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Limnetic Zooplankton of Lakes in Katmai National Monument, Alaska

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The Limnetic Zooplankton of Lakes in Katmai National Monument, Alaska

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NOTICE

ABSTRACT

The limnetic zooplankton in lakes of the Naknek River system in southwestern Alaska was sampled extensively during 1962-63. The numerically dominant forms of limnetic zooplankton were *Diaptomus sp.*, *Cyclops sp.*, *Daphnia longiremis*, *Bosmina coregoni*, *Kellicotia longispina*, and *Conochilus unicornis*. Some littoral and benthic forms were also identified but not studied in detail. Species composition and the relative abundance of each species differed considerably among the four major lakes and also among basins within the lakes. These differences were consistent with limnological differences in physical and chemical characteristics. Iliuk Arm, contains glacial flour from glaciers and pumice from volcanic activity and had the lowest standing crop. South Bay of Naknek Lake receives turbid water from Iliuk Arm and clear water from Brooks Lake and was more productive than Iliuk Arm, but much less so than other basins in Naknek Lake and the other lakes. The clear and warmer waters of the North Arm of Naknek Lake had the highest standing crops. Seasonal pulses of zooplankton occurred in mid-July and again in late-August. Annual changes were also studied and in nine out of ten comparisons, zooplankton were more abundant in 1963 than in 1962. Diel migrations of groups of zooplankton and individual dominant species were also examined.

INTRODUCTION

The sockeye salmon (Oncorhynchus nerka) resource of Bristol Bay in southwestern Alaska is one of the most valuable in the world (Hartman 1971). These anadromous fish spawn in lakes and rivers, then the young spend from 1 to 3 years in the lakes before migrating to the Pacific Ocean (Hartman and Burgner 1972). While in "nursery" lakes the young are pelagic zooplankton feeders (Johnson 1961; Hoag 1972); yet, relatively little is known about the zooplankton of Alaskan sockeye nursery lakes. Juday et al. (1932) sampled the net plankton of Karluk Lake on Kodiak Island where they found that rotifers constituted numerically by far the bulk of the net plankton. Nelson and Edmondson (1955) and Raleigh (1963) studied the zooplankton of shallow Bare Lake on Kodiak Island during and following artificial fertilization experiments. The zooplankton increased threefold after fertilization. Waters (1967) and Hoag (1972) reported general studies on some of the lakes draining to Bristol Bay.

In 1962 and 1963 the limnetic zooplankton were studied in four lakes of the Naknek River drainage system in Katmai National Monument on the Alaska Peninsula. This paper reports the occurrence, distribution, and abundance of zooplankton species during the growing seasons each year from June to October. Zooplankton abundance and species composition differed between basins within lakes, between lakes, within seasons and between seasons; the diel migratory behavior of zooplankton is also noted.

THE STUDY AREA

The Naknek River system consists of four major interconnected lakes--Coville, Grosvenor, Brooks, and Naknek--all draining through Naknek River to Bristol Bay (Figure 1). Naknek Lake has five relatively distinct basin areas--Iliuk Arm, North Arm, South Bay, Northwest Basin, and the large shallow West End. All these lakes and basins were formed or modified by glaciation (Mertie 1938). The general limnology of these study lakes and others around Bristol Bay was described by Burgner et al. (1969). They are subject to an oceanic climate since they are in the path of prevailing winds and storms from the Bering Sea. Thermoclines seldom develop in the summer; when they do, stratification is destroyed by the next strong windstorm. These lakes freeze over in November or early December and become ice free in May.

The watersheds are mainly sedimentary rock with some igneous outcrops and volcanic ash deposits (Keller and Reiser 1959); substantial differences occur between lakes in certain physical and chemical characteristics (Table 1). Summer transparency ranges from 0.5 m in glacial fed Iliuk Arm to 10.8 m in Brooks Lake. Summer mean high temperatures are lowest in Brooks Lake, and nearly 5°C warmer in shallow Coville Lake. Total dissolved solids, and some of the cation concentrations were severalfold higher in Naknek Lake which receives drainage from glaciers and the pumice and mineral deposits in the Valley of Ten Thousand Smokes.

The ichthyofauna of these lakes is subarctic with emphasis on the Salmonidae (Heard et al. 1969). Its modifying effect on the composition of the zooplankton by selective feeding has not been studied. In addition to the very abundant young sockeye and other salmonids, such competitors for the zooplankton as threespine sticklebacks (*Gasterosteus aculeatus*), ninespine sticklebacks (*Pungitius pungitius*), pygmy whitefish (*Prosopium coulteri*), least cisco (*Coregonus sardinella*), and pond smelt (*Hypomesus olidus*) are very abundant in some if not all of these lakes.

MATERIALS AND METHODS

Small high-speed Hardy plankton samplers as modified by Miller (1961) were used to sample the limnetic zooplankton. These samplers trail a long attached net with a high ratio of effective filtering area to sample aperature. Standard No. 10 bolting (.158 mm) silk nets with detachable collecting cups were used.

A standard plankton tow was for 1 minute and 43 seconds with the cable maintained at a 45° angle. Six samplers were towed simultaneously at depths of 1, 5, 10, 15, 25, and 35 meters. A Scripps 40-pound depressor was used to depress the cable. The six samplers towed for 1 minute and 43 seconds covered 152.4 m (500 ft) and each sampler theoretically strained 1.245 cubic meters of water. The sampler aperature is 10.2 cm in diameter. By maintaining a constant cable angle and towing in a large circle effects between tows of differences in boat weight, outboard motor sizes, water currents, and wind and wave conditions were minimized.

