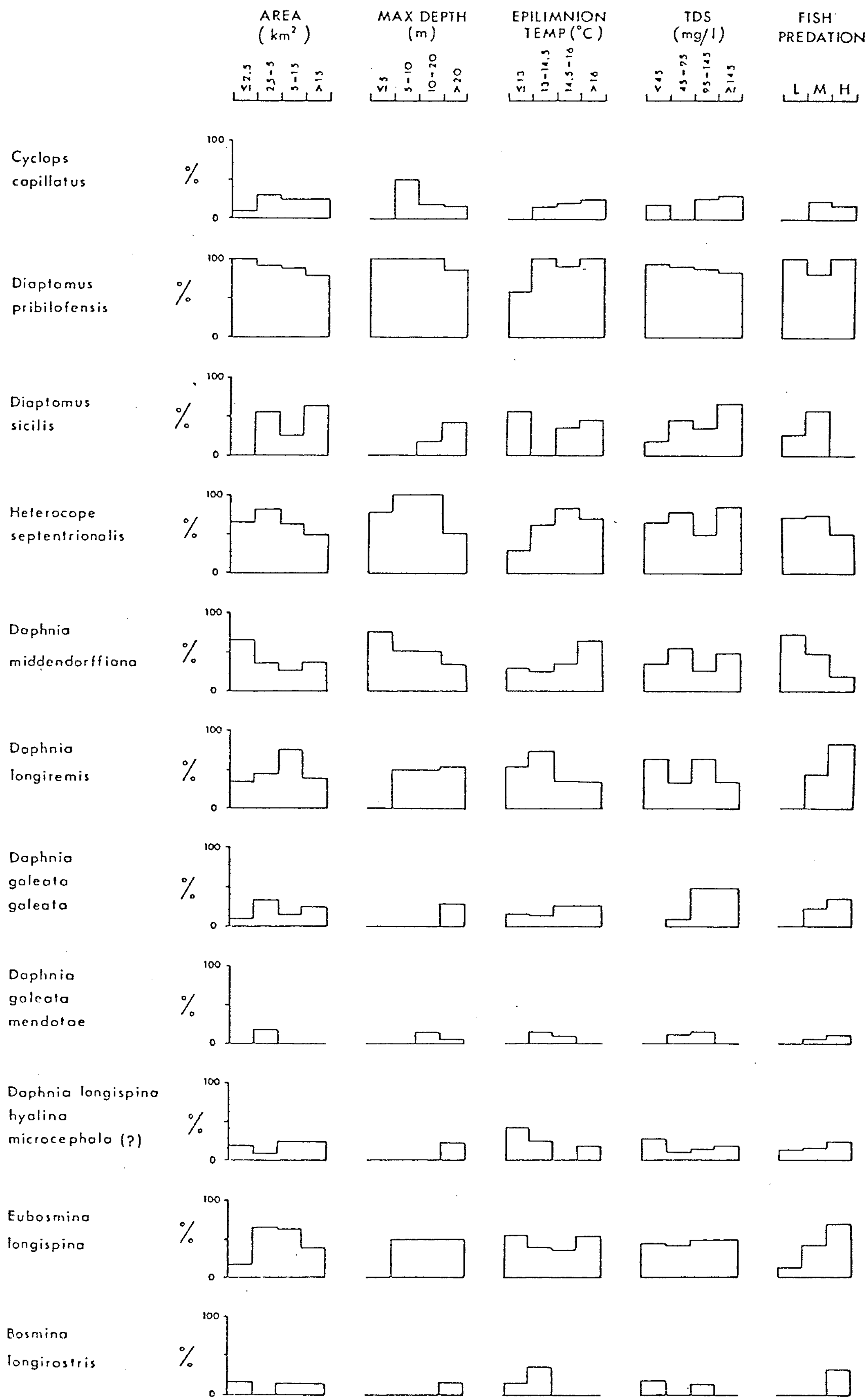
Heterocope septentrionalis was rarely numerically abundant, but was often a significant component of the total zooplankton biomass due to its large size. In terms of biomass, the relative abundance of Heterocope was greatest in shallow lakes with high epilimnetic concentrations of chlorophyll-a. Hetercope abundance was not significantly related to any measure of fish predation. The average adult size of Heterocope, however, decreased significantly with increasing intensities of fish predation (Table 6, Fig. 10n).

Daphnia longiremis, the smallest Daphnia, and D. middendorffiana, the largest Daphnia, were the most common daphnids in Yukon lakes. D. longiremis was the most abundant daphnid in lakes with "high" fish predation, and it did not occur in any of the seven "low predation" lakes. D. middendorffiana was dominant in "low predation" lakes, and was present in only one of the twelve "high predation" lakes. Lakes with "moderate" levels of fish predation were intermediate in terms of being dominated by either D. longiremis or D. middendorffiana. D. middendorffiana abundance was also significantly related to maximum depth, being greater in shallower lakes. This was probably not a direct causal relationship since D. middendorffiana appears to be excluded from deeper lakes by planktivorous fish. If depth has a genuine influence on the abundance of D. middendorffiana, one would expect the correlation between depth and D. middendorffiana abundance to still be significant if "high predation" lakes were excluded from the analysis (excluded because such lakes tend not to have D. middendorffiana regardless of their maximum depths). The resulting correlation coefficient, however, is not significant ($r = -0.32$, 26 degrees of freedom, $p > 0.1$). Also, maximum depth did not influence the presence or absence of D. middendorffiana in lakes of "low" or "moderate" fish predation. A chi-square test of the presence/absence of D. middendorffiana in "moderate" and "low" lakes classified into three depth categories ($\leq$10m, >10m and $\leq$30m, > 30m) yielded a non-significant chi-square value of 1.04 (2 degrees of freedom, $p > 0.5$).

Daphnia galeata galeata occurred more commonly in lakes with high TDS values, and did not occur in shallow, "low predation" lakes (Fig. 11). D. longispina hyalina microcephala (?) occurred in a wide variety of lake types, but was not found in shallow lakes. D. g. mendotae was found in two lakes of moderate size and depth. D. pulex (X schoedleri) ? was found only in West Halfway Lake, and D. schoedleri (X pulex) ? only in Frenchman Lake. Eubosmina longispina and Bosmina longirostris both occurred predominantly in lakes with "high" fish predation.

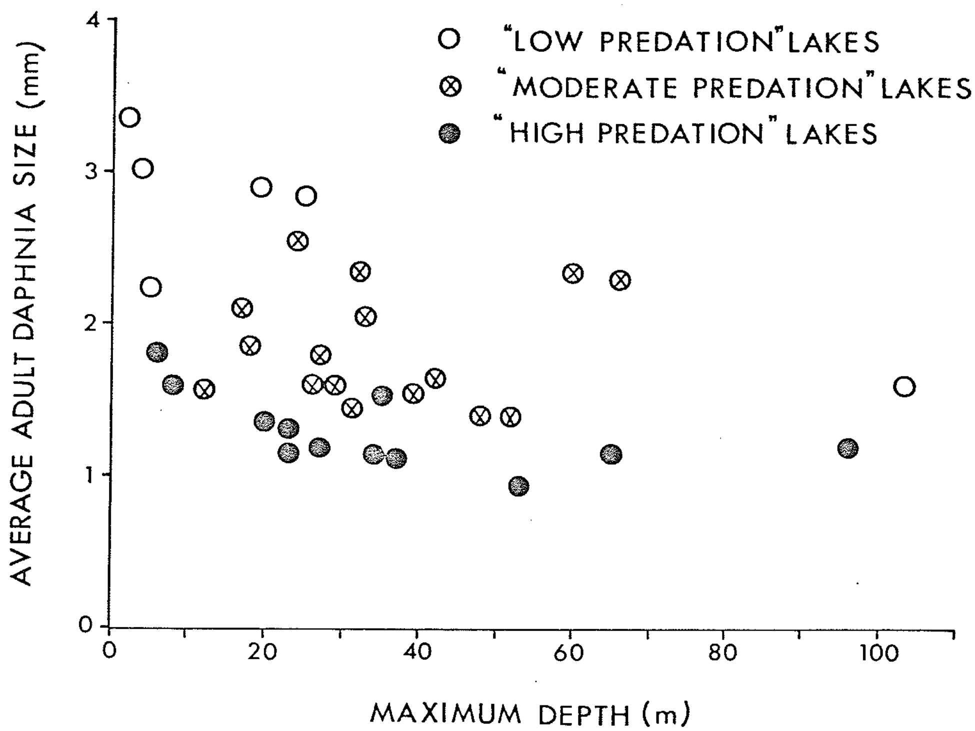
The average size of adult Daphnia females was closely related to both quantitative and qualitative indices of fish predation (Table 6, Fig. 10m), with low levels of predation favouring large Daphnia. Shallow, warm lakes also favoured the presence of large Daphnia, but this effect is difficult to distinguish from the predation effect since shallow lakes tended to have low intensities of fish predation. To separate these two effects, Daphnia size was plotted against maximum depth separately for each of the three qualitative levels of fish predation (Fig. 12).

Figure 11. Frequency distributions of the more common crustacean species in the 38 lakes classified according to area, depth, epilimnion temperature, TDS, and the qualitative index of fish predation (L="low", M="moderate", H="high"). A value of 100% means a species was present in all lakes of that category.



AREA (km²)
≤2.5
2.5-5
5-15
>15
MAX DEPTH (m)
≤5
5-10
10-20
>20
EPILIMNION TEMP (°C)
≤13
13-14.5
14.5-16
>16
TDS (mg/l)
<45
45-95
95-145
≥145
FISH PREDATION
L
M
H
100
%
0
Cyclops capillatus
Diaptomus pribilofensis
Diaptomus sicilis
Heterocope septentrionalis
Daphnia middendorffiana
Daphnia longiremis
Daphnia galeata galeata
Daphnia galeata mendotae
Daphnia longispina hyalina microcephala (?)
Eubosmina longispina
Bosmina longirostris

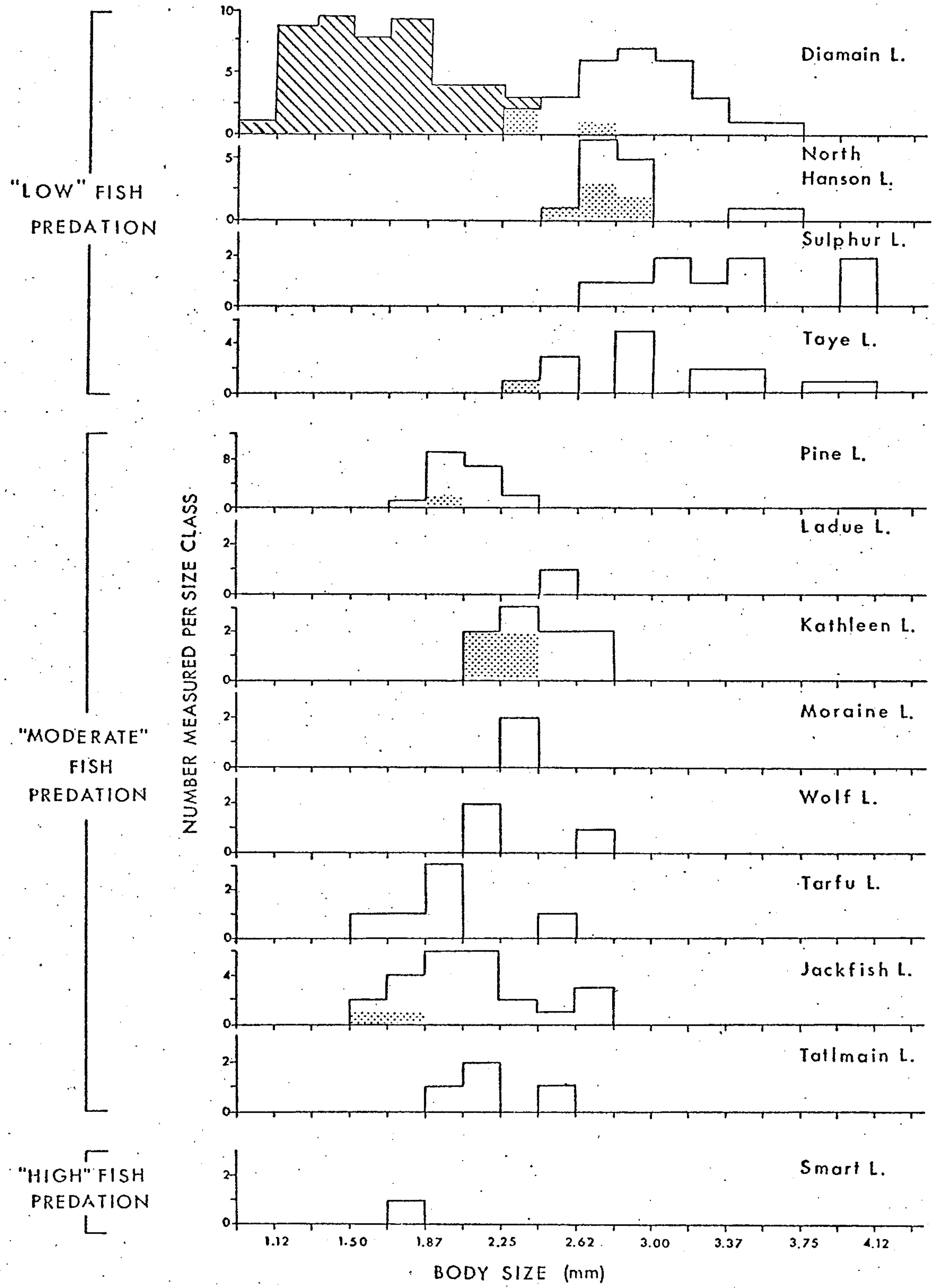
Figure 12. Average adult *Daphnia* size versus maximum depth of the lake. The qualitative index of fish predation for each lake is also indicated.


"LOW PREDATION" LAKES
"MODERATE PREDATION" LAKES
"HIGH PREDATION" LAKES
AVERAGE ADULT DAPHNIA SIZE (mm)
MAXIMUM DEPTH (m)
0
1
2
3
4
0
20
40
60
80
100

Fish predation affected _Daphnia_ size at all depths, but maximum depth was significantly related to _Daphnia_ size only for "high predation" lakes ($r = -0.75$, 10 degrees of freedom, $p < 0.01$). In this group of lakes, the two shallowest lakes, Smart and Dezadeash, contributed a great deal to the statistical significance of the relationship although each was represented by only one _Daphnia_ size measurement (no more adult _Daphnia_ were seen in samples from these two lakes). Therefore, _Daphnia_ size was influenced primarily by the intensity of fish predation, and perhaps to a lesser extent by the depth of the lake. Further work must be done to determine whether or not lake depth has a genuine effect on average _Daphnia_ size.

Changes in average _Daphnia_ size between lakes were partly due to changes in species composition (discussed previously), but also to changes in size within one species. _D. middendorffiana_ was probably heavily preyed upon by fish due to its large size, and adult size of this species decreased with increasing fish predation (Table 6). This size shift was due to individuals maturing at smaller sizes in lakes with "moderate" or "high" levels of fish predation (Fig. 13). Although some of the sample sizes are small in Fig. 13, the results are consistent between lakes in the same predation category. The large form of _D. longiremis_ was found too infrequently to allow determination of factors influencing its distribution. It tended, however, to occur in moderately deep-to-shallow lakes of "moderate" predation intensity; the small form preferred deeper lakes of "high" predation intensity. Brooks (1957) states that the large helmets characteristic of the large form only develop when the water in which _D. longiremis_ lives is quite warm. In these Yukon lakes, however, no significant thermal differences were

Figure 13. Size distributions of *Daphnia middendorffiana* in lakes of different predation intensities. Unshaded areas represent mature *Daphnia*, stippled areas *Daphnia* of questionable maturity, and lined areas immature *Daphnia*.


"LOW" FISH PREDATION
"MODERATE" FISH PREDATION
"HIGH" FISH PREDATION
NUMBER MEASURED PER SIZE CLASS
Diamain L.
North Hanson L.
Sulphur L.
Taye L.
Pine L.
Ladue L.
Kathleen L.
Moraine L.
Wolf L.
Tarfu L.
Jackfish L.
Tatlmain L.
Smart L.
1.12
1.50
1.87
2.25
2.62
3.00
3.37
3.75
4.12
BODY SIZE (mm)

noticed between lakes having the large form and lakes having the small form of *D. longiremis*.

Results from the lakes visited once are essentialy the same as those from the six lakes visited three times, and, therefore, these results may be taken as being well supported. However, some of the relationships seen in the six-lakes series, such as the decrease in diaptomid abundance with increasing fish predation, did not find confirmation in the series of lakes visited once.

The Crustacean Community

The limnetic crustacean community of lakes in general is remarkably simple, with only a few species being abundant and the remainder scarce (Pennak 1957). This community is exceptionally simple in Yukon lakes where usually only two species were numerically dominant--*Cyclops scutifer* and either *Diaptomus pribilofensis* or *D. sicilis*, usually the former (Table 4). Nonetheless, significant differences in species composition did exist between the 38 lakes, especially among the *Daphnia*. Therefore, a cluster analysis was performed to delineate groups of lakes with similar crustacean communities, and to determine which environmental factor(s) was (were) responsible for the differences between groups.

To perform the cluster analysis, Sorenson's similarity coefficient was calculated for all pairs of lakes (Appendix K). This coefficient equals 1.0 when the two communities being compared are identical in species composition, and equals 0 when the two communities have no species in common. Very rare species were excluded from the calculation because their absence from a lake sample may have been due to inadequacy of sampling rather than to a real absence from the lake. If a species was on the average less abundant than 4 individuals per lake sample in lakes where it was found, then there was a chance of 5% or greater of not finding this species in lakes where it was actually present but rare. (This follows directly from the Poisson distribution.) Since roughly 200 liters (8 traps) were sampled in lakes visited once, only species with average abundances, when present, greater than or equal to 4 individuals per 200 liters (0.02/liter) were abundant enough to ensure an error of less than 5% in their presence/absence data. The 16 limnetic crustacean species used to calculate similarity coefficients between lake communities are denoted by asterisks in Table 4.

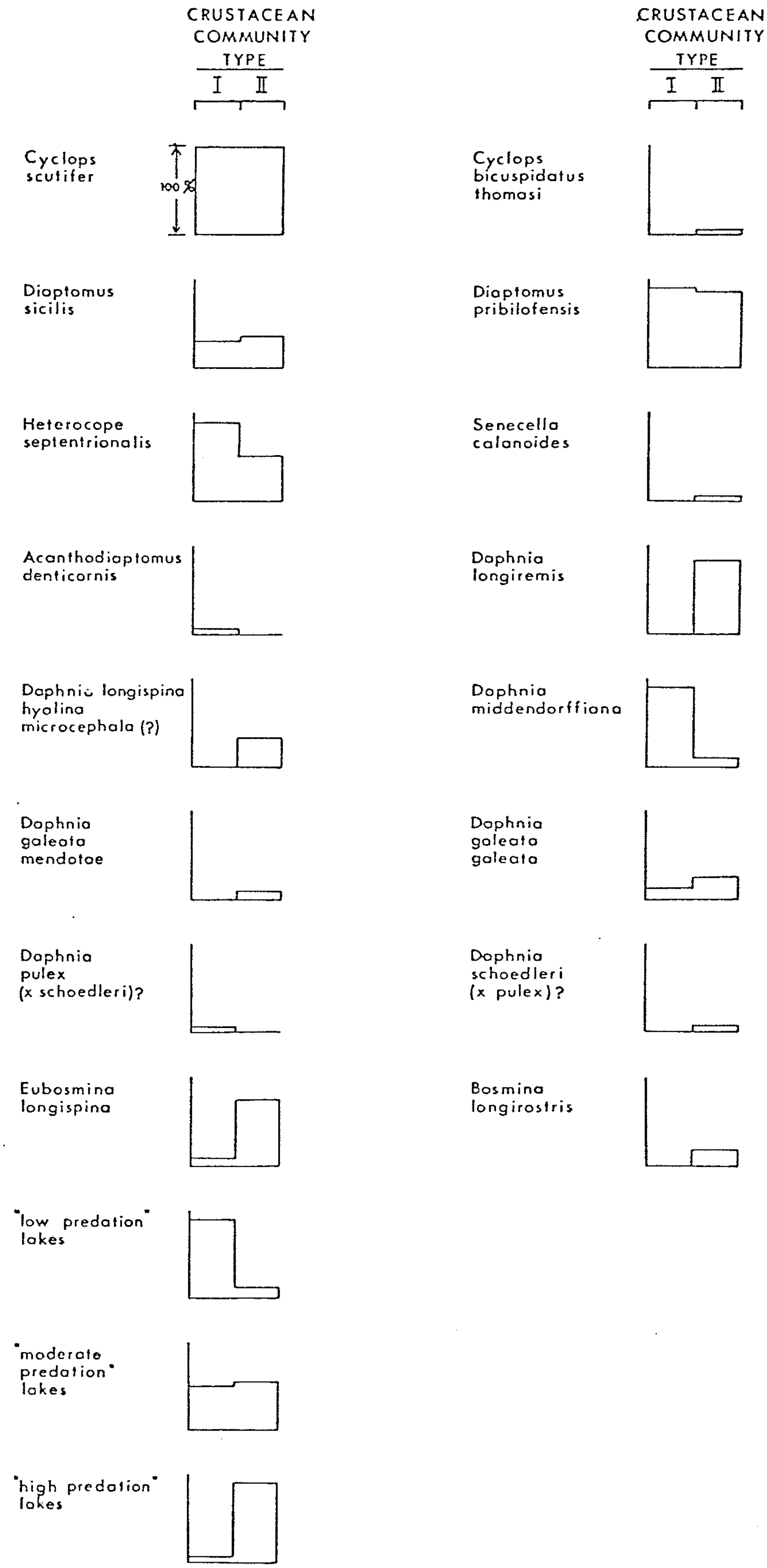
It should be noted that Sorenson's similarity coefficient is a measure of similarity in species composition, regardless of relative abundance of individual species. A major criticism of this coefficient, therefore, is that it may overestimate the importance of rare species relative to the abundant ones (Whittaker and Fairbanks 1958). This difficulty is lessened somewhat here as the very rare species were not considered.

Two community types were distinguished by the cluster analysis:

Community Type I - This community type was characterized by _C. scutifer_, _Diaptomus pribilofensis_, _H. septentrionalis_, and _Daphnia middendorffiana_. Sixteen lakes, the majority with "low" or "moderate" intensities of fish predation (Fig. 14), exhibited this type of community (6 "low predation" lakes, 9 "moderate", and 1 "high" [Smart Lake] - see Table 1).

Community Type II - This community type was characterized by _C. scutifer_, _Diaptomus pribilofensis_, _Daphnia longiremis_, and _Eubosmina_

Figure 14. The percentage occurrence of pelagic crustacean species within lakes of each crustacean community type; 100% means a species occurs in all lakes of that community type. For each of the three qualitative categories of fish predation, the percentage of lakes in each category belonging to either community type is indicated; 100% means that all lakes in that category belong to the same community type.