After collection, zooplankters were poured into glass jars and preserved in 3% formalin. In the laboratory, the preservative was carefully decanted to leave one volume of zooplankton to four volumes of preservative. After mixing by inversion, a 0.5 ml subsample was taken with a calibrated wide-mouth pipet and placed into an etched Sedgwick-Rafter cell. All organisms in the subsample were counted. At least 200 organisms we[illegible]unted and identified under a compound microcope for each sample. The counts were expanded to estimate numbers per cubic meter of lake water in the usual manner relating sample size to the volume of water strained.

The following factors place some constraint on interpretations from the samples. Significant local differences in horizontal distribution related to the swarming of zooplankters was reported by Kangas (1964) and others. The aperture of the samplers was only 10.2 cm in diameter, so swarming may have been a problem. Vertical stratification and diel migration which existed tended to complicate comparisons of standing crop estimated between basins and especially lakes. However, by basing comparisons on average numbers from six depths sampled simultaneously this complication was minimized.

The 0.158 mm mesh size used for collections also placed limitations on zooplankton counts. Many of the rotifers, smaller nauplii and all protozoans passed through the nets and hence were not quantitatively sampled.

Contamination introduced during the vertical retrieval haul from sample depth to the surface was probably insignificant because tows were made for nearly 2 minutes at depth and then brought rapidly to the surface. Furthermore, the diel samples show little if any contamination of deep water tows with primarily surface forms. There was no contamination while casting the samplers because they were lowered cup end first which effectively back flushed them.

Special sets of data collected demonstrate levels of statistical reliability that give confidence in making comparisons between samples and lakes. Samples were collected at the six depths six times at 2-hour intervals betwen 0600 and 1600 hours 1 day at Brooks Lake and 1 day at South Bay in Naknek Lake. Mean numbers, standard deviations and coefficients of variation of these samples for the six depths combined for Copepoda, Cladocera, Rotifera and the dominant species in these groups are given in Table 2. The coefficients of variation are relatively small for most of the dominant organisms. As the sampling was conducted throughout the day covering time sampled at other stations and lakes, the results give confidence in comparing differences in zooplankton numbers between stations, lakes and seasons.

A paired T-test was used on eight samples from Brooks Lake and eight samples from South Bay of Naknek Lake to find if population estimates of each species were identical (Table 3). The samples were collected at similar times throughout the season. The results show that the major species (*Diaptomus sp.*, *Cyclops* sp. and *Daphnia longiremis*) constituting the bulk of the standing crop were significantly more abundant in Brooks Lake than in South Bay of Naknek Lake. *Bosmina coregoni* and *Kellicotia longispina* were not significantly different in the two lakes.

Several forms were not enumerated to species because of taxonomic similarities and difficulties in identifying copepodite stages. *Diaptomus gracilis* and *Diaptomus pribilofensis* were not enumerated separately and are presented collectively as *Diaptomus sp*; *Cyclops strenuus* and *Cyclops capillatus* were also not enumerated separately and are presented here as *Cyclops sp*.

RESULTS AND DISCUSSION

Limnetic samples from the four Naknek River lakes and their basins consisted of five species of Copepoda, five species of Cladocera, and 10 species of Rotifera. Two other copepods and two other cladocerans were identified in littoral areas (Table 4). The dominant limnetic forms common to all lakes were *Diaptomus sp.*, *Cyclops sp.*, *Daphnia longiremis*, *Bosmina coregoni*, *Kellicotia longispina*, and *Conochilus unicornis*.

Distribution

Certain differences were found in the distribution of species between lakes. *Leptodora kindtii* was only found in Coville and Grosvenor Lakes. *Holopedium gibberum* was found in these two upper lakes and Brooks Lake. The rotifer *Ploesoma sp.* was only found in the South Bay of Naknek Lake. The rotifer *Conochiloides natans* was only found in Brooks Lake, whereas the rotifer *Conochilus unicornis* was found in all areas except Iliuk Arm. *Eurytemora yukonensis* was rare in Brooks Lake where it was found in only one of 138 samples taken from there.

Investigators of other subarctic lakes (e.g., Reed 1964) concluded that plankton communities of large subarctic lakes are relatively rich in species and relatively poor in numbers. Most of the species of cladocerans and rotifers found in the lakes of the Naknek River system are widely distributed and abundant in Northern United States, Canada, and Alaska. However, species of copepods from the Naknek River lakes tend to be more restricted to Northern Canada and Alaska. Yeatman, in Ward and Whipple (edited by Edmondson 1959) reported that *Cyclops strenuus* and *Cyclops capillatus* were generally relatively rare in North America. However, these two species were numerically the most abundant zooplankters in the Naknek River system lakes.

Of the six species mentioned as common in Lake Iliamna by Lenarz (1966) only Cyclops scutifer was not found in the Naknek lakes. Lake Iliamna is over 100 miles east of the Naknek River system and enters Bristol Bay via a separate drainage.

Relative Abundance

Differences were also found between lakes in the relative abundance of various species. Looking first at major groups of zooplankton (Figure 2) rotifers were more abundant in the uppermost major lake, Coville, in July when they equaled nearly half of the zooplankton. Cladocerans were most important numerically in Grosvenor Lake in both July and August. In all other lakes and Naknek Lake basins, copepods dominated the zooplankton.