CRUSTACEAN COMMUNITY TYPE
I II
CRUSTACEAN COMMUNITY TYPE
I II
100 %
Cyclops scutifer
Cyclops bicuspidatus thomasi
Diaptomus sicilis
Diaptomus pribilofensis
Heterocope septentrionalis
Senecella calanoides
Acanthodiaptomus denticornis
Daphnia longiremis
Daphnia longispina hyalina microcephala (?)
Daphnia middendorffiana
Daphnia galeata mendotae
Daphnia galeata galeata
Daphnia pulex (x schoedleri)?
Daphnia schoedleri (x pulex)?
Eubosmina longispina
Bosmina longirostris
"low predation" lakes
"moderate predation" lakes
"high predation" lakes

longispina, and was found in 22 lakes mostly of "moderate" or "high" intensities of fish predation (11 "high predation" lakes, 10 "moderate", and 1 "low" [Janet Lake] - see Table 1 and Fig. 14). Two small subgroups were present within this community type, each composed of 3 lakes. One subgroup, denoted as IIa in Table 1, was characterized by the additional presence of D. l. h. microcephala (?) and Bosmina longirostris, and was found in lakes of very low Secchi disc visibilities. Lakes of the other subgroup, denoted as IIb in Table 1, had very high Secchi disc visibilities, and were characterized by the additional presence of D. l. h. microcephala (?) and Diaptomus sicilis. Neither subgroup was intermediate between community types I and II since both were more different from type I than were the other members of II.

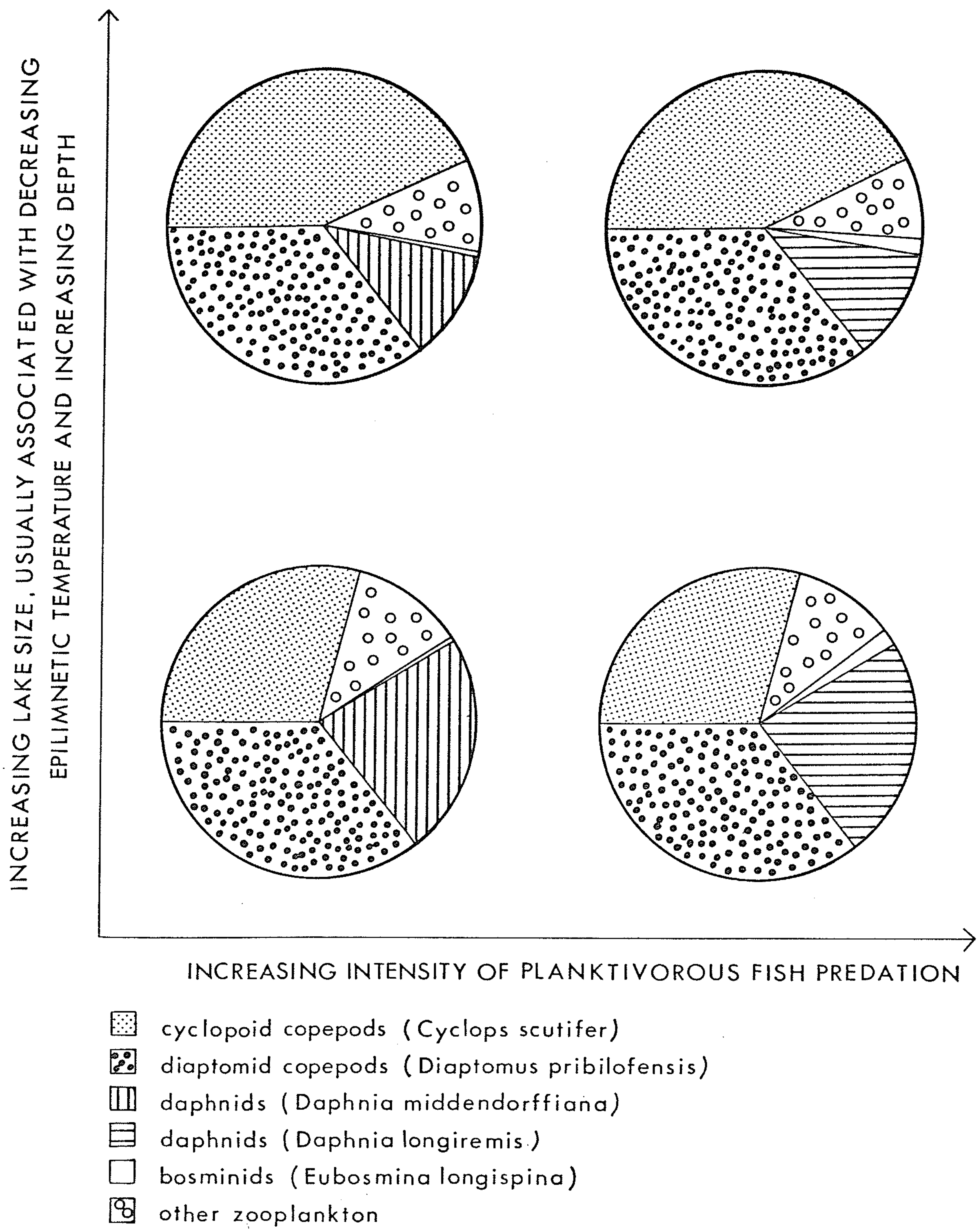
The frequencies of species occurrence within the two community types are shown in Fig. 14. Note that the species showing the greatest degree of segregation bwtween the two community types (D. middendorffiana, D. longiremis, and bosminids) are exactly those whose distribution and abundance were most influenced by fish predation. Note also that Heterocope was more common in community type I, while D. g. galeata, a relatively small daphnid, and D. l. h. microcephala (?), a daphnid of intermediate size, were more common in type II. The species composition of copepods varied little between community types, but cladocerans varied greatly and this variation appeared primarily to be a result of variation in the intensity of fish predation.

Lakes of similar maximum depth but radically different levels of fish predation were generally quite different in terms of their crustacean communities. For example, the similarity coefficient between Diamain and North Davis lakes was 0.40, and the coefficient between

North Hanson and Little Teslin lakes was 0.54. However, as indicated previously, extremes of maximum depth may influence *Daphnia* size and perhaps also species composition. If so, this might explain why Janet Lake, the only very deep "low predation" lake, belonged to community type II, while Smart Lake, the shallowest "high predation" lake, belonged to type I. More samples are needed from shallow "high predation" lakes and from deep "low predation" lakes before the effects of depth and fish predation can be separated with more certainty. It should be noted that the abundance of bosminids in these two lakes also conflicts with their supposed levels of fish predation, and the possibility that these lakes were incorrectly classified regarding fish predation cannot be ruled out.

The conclusions drawn from cluster analysis are, therefore, similar to those drawn from correlation analysis. The main environmental factors affecting the limnetic zooplankton communities of Yukon lakes are summarized in Fig. 15.

Figure 15. Effects of lake morphometry and fish predation on limnetic zooplankton communities of Yukon lakes. Complete circles represent total zooplankton biomass and segments how this biomass is proportioned among zooplankton groups. Species in brackets are the usual group dominants.


INCREASING LAKE SIZE, USUALLY ASSOCIATED WITH DECREASING
EPILIMNETIC TEMPERATURE AND INCREASING DEPTH
INCREASING INTENSITY OF PLANKTIVOROUS FISH PREDATION
cyclopoid copepods (Cyclops scutifer)
diaptomid copepods (Diaptomus pribilofensis)
daphnids (Daphnia middendorffiana)
daphnids (Daphnia longiremis)
bosminids (Eubosmina longispina)
other zooplankton

DISCUSSION

The trophic status of Yukon lakes is oligotrophic or oligotrophic/mesotrophic. This is not surprising considering the latitude of these lakes since lake productivity generally decreases with increasing latitude due to a shorter growing season, lower temperatures, and reduced nutrient supplies (Brylinski and Mann 1973; Patalas 1975).

Environmental factors significantly influencing zooplankton communities were detected using simple correlation analysis. A major criticism of using simple correlation coefficients is that they do not take into account all of the interrelationships between variables and, therefore, cannot differentiate between causal and spurious correlations. This problem was reduced here since only a few of the correlations were significant and correlations suspected of being spurious were examined further. In addition, partial correlation coefficients which could be reliably calculated confirmed the results obtained using simple coefficients.

The total abundance (biomass) of zooplankton in Yukon lakes appeared to be determined by lake productivity. TDS, but not chlorophyll-a, was related to zooplankton biomass probably because TDS is a more conservative measure of productivity and is subject to less temporal variation; maximum depth affected zooplankton biomass probably by affecting the volume available for population growth (see Results section). Such a relationship is not uncommon as other workers have observed significant positive correlations between the amount of zooplankton and the following measures of productivity: total dissolved solids (Rawson 1942; Northcote and Larkin 1956), hypolimnetic oxygen deficits (Rawson 1942), chlorophyll-a, and total phosphorus (Patalas 1972). Fish predation did not affect the total abundance of zooplankton.

The composition of the zooplankton community was influenced primarily by lake morphometry and by the intensity of fish predation. The relative abundance of C. scutifer increased with lake size while that of Daphnia decreased. The only approximately comparable results in the literature, to my knowledge, are from Schindler and Noven (1971) and Patalas (1963), both of whom found cladocerans to be relatively more abundant in small lakes. At present, these differences cannot be satisfactorily explained.

The relative abundances of cyclopoids, diaptomids, and daphnids were not affected by fish predation. Comparable data in the literature are scarce, but Kajak and Zawisza (1973) observed that stocking carp in a shallow lake did not affect the total biomass of filtrators (daphnids, diaptomids, bosminids) or of predators (cyclopoids). Although fish caused a decrease in the total biomass of large filtrators, this was compensated for by an increase in small filtrators. This is comparable to the present study where large Daphnia were replaced by a greater number of small Daphnia in the presence of planktivorous fish. When predation is very intense, even small Daphnia may not be able to survive and thus the relative abundance of daphnids might decrease. This was observed by Brooks and Dodson (1965) in Crystal Lake, a small lake heavily stocked with alewives which are obligate planktivores, and by Grygierek (1962) in small ponds heavily stocked with carp fry. Galbraith (1967) observed a decrease in Daphnia abundance (percent by volume of total zooplankton) after stocking a toxaphene-poisoned lake with rainbow trout, a facultative planktivore. It is difficult to attribute this decrease to the increase in fish predation since the effects of toxaphene and the stocking itself cannot be isolated. Indeed, the *Daphnia* population was very unstable at the time of the last sampling and conditions within the lake had probably not fully recovered from the poisoning and stocking.

Fish predation did have significant effects on species composition and size of zooplankton, particularly cladocerans. Copepods are generally less affected by fish predation than are cladocerans (Stenson 1972; Hrbacek 1962; Hrbacek et al. 1961), and higher predation levels appear to be necessary before copepod populations are significantly affected (Archibald 1975; Wells 1970). This is most likely due to the preference of planktivorous fish for cladocerans, particularly *Daphnia*, which is probably a result of their generally larger size and slow, jerky mode of locomotion which render *Daphnia* easily seen and easily caught (Brooks 1968). The average adult size of *C. scutifer* (1.17 mm), *Diaptomus sicilis* (1.23 mm), and *D. pribilofensis* (1.26 mm) were all below 1.35 mm (approximately the lower size limit of intensive fish predation -- Brooks 1968; Lyakhnovich et al. 1969), while the average adult sizes of all *Daphnia* species except *D. longiremis* were above 1.35 mm. Therefore, it is not surprising that fish predation affected the species composition and body size of *Daphnia* to a much greater extent than of *Diaptomus* or *Cyclops*.

The replacement of large *Daphnia* (*D. middendorffiana*) by small *Daphnia* (*D. longiremis*) with increasing fish predation in Yukon lakes is a phenomenon common to most situations involving lakes of different predation intensities. Large *Daphnia* dominate in lakes lacking planktivorous fish either because they are more efficient at food collection

(Brooks and Dodson 1965) or because they are less susceptible to size-selective invertebrate predation. In such lakes, invertebrate predators such as predatory copepods or *Chaoborus* larvae may significantly affect zooplankton community structure by selectively preying on small zooplankton (Dodson 1974). Small *Daphnia* dominate in lakes with planktivorous fish simply because they are less heavily preyed upon. Fish predation in Yukon lakes affected bosminid abundance in a manner similar to small *Daphnia*, and probably for similar reasons. Increases in bosminid abundance with increasing fish predation have been observed elsewhere (Grygierek 1962; Hrbacek 1962; Reif and Tappa 1966; Wells 1970).

In situations where fish predation is not intense enough to completely eliminate large *Daphnia* species, one might expect to find that these species have evolved forms less susceptible to predation as a result of selection pressure. *Daphnia lumholtzi* in the main part of Lake Albert, Africa, where planktivorous fish are rare, do not produce helmets (anterior extensions of the head) (Green 1967). However, in a small bay of the lake where planktivorous fish are common, *D. lumholtzi* apparently survives by producing a helmet which reduces the size of the visible portion of the body, but does not reduce food gathering ability which is apparently related to overall size. In Lake Michigan, the abundance of planktivorous alewives increased during the period 1954-1966, and the body size of *Daphnia retrocurva* at the onset of maturity decreased from 1.3 mm to 0.95 mm during the same period (Wells 1970). Similar decreases in the size at first reproduction within individual *Daphnia* species have been observed in other studies, always accompanied by increases in fish predation (Hrbacek and Hrbackova-Esslova 1960; Warshaw 1972).

A small reproductive size would be advantageous in the presence of size-selective predation since it would allow more reproduction to occur before the *Daphnia* entered a vulnerable size category. In the present study, *D. middendorffiana* appeared to mature at smaller sizes in "moderate" and "high predation" lakes than in "low predation" lakes, although more data are needed to be certain. Further work must also be done before the taxonomic status of the populations maturing at different sizes can be elucidated. (Are they different genetic strains, or different subspecies?)

It should be mentioned again that maximum depth of the lake and the intensity of fish predation were not independent of each other, and their separate effects on zooplankton communities were not always easy to isolate. The effects of depth on species composition and average size of *Daphnia* were especially difficult to determine, and further work on shallow "high predation" lakes and deep "low predation" lakes is needed to clarify this situation. Given present data, it would appear that if maximum depth has any effect at all on *Daphnia* size and/or species composition, only extremes of maximum depth are important with very shallow lakes favouring large *Daphnia* and very deep lakes favouring small *Daphnia*. This roughly corresponds to the general observation that pond-dwelling species of *Daphnia* are larger than lake-dwelling species (Brooks 1946), although this may not hold for individual *Daphnia* species. For example, body size of *D. cucullata* was found to increase with lake area in European lakes (Wagler 1923, cited in Brooks 1946).

Heterocope septentrionalis was the largest of the more common zooplankton species in Yukon lakes, and was also the copepod species most influenced by fish predation. The relative abundance of *Heterocope* was lower with higher levels of fish predation, but this was not statistically significant. Average adult size, however, decreased significantly with increasing fish predation.

The absence of Diaptomus sicilis from "high predation" lakes is not easily explained since D. pribilofensis was abundant in these lakes and yet is similar in body size and shape. Either factors other than fish predation are responsible for the absence of D. sicilis, or D. pribilofensis is somehow less susceptible to predation than D. sicilis (possibly better escape behaviour, different spatial distribution, or greater reproductive capacity).

In summary, lake productivity appeared to be most important in determining the total abundance of zooplankton in Yukon lakes, while the composition of this zooplankton was determined mainly by lake morphometry and by the intensity of planktivorous fish predation. Fish predation had very little effect on the quantitative aspects of the zooplankton community (relative abundance of various groups), but had a very profound effect on the qualitative aspects of the community (species composition, body size), especially with respect to cladocerans. These effects are essentially the same as those observed in more artificial situations where predation intensities are changed through poisoning and/or stocking of fish. However, in some of these "artificial" studies (for example, Brooks and Dodson 1965; Wells 1970) copepods were affected to a greater extent by predation than in the present study, and so it appears that natural predation levels in Yukon lakes are not as high as some of the levels produced by stocking or other artificial introductions of fish. Planktivorous fish predation does exert a genuine influence on the structure of limnetic zooplankton communities in natural situations, and at least on a regional scale reasonable predictions can be made about certain aspects of the fish fauna of a lake knowing only the composition of the zooplankton, and vice versa.

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APPENDICES

Appendix A. Chemical Analysis of Distilled Water Blanks

In order to account for possible leaching of materials out of the Gelman filter or out of the filter apparatus itself, two distilled water blanks were run through the filter apparatus and treated as though they were lake water samples. The results of the chemical analysis of these two blanks are presented below:

Chemical parameter		Blank replicate #1	Blank replicate #2	Average
Si	(mg/liter)	0.01	0.01	0.01
Cl^-	(mg/liter)	0.4	0.4	0.4
$SO_4^=$	(mg/liter)	<0.2	<0.2	~0.1
Ca^{++}	(mg/liter)	0.38	0.38	0.38
Mg^{++}	(mg/liter)	0.08	0.08	0.08
Na^+	(mg/liter)	0.23	0.18	0.205
K^+	(mg/liter)	0.01	0.03	0.02
TDS	(mg/liter)	50*	60*	55*
chlorophyll-a	(μg/liter)	0.09	0.10	0.095
total dissolved phosphorous	(μg/liter)	5	7	6
particulate phosphorus	(μg/liter)	1	3	2

*Blank TDS values were unbelievably high. Upon further investigation (mainly by Mike Capel of the Freshwater Insititute), it was found that the aluminum dishes used to evaporate the sample in an oven were the cause of the problem. They apparently oxidized while in the oven, thus increasing the weight of the dish and this additional weight was interpreted as dissolved solid.

Appendix B. References for Fish Length-Weight Data

In order to calculate the quantitative estimate of fish predation, length-weight data for the various fish species were needed. These data were obtained from the following sources (data from lakes of northern latitudes were used wherever possible):

Fish species	Lake(s) data taken from	Reference
Coregonus clupeaformis	Dezadeash and Little Teslin lakes, Y. T.	R. A. Bodaly unpubl. data
C. sardinella *Prosopium cylindraceum*	assumed to be the same as *C. clupeaformis*	
Salvelinus namaycush	Great Slave and Great Bear lakes, N.W.T.	Kennedy 1954; Miller and Kennedy 1948
Thymallus arcticus	Great Bear Lake, N.W.T., and northern Saskatchewan lakes	Miller 1946; Rawson 1950

Length-weight data were not needed for *Esox lucius*, *Lota lota*, or *Catostomus catostomus* as these species were assumed to eat essentially no zooplankton. Length-weight data were also not needed for *Stenodus leucichthys* or *Couesius plumbeus* as they were rare and were only caught in shore nets. (Fish caught in shore nets were excluded from the calculation.) *Coregonus nasus* and *Prosopium coulteri* were rarely caught, but when caught their length-weight curves were assumed to be equal to the *C. clupeaformis* curve.

Appendix C. Sample Calculation of the Quantitative Index of Planktivorous Fish Predation

In order to calculate the quantitative index of fish predation, only fish caught in the floating and deep nets were considered. Calculations for Tarfu Lake are shown below to illustrate the method:

floating net - only 2 *Thymallus arcticus* caught, and neither one contained any zooplankton in their stomachs.

deep net - 23 *Prosopium cylindraceum* and 9 *Salvelinus namaycush* were caught.

Prosopium: only 1 individual measured-35 cm fork length. (All individuals were of approximately the same size.) This corresponds to a wet weight of 480 g (see Appendix B), which was assumed to be the average weight for the 23 *Prosopium*. The average proportional contribution of zooplankton to the diet was 0.07 (Table 3).

Salvelinus: all 9 individuals were roughly measured - 6 about 30 cm and 3 about 60 cm fork length. The larger individuals averaged abou 2400 g wet weight; the smaller individuals about 260 g (see Appendix B). The average proportional contribution of zooplankton to the diet was 0 for the large trout, and 0.5 for the small trout (Table 3).

The predation index was calculated as follows:

$$\text{predation index} = \sum_{\substack{\text{over all}\\\text{species}}} \left[\begin{pmatrix}\text{number}\\\text{caught}\end{pmatrix} \times \begin{pmatrix}\text{proportion of}\\\text{zooplankton}\\\text{in diet}\end{pmatrix} \times \begin{pmatrix}\text{average}\\\text{weight of}\\\text{fish}\end{pmatrix} \right]$$

= (*Thymallus* values) + (*Prosopium* values) + (*Salvelinus* values)

= (2 x 0 x weight) + (23 x 0.07 x 480) + (3 x 0 x 2400 + 6 x 0.5 x 260)

= 0 + 773 + 780

= 1553

Thus, the quantitative index of predation for Tarfu Lake is 1553. This may be interpreted as 1553 g of fish caught per standard net set (excluding shore net) that were eating only zooplankton, or 1553 x 2 = 3106 g of fish caught per net set that were eating 50% zooplankton (50% of the diet was zooplankton), etc.

Appendix D. Sizes Used to Separate Large and Small Immature Zooplankton

In counting the zooplankton samples, immature individuals were measured approximately and classified as either "large" or "small". The sizes used to separate these two categories for the more common zooplankton species are shown below:

Zooplankton species	Body sizes (mm) used to separate "large" and "small" immature individuals*
Cyclops scutifer	0.66
Diaptomus sicilis	0.82
D. pribilofensis	0.82
Acanthodiaptomus denticornis	0.82
Daphnia longiremis (small form)	0.66
D. longiremis (large form)	immature individuals measured exactly
D. galeata galeata	0.88
D. g. mendotae	0.86
D. longispina hyalina microcephala(?)	0.86
D. middendorffiana ("low predation" lakes)	1.80
D. middendorffiana (all but above lakes)	1.41
D. pulex (x *schoedleri*)?	immature individuals measured exactly
D. schoedleri (x *pulex*)?	immature individuals measured exactly

*for copepods, the term "immature individuals" excludes nauplii

Appendix E. Sample Calculation of Biomass from Numbers of Zooplankton

To illustrate the calculation procedure, biomass is calculated below from numbers of Cyclops scutifer from Pine Lake, station 1, epilimnion sample, late summer visit (August 31, 1975):

Number of nauplii per liter	35.7
Number of "small" copepodids per liter	7.4
Number of "large" copepodids per liter	7.5
Number of adults per liter	1.5
Total number of C. scutifer individuals per liter	52.1

Nauplii-Average volume of cyclopoid nauplius = 0.0014 mm^3 (4 nauplii measured). Assuming unit density, the average wet weight of one nauplius is 0.0014 mg

Total wet weight of nauplii = 0.0014 x 35.7 = 0.05 mg/liter

Copepodids -Average weight of "small" copepodids = 0.0095 mg (derived from size measurements taken from the midsummer visit to Pine Lake and the length-weight curve given for copepods in Edmondson 1971).