Dominance of one species of copepod, cladoceran, or rotifer was evident in almost all samples. Usually one species in each group constituted the bulk of any given sample. For copepods it was usually Cyclops sp.; for cladocerans usually Daphnia longiremis; and for rotifers usually Kellicotia longispina or Conochilus unicornis (Tables 5-8). However, some differences in dominance occurred between lakes. The cladoceran Daphnia longiremis was dominant in Brooks and Coville Lakes in both July and August, 1962 (Tables 5 and 7). In Grosvenor Lake, Daphnia rosea was more abundant than Daphnia longiremis in July and strongly dominant in August. These observations support the report by Pennak (1957) that two species from the same genus present at the same time as dominants in a limnetic community is unusual, although this occasionally happens. He further stated that the periodicities of two species of the same genus may be different, or they may occupy different water strata, yet invariably one is always much more abundant.

Diversities in limnological conditions (Burgner et al. 1969) and the species composition of zooplankton between lakes in the Naknek River system have been noted. There were also differences within each lake in the relative abundance of species and overall standing crops.

In Brooks Lake, Station 2 was located nearer the major tributary entering the lake, and Station 1 nearer the outlet. Standing crops of zooplankton in July and August in 1962 were essentially the same at both stations but species differences occurred. Diaptomus sp. was twice as abundant downlake at Station 1, whereas Cyclops sp. occurred in virtually identical numbers at both stations. Cladocerans were more abundant at Station 2 in July, and at Station 1 in August (Tables 5 and 7).

The diversity of limnological conditions in the many areas of Naknek Lake was reflected in differences in the zooplankton (Tables 6 and 8). This lake had the highest and lowest standing crops in different basins on similar sampling dates. North West Basin in Naknek Lake is a relatively shallow bay almost completely separated from the rest of the Naknek Lake complex (Figure 1). It was sampled in July during a heavy Anabaena sp. bloom. The standing crop of zooplankton was very low, dominated by Bosmina coregoni and several rotifers. Perhaps, as Ryther (1954) suggests, the dense phytoplankton populations created conditions incompatible or actually lethal to many other aquatic organisms in North West Basin in July.

Illiuk Arm receives glacial flour, pumice, and silt from the Valley of Ten Thousand Smokes. Secchi disc readings seldom exceed 0.9 meters. Zooplankton were very low in numbers at both stations with little difference in species composition. No other lake or basin had such low standing crops. Copepods dominated the zooplankton.

South Bay receives turbid water from Iliuk Arm and clear water from Brooks Lake. Zooplankton were two to three times more abundant here than in Iliuk Arm but lower than in any other area in the Naknek River system.

Stations 3 and 4 were only 4 miles apart and had essentially the same standing crops and species composition; *Cyclops* sp., *Diaptomus* sp., and two species of rotifers dominated.

The water in North Arm Stations 7, 8, and 9 was clear and warm and had the largest standing crops of zooplankton in the Naknek Lake complex. Copepods dominated the zooplankton at all three stations. Rotifers were also important, at Stations 8 and 9 in July and 7 and 9 in August.

Only one station (12) was sampled in warm and shallow Coville Lake. The standing crop in July and August was high; *Cyclops* sp. were especially abundant but *Diaptomus* sp., cladocerans, and rotifers were well represented (Tables 5 and 7).

Grosvenor Lake is deep and slightly colder than most of the other lakes or basins. Station 14 in the middle of this long, narrow lake had the highest standing crop in both July and August. At the upper end, which receives water from Coville Lake, the standing crop was somewhat less. At the lower end of the lake, the water is relatively turbid due to a silty effluent from Hardscrabble Creek, and the standing crop was quite low (Tables 5 and 7).

Seasonal Changes in Standing Crop

Seasonal changes in the standing crop of zooplankton were documented at Brooks Lake (Station 1) and Naknek Lake (Station 3) in 1962 from early July through early October. The occurrence of two pulses of abundance was noted in Brooks Lake, whereas it was less pronounced in Naknek Lake (Figure 3). The highest number of zooplankton occurred in July in both lakes; then a midsummer depression occurred in both lakes at virtually the same time around mid-August. The late-summer pulse peaked about the first of September in both lakes; the subsequent rapid decline was similar in both lakes.

Seasonal changes in the species composition of the zooplankton (Figures 4 and 5) also occurred. The copepods comprised a large percent of the total plankton at all times. Cyclops sp. decreased in relative abundance whereas Diaptomus sp. tended to increase as the season progressed in both lakes. In Brooks Lake nauplii decreased whereas in Naknek Lake they remained relatively constant during the sampling period. Daphnia longiremis were most abundant in mid and late su ·r in both lakes. The relative peak abundance of Kellicotia longispina and Conochilus unicornis differed in the two lakes (Figures 4 and 5). No one dominant species showed two strong pulses. The pulses were largely a result of certain species peaking in abundance early in the summer, then declining, while other species, low in abundance early in the summer, peaked in late summer.

Miscellaneous species not included in either Figures 4 or 5 were common for relatively short time periods only. In Brooks Lake Holopedium gibberum and Daphnia rosea were common at certain times but virtually absent from South Bay of Naknek Lake. In South Bay Asplancha priodonta and Eurytemora yukonensis were common at certain times, but not in Brooks Lake.

Annual Differences in Standing Crop

Annual differences in the standing crop of zooplankton for four of the lakes were also noted. Zooplankton were collected at the same stations in Brooks and Naknek Lakes on three dates and in Coville and Grosvenor Lakes on two dates in 1963 corresponding to sampling dates in 1962. Even with limited data seasonal variations in abundance and the timing of species dominance was observed. Copepods were more abundant in 1963, especially so in Grosvenor Lake where they were nearly double (Table 9). In only two of the 10 comparisons were numbers in 1962 larger. Cladocerans were also more abundant in 1963. Only in July in Grosvenor Lake were they more abundant in 1962. In all remaining nine comparisons, numbers in 1963 were from 17 to 96 percent higher, averaging 27 percent higher.