Total wet weight of "small" copepodids = 0.0095 x 7.4
= 0.07 mg/liter

Average weight of "large" copepodids = 0.0414 mg

Total wet weight of "large copepodids = 0.0414 x 7.5
= 0.31 mg/liter

Adults-The size distribution of adults in this sample is shown below along with the average weights for each size class:

	Size class (mm)	1.02-1.09	1.09-1.17	1.17-1.25	1.25-1.33	1.33-1.41
A	Average length (mm) for each size class	1.05	1.13	1.21	1.29	1.37
B	Average weight (mg) for each size class	0.0627	0.077	0.0924	0.11	0.13
C	Number of measured adults in each size class	2	1	4	9	1
D	Proportion of measured adults in each size class	0.12	0.06	0.23	0.53	0.06
E	No. adults per liter in each size class (total no. adults per liter x D)	0.18	0.09	0.34	0.80	0.09
F	Total weight (mg) of adults per liter in each size class (E x B)	0.011	0.007	0.0314	0.088	0.0117

$$\text{Total wet weight of adults} = 0.011 + 0.007 + 0.0314 + 0.088 + 0.01$$
$$= \underline{0.149\ \text{mg/liter}}$$

$$\text{Total wet weight of } \underline{C.}\ \underline{\text{scutifer}} = 0.05 + 0.07 + 0.31 + 0.149$$
$$= \underline{0.58\ \text{mg/liter}}$$

Although the weight estimates of various life stages of *C. scutifer* are rather crude, greater accuracy is not justified since the main source of error in the overall biomass calculation is probably the estimate of zooplankton numbers.

Appendix F. Transformation of Data

Both analysis of variance and correlation analysis require that variables be normally distributed. A Kolmogorov-Smirnov test showed which variables needed to be transformed to achieve a normal distribution. All variables were logarithmically transformed ($\log(x + 1)$) except the following:

No transformation	Arc sine transformation (arc sine $\sqrt{x}$, where x is a proportion)	Square root transformation ($\sqrt{x}$)
-temperature -Secchi disc visibility -TDS -calcium -magnesium -epilimnion depth -relative abundance of diaptomids -average *Daphnia middendorffiana* size	-relative abundance of cyclopoids and daphnids -within-genus abundance of *Diaptomus sicilis*, *D. pribilofensis*, *Daphnia middendorffiana*, and *D. longiremis*	-relative abundance of bosminids, rotifers, and *Heterocope*

Appendix G. Limnological characteristics of 38 Yukon lakes. Chemistry values relate to samples from 1 m depth. Lakes with no entry in the "Epilimnion depth" column were either completely mixed (shallow lakes) or not clearly stratified. Asterisks denote lakes previously visited and for which preliminary limnological data were available prior to this survey (C. C. Lindsey unpublished data).

Lake	Location (latitude longitude)	Altitude (m)	Area (km^2)	Max known depth (m)	Sampling date (1975)	Depth at sampling station (m)	Epilimnion depth (m)	Epilmnion temp (°C)	Secchi disc visibility (m)	Chlorophyll-a (μg/liter)	Total phosphorus (μg/liter)	mg/liter: TDS	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$SO_4^{=}$	Cl^{-}	Si	Surface oxygen sample (mg/liter)	Depth of deepest oxygen sample (m)	Oxygen content of deepest oxygen sample (mg/liter)
Diamain*					June 19	22		9.2	6.1											13.3	21	13.4
Diamain*	62°55'N	460-610	18.8	25	Aug. 5	22	13	15.8	7.3	0.59	3.5	60	19.9	6.6	2.6	1.3	9.9	0.0	3.37	11.4	21	11.2
Diamain*	136°19'W				Sept. 6	25	17	12.4	5.5											12.6	24	10.8
Pine*					June 12	21		10.2	6.7											11.4	20	10.0
Pine*	60°49'	610-760	4.7	27	July 27	24	8	16.7	9.8	0.38	2.0	130	34.8	15.7	3.91	2.78	10.6	0.2	3.07	10.8	23	8.8
Pine*	137°27'				Aug. 31	22	13	14.0	12.8											11.0	21	8.1
Minto*					June 17	26		10.5	3.2											12.0	20	11.1
Minto*	63°41'	610-760	4.3	31	Aug. 3	23	7	15.5	5.4	1.22	8.5	90	28.6	7.9	1.64	0.56	11.7	0.0	2.14	9.0	22	8.5
Minto*	136°09'				Sept. 5	27		11.7	4.9											10.5	23	8.0
Fox*					June 22	46		7.5	5.8											12.4	40	11.7
Fox*	61°14'	760-910	16.0	48	Aug. 1	46	11.4	12.9	8.2	0.58	3.5	210	41.8	21.0	8.75	1.67	31.4	4.5	2.24	11.7	41	11.6
Fox*	135°28'				Sept. 4	46	17	11.7	8.5											10.7	45	10.1
Swan*					June 25	57		9.3	3.8											11.5	50	10.9
Swan*	59°53'	841	8.9	65	July 30	47	11.5	12.5	5.4	0.9	3.5	<5	7.35	1.5	0.88	0.34	2.1	0.1	2.78	10.5	45	10.4
Swan*	131°24'				Sept. 10	52		10.0	6.0											10.6	49	9.8
Lower Snafu*					June 14	24		11.3	3.6											10.9	23	8.1
Lower Snafu*	60°07'	771	3.5	37	July 29	24	8	15.5	7.0	1.11	11.5	140	42.4	12.9	4.3	1.4	21.3	0.0	3.27	10.4	23	7.2
Lower Snafu*	133°42'				Sept. 3	23	10	12.6	6.6											11.0	22	5.6
North Hanson*	64°01' 135°22'	610-760	1.6	19	July 1	13	5	18.2														
West Halfway	63°48' 135°48'	610-760	0.9	4.7	July 1	4.5		14.9+														
Janet	63°40' 135°30'	460-610	17.2	103	July 4	69	9	18.8	4.0	0.6		85	13.1	5.83	1.2	0.56	15.5	0.2	2.01	10.6	30	10.6
Sulphur	60°57' 137°59'	760-910	1.2	2	July 11	2			to bottom													
Taye	60°56' 136°20'	610-760	8.1	3	July 17	3		18.0	2.1	2.28		65	23.2	3.41	2.24	1.36	7.9	0.2	3.14	10.6	2	10.6
Hungry	65°39' 136°02'	305-460	6.6	4	Aug. 5	4		14.4	0.9	7.21		15	4.42	0.97	1.49	0.24	10.1	1.0	0.88			
Summit*	60°26' 133°39'	760-910	1.9	13	June 28	12.5		13.4	3.4	3.52		75	18.8	13.3	1.01	0.83	4.9	0.6	4.5	10.4	11.0	7.4
Ladue	64°01' 135°15'	610-760	2.4	24	July 5	10	4	16.8	3.0	0.62		65	21.5	6.71	1.16	0.27	29.4	0	1.7	9.4	9.0	8.7
Kathleen	64°15' 134°13'	610-760	2.6	60	July 7	40	4	17.0	4.6	0.28		145	33.4	16.5	1.39	0.43	20.7	1.0	1.81	9.3	30	6.8
Kluane*	61°15' 138°40'	781	409.5	82	July 11	38		9.9	3.4	0.03		125	31.1	9.0	2.68	2.36	35.4	3.6	1.43			
Kloo	60°58' 137°52'	860	12.5	12	July 12	11	5	17.1	2.4	0.98		55	21.5	2.2	2.32	1.8	6.7	0.2	2.4	9.15	9	8.1
Jo-Jo	60°35' 136°20'	888	6.6	52	July 15	50	5	10.6	7.0	0.26		<5	4.79	1.85	1.61	1.01	2.1	0.6	2.7	10.7	30	11.0
Moraine	60°59' 136°45'	910-1070	4.2	32	July 16	28	7.5	14.6	6.1	0.64		25	13.7	11.2	1.6	1.51	4.7	0.6	2.41	9.8	20	10.2
Snafu	60°11' 133°26'	878	4.7	29	July 20	20	9.5	14.6	3.7	4.9		105	33.9	11.1	3.88	1.32	14.7	0	3.77	10.4	17	8.0
Pygmy	60°14' 133°22'	760-910	0.5	18	July 21	15.5	5	14.9	2.4	5.86		55	23.2	7.6	2.49	0.81	10.3	0	4.09	11.0	14	2.3
Wolf	60°39' 131°40'	991	74.4	66	July 22	55		12.6	6.1	1.1		25	15.9	3.11	1.30	0.69	4.5	0.2	2.89	11.0	20	11.6

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Appendix G (cont'd).

Lake	Location (latitude longitude)	Altitude (m)	Area (km^2)	Max known depth (m)	Sampling date (1975)	Depth at sampling station (m)	Epilimnion depth (m)	Epilmnion temp (°C)	Secchi disc visibility (m)	Chlorophyll-a (µg/liter)	Total Phosphorus (µg/liter)	mg/liter: TDS	mg/liter: Ca^{++}	mg/liter: Mg^{++}	mg/liter: Na^{+}	mg/liter: K^{+}	mg/liter: $SO_4^{=}$	mg/liter: Cl^{-}	mg/liter: Si	Surface oxygen sample (mg/liter)	Depth of deepest oxygen sample (m)	Oxygen content of deepest oxygen sample (mg/liter)
Margaret	65°21' 134°30'	490	4.5	26	Aug. 3	20	6.5	15.3	2.4	1.56		5	10.2	3.67	0.32	0.36	6.7	1.4	0.59			
Tarfu	60°04' 133°43'	760	3.3	33	Aug. 13	32	10.5	15.1	5.2	0.9		105	33.4	12.5	4.12	1.61	13.5	0.2	3.71	10.6	25	6.8
Wheeler	59°41' 129°10'	610-760	2.8	30	Aug. 19	30	9	17.3	3.4	1.2		225	51.9	30.1	3.33	1.58	32.0	0	4.99	7.6	29	4.6
Frenchman	62°10' 135°50'	460-610	14.1	39	Aug. 21	31	9	16.4	6.7	0.6		285	42.9	10.9	16.1	3.94	75.0	2.8	2.12	10.4	30	4.8
Jackfish	61°56' 132°32'	305-910	1.7	17	Aug. 23	15	8	16.4		1.2		395	75.0	33.7	4.68	1.98	199.0	0	2.17	11.0	14	2.7
Tatlmain	62°37' 135°59'	557	33.2	42	Sept. 7	40		12.5	2.7	3.0		145	44.0	11.7	4.19	2.66	15.7	0.6	1.49	12.7	39	5.1
Little Teslin*	60°29' 133°24'	760-910	2.8	20	Aug. 27	17		14.3	5.5	1.8		115	23.2	12.0	1.82	1.5	3.5	0	1.89	11.3	16.5	1.5
Tatchun*	62°17' 136°07'	460-610	6.6	53	June 21	30		12.5	1.8													
East Clark	64°09' 134°54'	610-760	1.6	23	July 6	23	5	16.3	4.0	0.16		55	20.4	6.04	1.04	0.09	15.9	0.6	1.44	10.2	20.0	8.0
Deazadeash*	60°28' 136°58'	703	77.2	7.6	July 26	5.5		13.1		1.24		35	15.9	2.11	1.92	1.06	5.9	0.6	1.87			
North Davis	66°11' 136°25'	305-460	1.2	23	Aug. 6	21	6.5	14.2	1.2	1.82		25	9.42	2.36	1.8	0.83	25.4	0	1.45			
South Davis	66°10' 136°25'	305-460	1.6	27	Aug. 9	20	7	13.3	0.7	1.37		25	6.6	1.9	1.86	0.65	18.5	0	1.46			
Morley	60°00' 132°05'	760-910	13.2	34	Aug. 14	29		14.1	4.0	0.7		15	13.0	2.78	1.12	0.41	3.5	0	2.85	10.3	28	8.1
Smart	59°57' 131°46'	760-910	1.4	6	Aug. 15	6		16	2.0	2.5		25	12.2	3.33	1.28	0.49	2.7	0.2	2.46	11.2	5	9.4
Little Salmon	62°11' 134°40'	608	62.6	96	Aug. 22	77		13.1	6.4	0.5		95	31.1	9.73	1.58	0.86	17.5	0	2.92	11.9	48	14.0
Bruce	61°49' 132°06'	305-910	2.5	35	Aug. 24	34	5.5	15.7	4.0	2.2		115	21.5	11.4	5.54	1.65	16.5	3.6	0.21	9.6	32	0.4

+unreliable as very few temperature measurements taken-surface water was 18°C, bottom was 11°C.