Rotifers, however, were less abundant on the average in 1963 in Brooks and Naknek Lakes. They were about the same density both years in Grosvenor Lake. Only in Coville Lake were they more abundant in 1963, as were cladocerans and copepods.

The composite zooplankton showed larger numbers in nine cases out of 10 in 1963 (Table 9). Unpublished data show that solar radiation and primary productivity were higher in 1963 than in 1962, a condition under which larger populations of phytoplankton, and subsequently, zooplankton, were expected.

Diel Vertical Migrations

Diel vertical migrations of many marine and freshwater species of zooplankton have already been described. Most investigators agree that light is the primary environmental factor responsible for diel movements. However, Pennak (1944) reported that diel movements of zooplankton cannot be predicted in an uninvestigated lake and that factors other than light must play an important role. Other contributing factors suggested by many workers include: temperature, wind, gravity, oxygen depletion, carbon dioxide accumulation, and age or condition of the individual organisms.

The diel distributions of zooplankton were studied in clear Brooks Lake on July 30, 1962 and in somewhat turbid South Bay of Naknek Lake on August 15, 1962. July 30 was bright, clear, and calm; August 15 was a dark day with rain most of the time. Samples were taken at depths of 1, 5, 10, 15, 25, and 35 meters every 2 hours from 0000 to 2200 hours. Figures 6, 7, and 8 show the percent of organisms occurring at each depth.

Cladocerans and rotifers exhibited substantial vertical migrations during the 24-hour periods at both Brooks Lake and Naknek Lake (Figures 6 and 7). Large proportions of these zooplankton ascended near to the surface waters at night and descended to depths of 5, 10, and 15 meters during the day. The diurnal descent went deeper in the more transparent Brooks Lake than in Naknek Lake while the nocturnal ascent reached closer to the surface in Naknek Lake. Almost no cladocerans or rotifers were found at 1 meter below the surface between 0600 and 1600 hours at Brooks Lake and between 1000 and 1600 hours at Naknek Lake. The typical summer secchi disc reading at Naknek Lake is 4.4 m and at Brooks Lake is 10.8 m (Burgner et al. 1969); consequently diel vertical migrations in Brooks Lake were more pronounced. The median values are plotted for each sample distribution in Figures 6 and 7. They essentially divide distributions described above. The deep distribution of copepods, especially during mid-day in Naknek Lake, exceeded the deepest sampling depth of 35 meters. However, the population of cladocerans and rotifers was distributed nearly entirely above 35 meters.

Copepods in Naknek Lake also showed a substantial diel migration as both the shape of the depth distribution and plot of median values illustrate (Figure 7). In both Naknek and Brooks Lakes copepods were distributed deeper in the water column than cladocerans and rotifers. In no groups in either lake, however, was midnight sinking of entomostraca observed as reported elsewhere by Cushing (1951) for example. However, our sampling depths of 1, 5 and 10 meters precluded noting vertical changes between these depths.

The diel distributions of individual species that dominated the zooplankton in Brooks Lake during July help explain the character of the migrations when the species are grouped. Neither the two species of *Cyclops* nor the two species of *Diaptomus sp.* exhibited much diel migration (Figure

8), which was essentially the same situation when all copepods including nauplii were grouped (Figure 6), although if all four species had been considered independently this may not have been so. Daphnia longiremis was the most abundant cladoceran and its diel vertical migrations (Figure 8) characterized that of the grouped cladocerans. The less abundant Holopedium gibberum exhibited diel migrations, but they were less pronounced and confined to depths of less than 10 meters. The rotifers, Kellicotia longispina and Conochilus unicornis, were about equally abundant and the grouped pattern of diel distributions of all rotifers reflects the combinations of the separate and different behaviors. Both rotifers showed vertical migrations but utilized different levels in the water column. Kellicotia longispina migrated mainly between 5 and 20 meters with some individuals reaching the surface at night. Conochilus unicornis migrated between the surface and 10 m. At night when both species were nearer the surface, the grouped distribution shows primarily one bulge of abundance around 5 meters, but by mid-day the grouped distribution (Figure 6) shows two strata of abundance at 5 and 15 meters representing the differential diurnal distribution of the shallower Conochilus unicornis and the deeper Kellicotia longispina.

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Table 1. Physical and chemical characteristics of four lakes in the Naknek River system and Iliuk Arm (Burgner et al. 1969, and unpublished data).

	Units	Brooks Lake	Grosvenor Lake	Coville Lake	Naknek* Lake	Iliuk Arm
Area	km^2	75	73	33	516	94
Maximum depth	m	79	107	53	71-167	173
Mean depth	m	45	50	19	13-63	96
Volume	km^3	3.39	3.68	0.64	16.15	9.00
Altitude	m	19	31	33	10	10
Shoreline development		1.70	2.54	1.86	1.41-2.07	1.71
Total dissolved solids	ppm	75	54	52	140	
pH		7.3	7.2	7.1	7.4	7.3
Total alkalinity	ppm	27	25	25	29	
Sodium	ppm	4.3	3.0	3.2	10.4	
Potassium	ppm	1.0	0.5	0.5	1.2	
Magnesium	ppm	2.2	1.9	1.2	4.2	
Calcium	ppm	8.9	6.9	7.8	18.2	
Silica	ppm	10.5	7.7	9.0	9.3	
Summer secchi disc	m	10.8	8.4	5.4	4.4	0.5
Summer high mean temp.	°C	10.7	14.5	15.6	13.4	11.0

* Includes several basins.

Table 2. Mean number of zooplankton per cubic meter, including standard deviations and coefficients of variation, for diurnal samples collected from Brooks Lake, 30 July 1962 and the South Bay of Naknek Lake, 15 August 1962.