Appendix H. Number of fish of each species caught in standard overnight net sets in 38 Yukon lakes. Lakes visited three times are presented first, followed by the 32 lakes visited once grouped according to "low", "moderate", and finally "high" levels of fish predation. Sampling dates for these 32 lakes are given in Appendix G.

Fish species caught per overnight set in various nets

SHORE NET (1 experimental gill net)

Lake	Sampling Date	other	GNP	LL	LNS	PC	WF_1	LT	AG	WF_h	cisco
Diamain*		NO FISH CAUGHT									
Pine	June 12	NOT SET									
	July 27		2								
	Aug. 31		6				5				
Minto	June 17	NOT SET									
	Aug. 3		5				5				
	Sept. 5		11				20				
Fox	June 22					3	2	4	2		
	Aug. 1					5	5	5	8		
	Sept. 4					2	13	4	12		
Swan	June 25		4			1	16	3			
	July 30	NOT SET									
	Sept. 10		3			4	3	6			
Lower Snafu	June 14		5				16	1			
	July 29		1				8		2		
	Sept. 3	NOT SET									
North Hanson		NOT SET									
West Halfway		NOT SET									
Janet			2		1						
Sulphur		NO FISH CAUGHT									
Taye			11								
Hungry		NOT SET									
Summit			1				15				
Ladue			3				17				
Kathleen							1	1	3		
Kluane		NOT SET									
Kloo		NOT SET									
Jo-Jo								12	7		
Moraine			3					2	5		
Snafu		NOT SET									
Pygmy			1				32				
Wolf						5		3			
Margaret			8				24	5			
Tarfu			9			23		3	8		
Wheeler			2				10	1			
Frenchman			4				5				
Jackfish			6						6		
Taltmain			2				36	1			
Little Teslin					30		11			4	
Tatchun			5				17				
East Clark		1	2				13				
Dezadeash			1	1	1	2	7	2		2	
North Davis		1	4		4		14				1
South Davis			3	1	8		10				1
Morley			1			1	12	1			
Smart			4			2	22				
Little Salmon					5	6	7	1			
Bruce		2			50	1			50		

DEEP NETS (2 experimental gill nets)

Lake	Sampling Date	other	GNP	LL	LNS	PC	WF_1	LT	AG	WF_h	cisco
Diamain*		NO FISH CAUGHT									
Pine	June 12			1							
	July 27			2				1			
	Aug. 31			3			1	2			
Minto	June 17						14	1			
	Aug. 3			1			5	1			
	Sept. 5			1			1				
Fox	June 22			1			3	2			
	Aug. 1							2			
	Sept. 4							2			
Swan	June 25	2		3			4	2			
	July 30			1			6				
	Sept. 10	1		1			11	1			
Lower Snafu	June 14						6	1			4
	July 29			2			14	4			47
	Sept. 3										42
North Hanson		NO FISH CAUGHT									
West Halfway			1								
Janet				1							
Sulphur			10								
Taye			19								
Hungry			2								
Summit				1			33				
Ladue				1			10	7			
Kathleen							1	6			
Kluane							44	2			
Kloo							37				
Jo-Jo								6			
Moraine				1				4			
Snafu				1			5	7			
Pygmy				1			25				
Wolf				2				1			
Margaret		NO FISH CAUGHT									
Tarfu						23		9			
Wheeler							9	1			
Frenchman							3	2			
Jackfish									50		
Taltmain			3	2			63	9			
Little Teslin					10		34			8	
Tatchun				1							
East Clark							6	2			5
Dezadeash				2		1	51	10		13	
North Davis				4							
South Davis		NO FISH CAUGHT									
Morley					1		13	1			7
Smart						2	55				1
Little Salmon		1					3	1			
Bruce		NO FISH CAUGHT									

FLOATING NETS (2 experimental gill nets)

Lake	Sampling Date	other	GNP	LL	LNS	PC	WF_1	LT	AG	WF_h	cisco
Diamain*		NO FISH CAUGHT									
Pine	June 12						1	1			
	July 27	NO FISH CAUGHT									
	Aug. 31						5				
Minto	June 17						1				
	Aug. 3	NO FISH CAUGHT									
	Sept. 5						1				
Fox	June 22						1				
	Aug. 1	NO FISH CAUGHT									
	Sept. 4	NO FISH CAUGHT									
Swan	June 25							3			3
	July 30										1
	Sept. 10							1			5
Lower Snafu	June 14		2								27
	July 29										78
	Sept. 3						2				6
North Hanson			1								
West Halfway		NOT SET DUE TO SHALLOWNESS									
Janet		NO FISH CAUGHT									
Sulphur		NOT SET DUE TO SHALLOWNESS									
Taye		NOT SET DUE TO SHALLOWNESS									
Hungry			5								
Summit							3				
Ladue		NO FISH CAUGHT									
Kathleen		NO FISH CAUGHT									
Kluane		NO FISH CAUGHT									
Kloo							46				
Jo-Jo								12			
Moraine									3		
Snafu							3	2	3		
Pygmy			6				77				
Wolf								3			
Margaret			4								
Tarfu									2		
Wheeler							55				
Frenchman							3				
Jackfish									1		
Taltmain			1				23				
Little Teslin							6			76	
Tatchun			2				1				
East Clark							2				
Dezadeash								2		114	
North Davis			2				3				
South Davis			5								160
Morley					1						64
Smart			1			2	26				
Little Salmon							2				10
Bruce									20		

Fish species legend: other = Prosopium coulteri (Swan L.), Stenodus leucichthys (East Clark L.), Coregonus nasus (North Davis L., Little Salmon L.) Couesius plumbeus (Bruce L.)

GNP = Esox lucius (pike)
LL = Lota lota (burbot)
LNS = Catostomus catostomus (longnose sucker)
PC = Prosopium cylindraceum (round whitefish)
LT = Salvelinus namaycush (lake trout)
AG = Thymallus arcticus (arctic grayling)
WF_1 = Coregonus clupeaformis (low gill raker form of lake whitefish) see Lindsey 1963
WF_h = Coregonus clupeaformis (high gill raker form of lake whitefish) see Lindsey 1963
cisco = Coregonus sardinella (least cisco)

*Only 1 set of the shore net in 1975. Two sets of floating and deep nets were done in 1970, along with many beach seines, and no fish were caught (C.C. Lindsey unpublished data).

Appendix I. Numerical abundance of crustacean zooplankton species in the six Yukon lakes visited three times, and certain other zooplankton parameters of these lakes. Zone e = epilimnion; zone h = hypolimnion. L, M, and H refer to "low", "moderate", and "high" levels of planktivorous fish predation, respectively. Total zooplankton includes rotifers and crustaceans. Values given for total zooplankton abundance (mg/cm²), number of crustacean species, and average *Heterocope* size are averages for the entire water column.

Lake	Crustacean community type	Qualitative index of fish predation	Sampling date (1975)	Quantitative index of fish predation	Zone	No. crustaceans/liter	No. rotifers/liter	Total zooplankton abundance mg/liter	Total zooplankton abundance mg/cm²	Total no. crustacean species	Average adult *Heterocope* size (mm)	Average adult *Daphnia* size (mm)
			June 19		e	51.8	14.9	0.74	1.28	4		2.72
					h	50.4	17.4	0.46				3.18
Diamain	I	L	Aug. 5	0	e	20.3	25.2	1.06	2.06	5	3.4	2.94
					h	56.9	22.4	0.76				2.72
			Sept. 6		e	19.2	8.2	0.99	2.34	5	3.5	3.24
					h	62.0	9.4	0.81				3.23
			June 12	825	e	80.8	165.0	2.21	4.00	9		1.74
					h	111.0	48.0	1.67				1.72
Pine	IIb	M	July 27	0	e	60.3	35.2	2.23	6.67	9		1.86
					h	150.0	6.8	3.06				1.71
			Aug. 31	333	e	84.4	153.0	2.71	6.93	9		2.14
					h	204.0	119.0	3.78				1.95
			June 17	633	e	137.0	34.7	1.60	2.06	4		1.22
					h	50.6	5.3	0.36				0.98
Minto	II	M	Aug. 3	190	e	61.4	30.5	2.43	4.08	5		1.45
					h	82.2	101.0	1.42				1.48
			Sept. 5	55	e	45.8	45.1	2.09	3.18	5		1.58
					h	70.7	30.7	0.72				1.57
			June 22	720	e	69.2	13.3	1.48	4.68	6		1.48
					h	74.8	6.8	0.84				1.63
Fox	IIb	M	Aug. 1	25	e	77.8	40.2	1.94	8.58	5		1.35
					h	104.0	40.9	1.84				1.45
			Sept. 4	112	e	74.9	22.5	1.97	7.45	6		1.49
					h	99.0	28.1	1.42				1.45
			June 25	437	e	9.6	5.0	0.30	1.85	5		1.06
					h	13.2	10.4	0.33				1.13
Swan	II	H	July 30	418	e	18.7	8.2	0.36	1.71	4		1.17
					h	18.5	11.4	0.36				1.16
			Sept. 10	938	e	31.8	51.4	0.77	2.79	6		1.15
					h	60.0	33.7	0.47				1.18
			June 14	2791	e	83.0	206.0	2.30	4.94	7		1.08
					h	57.2	84.1	1.91				1.15
Lower Snafu	II	H	July 29	8189	e	128.0	60.1	2.48	9.67	7	2.9	1.20
					h	183.0	227.0	4.80				1.04
			Sept. 3	4535	e	115.0	51.8	1.90	5.73	8		1.14
					h	180.0	152.0	2.95				1.12

Pelagic crustacean species - no./liter

Lake	Sampling date	Zone	*Cyclops scutifer* Sars	*Cyclops capillatus* Sars	*Cyclops vernalis* Fischer	*Cyclops bicuspidatus thomasi* Forbes	*Diaptomus sicilis* Forbes	*Diaptomus pribilofensis* Juday and Muttkowski	*Heterocope septentrionalis* Juday and Muttkowski	*Senecella calanoides* Juday	*Acanthodiaptomus denticornis* (Wierzejski)
Diamain	June 19	e	31.2				20.3		0.5		
		h	38.8				11.5		0.24		
	Aug. 5	e	7.5				2.36	10.1	0.06		
		h	52.6				0.29	3.83	0.06		
	Sept. 6	e	12.1				3.19	3.56	0.05		
		h	58.5				0.91	2.41	0.03		
Pine	June 12	e	29.6	0.01			46.9	1.77		0.12	
		h	6.55	<.01			35.0	9.7		0.3	
	July 27	e	21.2				22.7	11.4		0.07	
		h	129				4.46	21.0		0.4	
	Aug. 31	e	57.5		<.01?*		18.0	1.34		0.19	
		h	17.4				17.1	7.3		0.47	
Minto	June 17	e	73.0				63.5				
		h	38.3				12.1				
	Aug. 3	e	21.2				30.1				
		h	71.6				7.4				
	Sept. 5	e	18.2				22.3				
		h	66.1				3.54				
Fox	June 22	e	25.4	<.01			43.5				
		h	54.4				20.3				
	Aug. 1	e	37.8				33.6				
		h	88.9				12.4				
	Sept. 4	e	43.9				24.9				
		h	88.4				7.7				
Swan	June 25	e	7.0	<.01				1.45			
		h	11.6					0.66			
	July 30	e	12.1					3.0			
		h	16.3					1.04			
	Sept. 10	e	19.1					4.19			
		h	54.2					1.57			
Lower Snafu	June 14	e	51.5	<.01				26.1	0.01		
		h	48.7					7.11	0.04		
	July 29	e	62.8					28.2			
		h	131					8.7	<.01		
	Sept. 3	e	80.4	<.01				3.2			
		h	153					4.8			