	Brooks Lake		South Bay	
	X* SD**	C***	X* SD**	C***
Copepoda	3786 ± 413	11%	1782 ± 315	18%
Cyclops sp.	2032 ± 322	16%	946 ± 156	16%
Diaptomus sp.	900 ± 146	16%	472 ± 104	22%
Cladocera	1014 ± 83	8%	132 ± 15	11%
D. longiremis	849 ± 67	8%	48 ± 13	27%
B. coregoni	57 ± 30	53%	89 ± 19	21%
Rotifera	459 ± 101	22%	1219 ± 220	18%
K. longispina	297 ± 62	21%	481 ± 172	35%

* Mean

** Standard deviation

***Coefficients of variation

Table 3. Paired T-test on plankton in Brooks Lake and Naknek Lake to find if populations are identical.

	Diaptomus	Cyclops	Daphnia	Bosmina	Kellicotia
$\bar{d}$	1020	1115	533	19	6
$SD_{\bar{d}}$	200	338	127	30	93
t	5.10**	3.30*	4.20**	0.62	0.07
df	7	7	7	7	7

$\bar{d}$ = Average difference (Brooks - Naknek).

$SD_{\bar{d}}$ = Standard deviation of the difference.

t = T-value

df = Degrees of freedom

* $p < .05$

** $p < .01$

Table 4. Zooplankton species found in lakes of the Naknek River system in southwestern Alaska, 1962-63.

Organisms	Habitat*
Copepoda	
Calanoida	
Diaptomus gracilis. Sars, 1863 [*Eudiaptomus gracilus* (Sars) 1863][+]	Limnetic
Diaptomus pribilofensis. Juday and Muttowski, 1915. [*Leptodiaptomus pribilotensis* (Juday and Muttowski) 1915][+]	Limnetic
Eurytemora yukonensis. M.S. Wilson, 1953.	Limnetic
Cyclopoida	
Cyclops strenuus. Fischer, 1851.	Limnetic
Cyclops capillatus. Sars, 1863. [*Acanthocyclops capillatus* (Sars) 1863][+]	Limnetic
Harpacticoida	
Attheyella nordenskiolkii. (Lilljeborg), 1902).	Littoral, Benthic
Bryocamptus nivalis. (Willey), 1925.	Benthic
Cladocera	
Haplopoda	
Leptodora kindtii. (Focke), 1844.	Limnetic
Eucladocera	
Holopedium gibberum. Zaddach, 1855.	Limnetic
Daphnia longiremis. Sars, 1861.	Limnetic
Daphnia rosea. Sars, 1862 emend. Richards, 1896.	Ponds and Lakes
Scapholeberis kingi. Sars, 1903.	Ponds and Lakes
Bosmina coregoni. Baird, 1857.	Ponds and Lakes
Polyphemus pediculus. (Linne'), 1761.	Ponds and Marshes
Rotifera	
Kellicotia longispina. (Kellicotia, Ahlstrom)	Limnetic
Keratella hiemalis. Carlin, 1943.	Limnetic
Keratella cochlearis. (Keratella, Bory de St. Vincent)	Limnetic
Gastropus sp. Imhof	Limnetic

Table 4. (Continued)

Organisms	Habitat
Asplanchna priodonta. Gosse, 1850.	Limnetic
Ploesoma sp. Herrick.	Limnetic
Polyarthra sp. Ehrenberg.	Limnetic
Filinia terminalis. (Plate), 1886.	Limnetic
Conochiloides natans. (Conochiloides, Hlava).	Limnetic
Conochilus unicornis. (Conochilus, Hlava).	Limnetic

* Mostly as adapted from Pennak (1953) and Ward and Whipple (1959) 2nd ed.

+ Names by G. E. Hutchinson accepted by many workers as discussed (B. Tork, personal communication) in Treatise on Limnology, Vol. II, p. 625.

Table 5. Standing crop of zooplankton by species at different stations in Brooks, Coville, and Grosvenor Lakes in July 1962 (mean number per cubic meter for six sampling depths).

	Brooks		Coville	Grosvenor		
Station No.	1	2	12	13	14*	15*
Date	7/14	7/14	7/20	7/19	7/19	7/19
Species						
Eurytemora yukonensis			6		8	
Diaptomus sp.	1198	2146	502	462	1650	46
Cyclops sp.	4046	3737	2815	3599	5006	1354
Nauplii	1615	993	623	649	930	46
Copepoda total	6859	6876	3946	4710	7594	1446
Leptodora kindtii			3			
Holopedium gibberum	30	205	66			
Daphnia longiremis	574	976	200	194	1162	60
Daphnia rosea		25	40	380	1752	31
Bosmina coregoni	30	115	197	399	1912	100
Cladocera total	634	1321	506	973	4826	191
Kellicotia longispina	320	242	336	625	1146	64
Asplanchna priodonta			22	116	535	4
Conochilus unicornis	303	599	3469	1398	1334	30
Misc. rotifers	22	25	8	27	52	5
Rotifera total	645	866	3835	2166	3067	103
Total zooplankton	8138	9063	8287	7849	15487	1740

* Mean of four depths only.

Table 6. Standing crop of zooplankton by species at different stations in Iliuk Arm and other basins of Naknek Lake in July 1962 (mean number per cubic meter for six sampling depths).

Area	South Bay		Iliuk Arm	North Arm			N.W. Basin	West End
Station No.	3	4	5	7	8	9*	10**	11***
Date	7/11	7/11	7/4	7/5	7/11	7/11	7/26	7/26
Species								
Eurytemora yukonensis	216	216		6	19	35	111	99
Diaptomus sp.	518	692	20	553	1918	1712	128	1261
Cyclops sp.	1352	932	1560	4129	7193	7058	202	4084
Nauplii	343	636	175	819	1183	1000	181	644
Copepoda total	2474	2476	1755	5507	10313	9805	622	6088
Daphnia longiremis	56	21	1	83	239	769		653
Bosmina coregoni	35	33	3	44	190	368	972	130
Cladocera total	91	54	4	127	429	1137	972	383
Kellicotia longispina	127	63	14	74	192	115	133	437
Keratella cochlearis	1	4			9		1	
Asplanchna priodonta	28	30	5		8	56	215	
Conochilus unicornis	74	68		77	831	596	1141	
Misc. rotifers	4	65		10	14	88	8	
Rotifera total	234	230	19	161	1054	855	1498	437
Total zooplankton	2799	2760	1778	5795	11796	11797	3092	6908

* Mean of five depths only.

** Mean of four depths only.

*** Shallow water - mean of 1- and 5-meter samples only.

Table 7. Standing crop of zooplankton by species at different stations in Brooks, Coville, and Grosvenor Lakes in August 1962 (mean number per cubic meter for six sampling depths.)

	Brooks		Coville	Grosvenor		
Station No.	1	2*	12	13	14	15
Date	8/17	8/28	8/20	8/21	8/21	8/21
Species						
Eurytemora yukonensis			16			
Diaptomus sp.	903	1671	1013	373	1170	558
Cyclops sp.	1838	1805	4097	1652	2076	1165
Nauplii	447	156	686	55	174	58
Copepoda total	3188	3632	5812	2080	3420	1781
Leptodora kindtii				9	11	2
Holopedium gibberum	153	95	3		22	4
Daphnia longiremis	1118	608	460	318	323	434
Daphnia rosea	38	51	58	935	1846	1388
Bosmina coregoni	153	158	332	536	620	639
Cladocera total	1462	912	853	1798	2822	2467
Kellicotia longispina	251	150	275	125	266	151
Keratella cochlearis			5			15
Asplanchna priodonta		102	38	28	146	73
Conochilus unicornis	33	53	279	66	43	33
Misc. rotifers		31	1			1
Rotifera total	284	336	598	219	455	273
Total zooplankton	4934	4880	7263	4097	6697	4521

* Mean of five depths only.

Table 8. Standing crop of zooplankton by species at different stations in Iiuk Arm and other basins of Naknek Lake in August 1962 (mean number per cubic meter for six sampling depths.)

Area	South Bay		Iliuk Arm		North Arm		
Station No.	3	4	5	6	7	8	9
Date	8/15	8/27	8/9	8/9	8/9	8/13	8/31
Species							
Eurytemora yukonensis	101	131			18	21	2
Diaptomus sp.	411	513	69	73	1685	890	504
Cyclops sp.	797	1062	373	429	3043	2054	1074
Nauplii	286	252	154	269	368	204	249
Copepoda total	1595	1958	596	771	5114	3169	1829
Daphnia longiremis	30	166	2	10	823	387	270
Daphnia rosea						8	
Bosmina coregoni	95	191	1	8	622	231	218
Cladocera total	125	357	3	18	1445	626	488
Kellicotia longispina	229	658	62	126	300	239	516
Keratella cochlearis		1				4	1
Asplanchna priodonta	90	28	31	184	84	24	280
Conochilus unicornis	582	365			612	1	1140
Misc. rotifers	121	17		1	3	1	1
Rotifers total	1022	1069	93	311	999	269	1938
Total zooplankton	2742	3384	692	1100	7558	4064	4255

Table 9. Standing crop of zooplankton in lakes of the Naknek River system in 1962 and 1963 on similar dates (mean number per cubic meter for six sampling depths).

Lake	Date	Copepods	Cladocerans	Rotifers	Total
Brooks	7/3/62	4108	516	297	4921
(Station 1)	7/5/63	6066	616	1294	7976
	7/30/62	4054	854	440	5348
	7/29/63	5234	1086	360	6690
	9/9/62	3452	483	739	4674
	9/6/63	4131	586	277	4994
Naknek	7/5/62	4192	97	245	4534
(Station 3)	7/6/63	2030	113	243	2386
	8/5/62	2141	293	864	3298
	8/6/63	2876	374	411	3661
	9/7/62	1465	104	449	2018
	9/6/63	1830	621	165	2616
Coville	7/20/62	3945	507	3835	8287
(Station 12)	7/13/63	4378	1819	5965	12162
	8/20/62	5812	853	597	7262
	8/12/63	5004	2443	1232	8679
Grosvenor	7/19/62	4710	972	2166	7848
(Station 13)	7/13/63	7421	825	2060	10306
	8/21/62	2080	1797	218	4095
	8/12/63	5672	3368	3177	12217