Lake	Sampling date	Zone	*Daphnia longiremis* Sars	*Daphnia galeata galeata* Sars	*Daphnia galeata* Sars *mendotae* Birge	*Daphnia longispina hyalina* Leydig var. *microcephala* Sars(?)	*Daphnia middendorffiana* Fischer	*Daphnia pulex* Leydig (X *schoedleri*)?	*Daphnia schoedleri* Sars (X *pulex*)?	*Eubosmina longispina* (Leydig)	*Bosmina longirostris* (O. F. Muller)	*Chydorus sphaericus* (O. F. Muller)	*Leptodora kindtii* Focke	*Holopedium gibberum* Zaddach
Diamain	June 19	e					0.07							
		h					0.03							
	Aug. 5	e					0.23							
		h					0.06							
	Sept. 6	e					0.34							
		h					0.11							
Pine	June 12	e	0.04			1.44	0.29			0.52				
		h	0.05			0.55	0.16			0.16				
	July 27	e				1.61	2.57			0.69				
		h	0.44			1.86	2.17			0.17				
	Aug. 31	e	0.14			0.99	5.56			0.73				
		h	0.36			1.05	3.91			0.67				
Minto	June 17	e			0.64					0.05				
		h			0.11					0.01				
	Aug. 3	e			10.0					0.08			0.05	
		h			3.2					<.01			0.04	
	Sept. 5	e			5.13					0.23			<.01	
		h			0.95					0.07			<.01	
Fox	June 22	e	0.07			0.12				0.06				
		h	0.01			0.02				0.04				
	Aug. 1	e	0.19			5.7				0.62				
		h	0.11			2.3				0.49				
	Sept. 4	e	0.26			4.11				1.7				
		h	0.25			1.2				1.3				
Swan	June 25	e	0.7							0.47		<.01		
		h	0.81							0.15				
	July 30	e	1.61							2.11				
		h	0.54							0.54				
	Sept. 10	e	3.8							4.66		<.01		
		h	1.68							2.43		<.01		
Lower Snafu	June 14	e	4.19	0.36						0.83				
		h	1.02	0.12						0.18				
	July 29	e	16.7	20.0						0.92			0.04	
		h	33.7	6.13						3.9			0.03	
	Sept. 3	e	19.2	11.5						0.34		.02	<.01	
		h	15.5	4.9						1.2		.02	0.01	

Littoral crustacean species - no./liter

Lake	Sampling date	Zone	*Eucyclops agilis* (Koch)	*Eucyclops speratus* (Lilljeborg)	*Macrocyclops albidus* (Jurine)	Harpacticoida	*Polyphemus pediculus* (Linne)	*Leydigia quadrangularis* (Leydig)	*Camptocercus rectirostris* Schoedler	*Scapholeberis kingii* Sars	*Eurycercus lamellatus* (O. F. Muller)	*Sida crystallina* (O. F. Muller)	*Alona affinis* (Leydig)	No. *Chaoborus* larvae/liter	No. amphipods/liter
Diamain	June 19	e												.02	.003
		h												.23	
	Aug. 5	e													
		h												.04	.003
	Sept. 6	e												.01	
		h												.08	
Pine	June 12	e													
		h													
	July 27	e					<.01								
		h					<.01								
	Aug. 31	e													
		h													
Minto	June 17	e													
		h													
	Aug. 3	e													
		h													
	Sept. 5	e													
		h													
Fox	June 22	e													
		h													
	Aug. 1	e													
		h													
	Sept. 4	e													
		h						<.01							
Swan	June 25	e													
		h													
	July 30	e													
		h													
	Sept. 10	e							<.01						
		h							<.01						
Lower Snafu	June 14	e													
		h													
	July 29	e													
		h													
	Sept. 3	e													
		h													

*Question marks denote probable but not certain identifications.

Appendix J. Numerical abundance of crustacean zooplankton species in the 32 Yukon lakes visited once, and certain other zooplankton parameters of these lakes. Zone e = epilimnion; zone h = hypolimnion; zone wc = entire water column. L, M, and H refer to "low", "moderate" and "high" levels of planktivorous fish predation, respectively. Total zooplankton includes rotifers and crustaceans. Values given for total zooplankton abundance (mg/cm2), number of crustacean species, and average Heterocope size represent the entire water column.

Lake	Crustacean community type	Qualitative index of fish predation	Quantative index of fish predation	Zone	No. crustaceans/liter	No. rotifers/liter	Total zooplankton abundance mg/liter	Total zooplankton abundance mg/cm2	Total no. crustacean species	Average adult Heterocope size(mm)	Average adult Daphnia size(mm)	Pelagic crustacean species - no./liter: Cyclops scutifer Sars	Cyclops capillatus Sars	Cyclops vernalis Fischer	Cyclops bicuspidatus thomasi Forbes	Diaptomus sicilis Forbes	Diaptomus pribilofensis Juday and Muttkowski	Heterocope septentrionalis Juday and Muttkowski	Senecella calanoides Juday	Acanthodiaptomus denticornis (Wierzejski)
North Hanson	I	L	0	e	88.4	23.0	2.98	3.58	4	3.55	2.89	72.3					11.9	0.17		
				h	43.0	12.0	1.01				2.85	39.4					2.26	.08		
West Halfway	I	L	0	wc	78.0	427.0	3.61	1.80	4		2.23	60.5					.04			
Janet	II	L	0	e	22.8	168.5	1.26	3.59	7		1.68	7.0				1.26	5.82			
				h	21.8	28.0	0.39				1.55	17.1				0.91	2.5			
Sulphur	I	L	0	wc	61.8	7.2	1.67	0.33	5	3.70	3.34	8.07+					52.5	.08		
Taye	I	L	0	wc	25.2	3.9	1.60	0.48	6	3.25	3.06	0.27					24.0	0.5		
Hungry	I	L	0	wc	106.0	163.0	2.23	0.89	5	3.35		71.07					10.8	.02		23.6
Summit	I	M	1753	e	88.6	485.0	3.35	3.48	4	3.10		57.2					31.0	0.42		
				h	215.0	148.0	1.59					207					7.81	0.21		
Ladue	I	M	372	e	77.5	91.1	1.61	1.25	4	3.05	2.53	54.7					22.67	0.15		
				h	31.1	32.0	1.0					18.8					12.17	0.11		
Kathleen	I	M	32	e	14.3	70.4	0.99	1.95	6	3.35	2.38	3.4				9.43	0.73	0.11		
				h	24.3	9.2	0.42				2.34	21.0				3.14	0.16	<.01		
Kluane	I	M	1480	e	16.0	23.7	0.33	1.11	2			5.74				10.2				
				h	19.2	6.6	0.28					8.15				11.1				
Kloo	II	M	11770	e	45.0	311.0	3.07	2.17	6	3.05	1.51	7.47				1.0	26.8	0.11		
				h	81.5	86.8	1.26				1.63	74.3				0.37	4.10	0.23		
Jo-Jo	IIb	M	4145	e	28.4	32.2	0.51	2.19	5		1.51	24.4				3.18				
				h	36.0	17.1	0.43				1.29	35.0				0.9				
Moraine	I	M	25	e	56.9	42.9	1.49	3.68	4	3.15	2.34	36.6					20.2	.07		
				h	100.0	31.2	1.23				2.34	94.8					5.82	.04		
Snafu	II	M	1691	e‡	29.7	82.3			5	3.40	1.64	29.0					0.43	0.03		
				h	105.0	189.0	1.89				1.53	93.3					11.5	.04		
Pygmy	II	M	12075	e	38.8	98.5	1.66	2.59	4	2.90	1.76	5.5					33.2	.13		
				h	37.7	46.4	1.77				1.95	27.0					10.0	.57		
Wolf	I	M	0	e	24.5	61.6	1.13	4.75	4	3.30	2.16	9.34					14.9	0.1		
				h	35.5	40.2	0.87				2.44	33.0					2.4	.07		
Margaret	II	M	0	wc	24.3	15.0	0.81	1.62	8	3.20	1.60	18.5	.01			5.38	0.19	.03		
Tarfu	I	M	1553	e	60.9	130.0	1.80	5.91	5	3.05	1.83	38.0					22.4	.23		
				h	78.7	66.9	1.87				2.25	56.6				2.55	19.1	0.31		
Wheeler	II	M	565	e	39.6	182.0	2.03	5.85	5	3.00		13.0				2.1	24.2	0.18		
				h	95.5	105.0	1.91					78.1				11.0	6.32	.07		
Frenchman	II	M	337	e	54.9	267.0	2.09	10.6	8	3.40	1.65	34.5					10.0	.02		
				h	197.0	143.0	4.14				1.39	182	.067				6.05	.02		
Jackfish	I	M	2177	e	56.5	130.0	2.6	4.73	8	3.45	2.14	38.1	.01				13.3	.02		
				h	169.0	310.0	3.97				2.07	148					13.3			
Tatlmain	I	M	5295	e	71.2	28.8	2.73	10.3	6	3.20	1.62	41.8				18.4	3.06	.02		
				h	85.3	33.2	2.48				1.65	67.6				11.1	4.44	.02		
Little Teslin	II	H	15591	e	75.7	26.3	2.38	4.66	9	2.70	1.41	57.0					6.85			
				h	197.0	115.0	3.14				1.29	177			.09		4.17	0.01		
Tatchun	IIa	H	320	e	57.0	274.0	0.40	1.51	7		0.82	48.2					8.04?			
				h	30.7	52.1	0.54				1.11	30.1					.31?			
East Clark	II	H	2130	e	37.2	52.8	0.82	1.34	8		1.24	25.1					4.13			
				h	22.3	24.5	0.48				1.38	19.8					0.62			
Dezadeash*	II	H	17800	wc	41.4	183.0	2.60	1.30	10	2.55	1.60	19.17	.05				15.07	.69		
North Davis	IIa	H	1536	wc	26.0	25.8	0.55	1.15	6		1.14	22.2					2.5			
South Davis	IIa	H	1536	wc	51.2	26.3	0.82	1.63	7		1.17	45.2					2.24			
Moxley	II	H	1100	e	13.7	58.8	0.17	1.37	6	2.95	0.96	8.7					4.52			
				h	43.0	16.5	0.67				1.29	37.6					4.67	.06		
Smart	I	H	8205	wc	96.2	35.7	1.53	0.92	4	3.10	1.78	75.8					19.9	.16		
Little Salmon	II	H	5290	e	59.8	41.7	0.44				1.33	58.5					0.63			
				wc	23.1	7.0	0.13	1.0	6		1.20	22.8					0.25			
Bruce	II	H	4290	e	44.7	144.0	2.88	7.12	5	3.05	1.44	15.0					24.0	.04		
				h	55.8	42.6	1.99				1.60	43.6					7.16	.05		