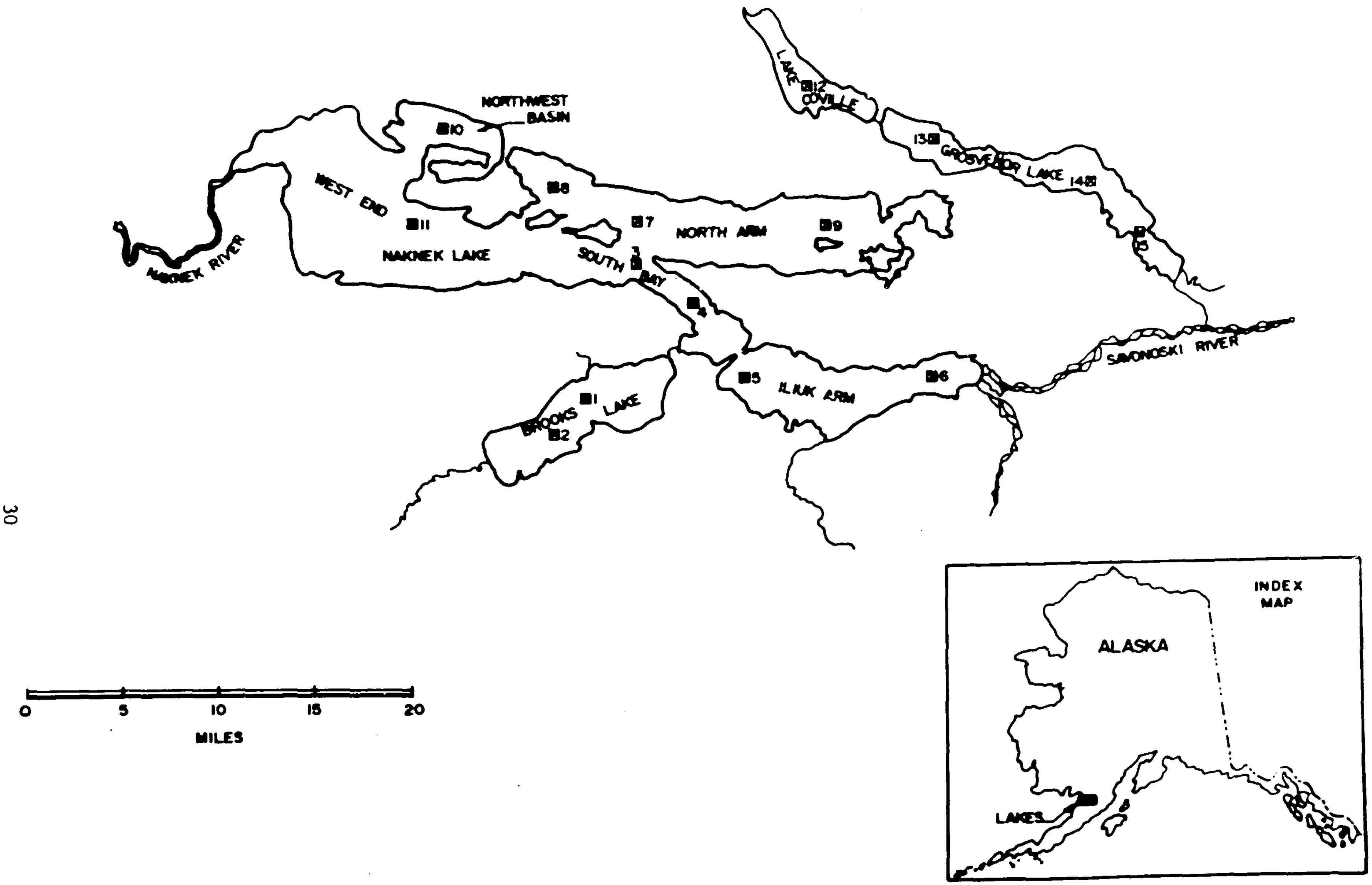

Figure 1. Lakes and lake basins of the Naknek River system in southwestern Alaska showing stations where zooplankton were sampled, 1962-63.