Lake	Daphnia longiremis Sars	Daphnia galeata galeata Sars	Daphnia galeata Sars mendotae Birge	Daphnia longispina hyalina Leydig var. microcephala Sars(?)	Daphnia middendorffiana Fischer	Daphnia pulex Leydig (X schoedleri)?	Daphnia schoedleri Sars (X pulex)?	Eubosmina longispina (Leydig)	Bosmina longirostris (O. F. Muller)	Chydorus sphaericus (O. F. Muller)	Leptodora kindtii Focke	Holopedium gibberum Zaddach
North Hanson					4.1							
					1.22							
West Halfway						17.3						
Janet				7.7				1.0				
				1.11				0.1				
Sulphur					1.13					.02		
Taye					0.41					.05		
Hungry					.42?							
Summit					.02?							
					.02?							
Ladue					.02							
					.01							
Kathleen		.03			0.5							
					.03							
Kluane												
Kloo	8.84=							.77				
	2.11=							.46				
Jo-Jo				.84				.05				
	<.01=			.07				.02				
Moraine					.04							
					.02							
Snafu	.13=	0.1										
	.35=	.03										
Pygmy	.01=											
	.03=											
Wolf					.12							
					.02							
Margaret	.07=							.07				<.01
Tarfu					.19							
					.04							
Wheeler								.08				
								<.01				
Frenchman	.16	9.0					1.3					
	4.21	3.56					1.03					
Jackfish					3.29			1.88				
					1.99			5.44				
Tatlmain		7.9			.06							
		1.99			.06							
Little Teslin	1.68		10.1					<.01			.05	
	9.46		5.86					.19			.08	
Tatchun	.12							0.34	.23			
	.26			.02				0.1	.01		<.01	
East Clark	1.47	5.17			.1?			1.19		<.01		
	.35	1.49						.07				
Dezadeash*	.01=							5.86		.14		.04
North Davis	1.07			0.29					<.01		<.01	
South Davis	2.98			.65					.13		<.01	
Moxley	0.2							.22				
	.06							.54				.02
Smart					0.24							
Little Salmon	.16	.05							.46			
	.02	<.01							.03	<.01		
Bruce		.15						5.59				
		.02						4.94				

Lake	Littoral crustacean species - no./liter: Eucyclops agilis (Koch)	Eucyclops speratus (Lilljeborg)	Macrocyclops albidus (Jurine)	Harpacticoida	Polyphemus pediculus (Linne)	Leydigia quadrangularis (Leydig)	Camptocercus rectirostris Schoedler	Scapholeberis kingii Sars	Eurycercus lamellatus (O. F. Muller)	Sida crystallina (O. F. Muller)	Alona affinis (Leydig)	No. Chaoborus larvae/liter	No. amphipods/liter
North Hanson													
West Halfway					.07							0.1	
Janet					.01			.03					
					.07								
Sulphur													0.1
Taye	.01												
Hungry												0.11	
Summit													
Ladue													
Kathleen													
Kluane													
Kloo													
Jo-Jo													
Moraine													
Snafu													
Pygmy													
Wolf													
Margaret													
Tarfu													
Wheeler													
Frenchman													
	.02?												
Jackfish													
			0.01?								0.01		
Tatlmain													
Little Teslin													
		.01?											
Tatchun													
East Clark					<.01								
Dezadeash*				0.54					0.34				
North Davis													
South Davis										<.01			
Moxley													
Smart													
Little Salmon													
Bruce													

+Question marks denote probable, but not certain identifications
‡Same of sample spilled, so results are only qualitative, not quantitative
*Daphnia longispina hyalina microcephala(?) was found in Dezadeash L. in August 1970, but not in 1975
=Large form of Daphnia longiremis present (see text)

Appendix K. Matrix of community similarity coefficients (after Sorenson 1948, cited in Southwood 1966) for crustacean zooplankton communities of 38 Yukon lakes. Reading across for each lake, the top row of coefficients corresponds to the top row of lakes names (Tatlmain through Dezadeash), the second row of coefficients to the second row of lake names, etc. For example, the coefficient between Diamain L. and Tatchun L. is 0.36.

Lake Name \ Lake Name	Tatlmain Wolf North Hanson	Bruce Pygmy Summit	Jackfish Snafu Tatchun	Little Salmon Taye Little Teslin	Frenchman Moraine Diamain	Wheeler Jo-Jo Minto	Smart Kloo Fox	Morley Kluane Swan	Tarfu Sulphur Lower Snafu	South Davis Kathleen	North Davis East Clark	Hungry Ladue	Margaret Janet	Dezadeash West Halfway
Bruce	0.73													
Jackfish	0.73	0.80												
Little Salmon	0.54	0.60	0.40											
Frenchman	0.67	0.73	0.54	0.73										
Wheeler	0.73	0.80	0.80	0.40	0.54									
Smart	0.80	0.67	0.89	0.44	0.60	0.67								
Morley	0.54	0.80	0.80	0.60	0.73	0.80	0.67							
Tarfu	0.91	0.60	0.80	0.40	0.54	0.80	0.89	0.60						
South Davis	0.36	0.40	0.40	0.80	0.54	0.40	0.44	0.60	0.40					
North Davis	0.36	0.40	0.40	0.80	0.54	0.40	0.44	0.60	0.40	1.00				
Hungry	0.73	0.60	0.80	0.40	0.54	0.60	0.89	0.60	0.80	0.40	0.40			
Margaret	0.67	0.73	0.73	0.54	0.67	0.91	0.60	0.91	0.73	0.54	0.54	0.54		
Dezadeash	0.54	0.80	0.80	0.60	0.73	0.80	0.67	1.00	0.60	0.60	0.60	0.60	0.91	
Wolf	0.80	0.67	0.89	0.44	0.60	0.67	1.00	0.67	0.89	0.44	0.44	0.89	0.60	0.67
Pygmy	0.75	0.67	0.67	0.67	0.80	0.67	0.75	0.89	0.67	0.67	0.67	0.67	0.80	0.89
Snafu	0.73 0.67	0.80 0.89	0.60	0.80	0.91	0.60	0.67	0.80	0.60	0.60	0.60	0.60	0.73	0.80
Taye	0.80 1.00	0.67 0.75	0.89 0.67	0.44	0.60	0.67	1.00	0.67	0.89	0.44	0.44	0.89	0.60	0.67
Moraine	0.80 1.00	0.67 0.75	0.89 0.67	0.44 1.00	0.60	0.67	1.00	0.67	0.89	0.44	0.44	0.89	0.60	0.67
Jo-Jo	0.36 0.22	0.40 0.44	0.40 0.40	0.40 0.22	0.36 0.22	0.60	0.22	0.60	0.40	0.60	0.60	0.20	0.73	0.60
Kloo	0.67 0.60	0.73 0.80	0.73 0.73	0.54 0.60	0.67 0.60	0.91 0.73	0.60	0.91	0.73	0.54	0.54	0.54	1.00	0.91
Kluane	0.50 0.33	0.29 0.33	0.29 0.29	0.29 0.33	0.25 0.33	0.57 0.57	0.33 0.50	0.29	0.57	0.29	0.29	0.29	0.50	0.29
Sulphur	0.80 1.00	0.67 0.75	0.89 0.67	0.44 1.00	0.60 1.00	0.67 0.22	1.00 0.60	0.67 0.33	0.89	0.44	0.44	0.89	0.60	0.67
Kathleen	1.00 0.80	0.73 0.60	0.73 0.73	0.54 0.80	0.67 0.80	0.73 0.36	0.80 0.67	0.54 0.50	0.91 0.80	0.36	0.36	0.73	0.67	0.54
East Clark	0.67 0.60	0.73 0.60	0.73 0.73	0.73 0.60	0.67 0.60	0.54 0.54	0.60 0.67	0.73 0.25	0.54 0.60	0.54 0.67	0.54	0.54	0.67	0.73
Ladue	0.80 1.00	0.67 0.75	0.89 0.67	0.44 1.00	0.60 1.00	0.67 0.22	1.00 0.60	0.67 0.33	0.89 1.00	0.44 0.80	0.44 0.60	0.89	0.60	0.67
Janet	0.54 0.44	0.60 0.44	0.60 0.40	0.40 0.44	0.36 0.44	0.80 0.80	0.44 0.73	0.60 0.57	0.60 0.44	0.60 0.54	0.60 0.54	0.40 0.44	0.73	0.60
West Halfway	0.44 0.57	0.50 0.57	0.50 0.50	0.50 0.57	0.44 0.57	0.50 0.25	0.57 0.44	0.50 0.40	0.50 0.57	0.50 0.44	0.50 0.44	0.50 0.57	0.44 0.50	0.50
North Hanson	0.80 1.00	0.67 0.75	0.89 0.67	0.44 1.00	0.60 1.00	0.67 0.22	1.00 0.60	0.67 0.33	0.89 1.00	0.44 0.80	0.44 0.60	0.89 1.00	0.60 0.44	0.67 0.57
Summit	0.80 1.00 1.00	0.67 0.75	0.89 0.67	0.44 1.00	0.60 1.00	0.67 0.22	1.00 0.60	0.67 0.33	0.89 1.00	0.44 0.80	0.44 0.60	0.89 1.00	0.60 0.44	0.67 0.57
Tatchun	0.33 0.40 0.40	0.54 0.60 0.40	0.54 0.54	0.73 0.40	0.50 0.40	0.54 0.73	0.40 0.67	0.73 0.25	0.36 0.40	0.91 0.33	0.91 0.67	0.36 0.40	0.67 0.73	0.73 0.44
Little Teslin	0.46 0.54 0.54	0.67 0.73 0.54	0.67 0.67 0.62	0.50 0.54	0.62 0.54	0.67 0.50	0.54 0.77	0.83 0.22	0.50 0.54	0.50 0.46	0.50 0.62	0.50 0.54	0.77 0.50	0.83 0.40
Diamain	0.91 0.89 0.89	0.60 0.67 0.89	0.80 0.60 0.36	0.40 0.89 0.50	0.54 0.89	0.80 0.40	0.89 0.73	0.60 0.57	1.00 0.89	0.40 0.91	0.40 0.54	0.80 0.89	0.73 0.60	0.60 0.50
Minto	0.40 0.25 0.25	0.44 0.25 0.25	0.44 0.22 0.40	0.22 0.25 0.54	0.20 0.25 0.44	0.67 0.67	0.25 0.60	0.44 0.67	0.44 0.25	0.22 0.40	0.22 0.40	0.22 0.25	0.60 0.67	0.44 0.29
Fox	0.36 0.22 0.22	0.40 0.44 0.22	0.40 0.40 0.73	0.40 0.22 0.50	0.36 0.22 0.40	0.60 1.00 0.67	0.22 0.73	0.60 0.57	0.40 0.22	0.60 0.36	0.60 0.54	0.20 0.22	0.73 0.80	0.60 0.25
Swan	0.40 0.50 0.50	0.67 0.75 0.50	0.67 0.67 0.80	0.67 0.50 0.73	0.60 0.50 0.44	0.67 0.67 0.50	0.50 0.80 0.67	0.89 0.33	0.44 0.50	0.67 0.40	0.67 0.80	0.44 0.50	0.80 0.67	0.89 0.57
Lower Snafu	0.67 0.60 0.60	0.91 0.80 0.60	0.73 0.91 0.67	0.73 0.60 0.77	0.83 0.60 0.54	0.73 0.54 0.40	0.60 0.83 0.54	0.91 0.25 0.80	0.54 0.60	0.54 0.67	0.54 0.83	0.54 0.60	0.83 0.54	0.91 0.44
Pine	0.57 0.50 0.50	0.46 0.50 0.50	0.62 0.46 0.71	0.46 0.50 0.53	0.43 0.50 0.62	0.62 0.77 0.50	0.50 0.71 0.77	0.62 0.40 0.67	0.62 0.50 0.57	0.62 0.57	0.62 0.71	0.46 0.50	0.71 0.77	0.62 0.36