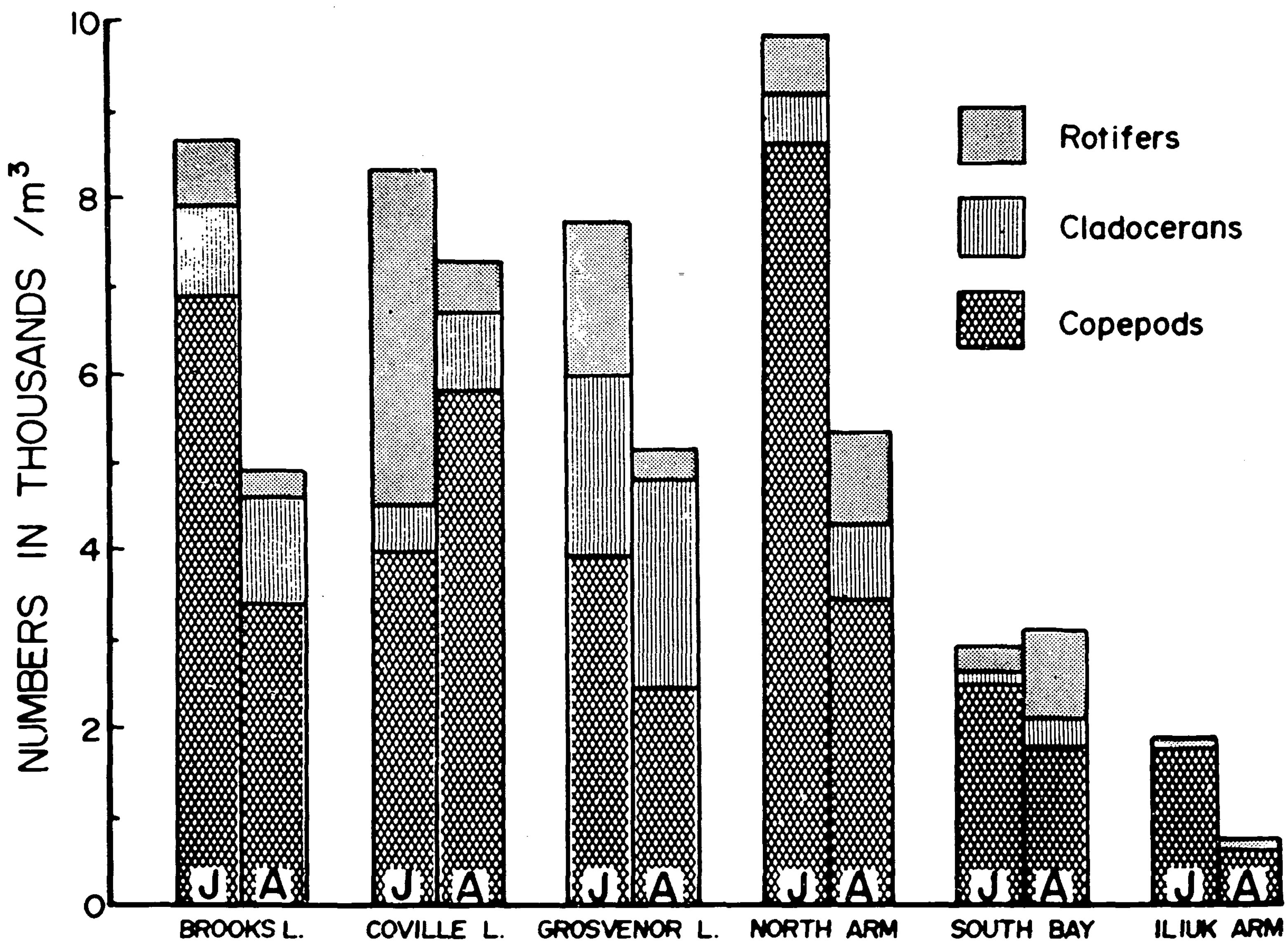

Figure 2. Standing crop of zooplankton in July and August 1952 in lakes and lake basins of the Naknek River system (mean number per cubic meter for six sampling depths).

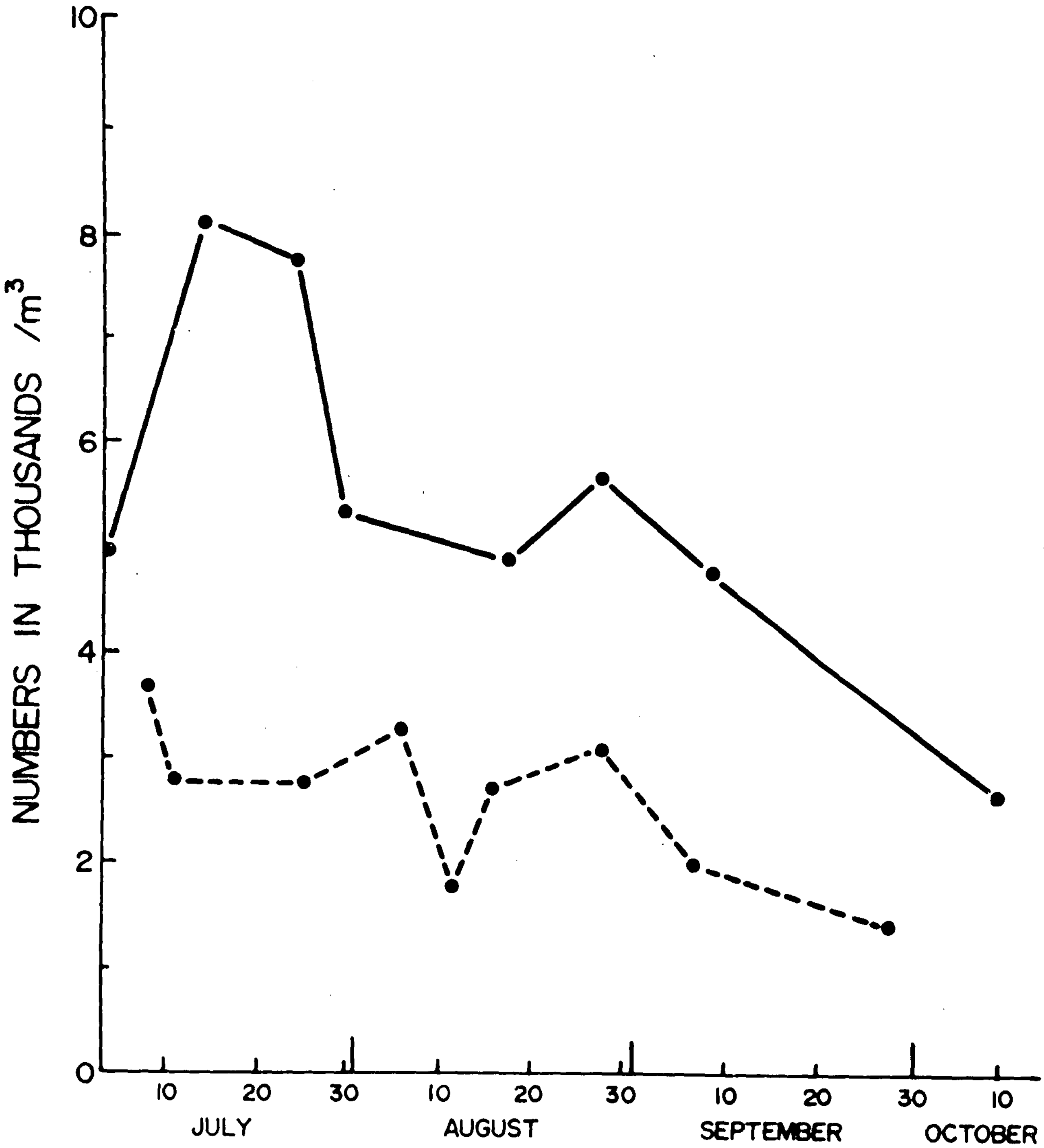

Figure 3. Standing crop of zooplankton during 1962 in Brooks Lake (——) and Naknek Lake (---) shown as mean number per cubic meter for six sampling depths.

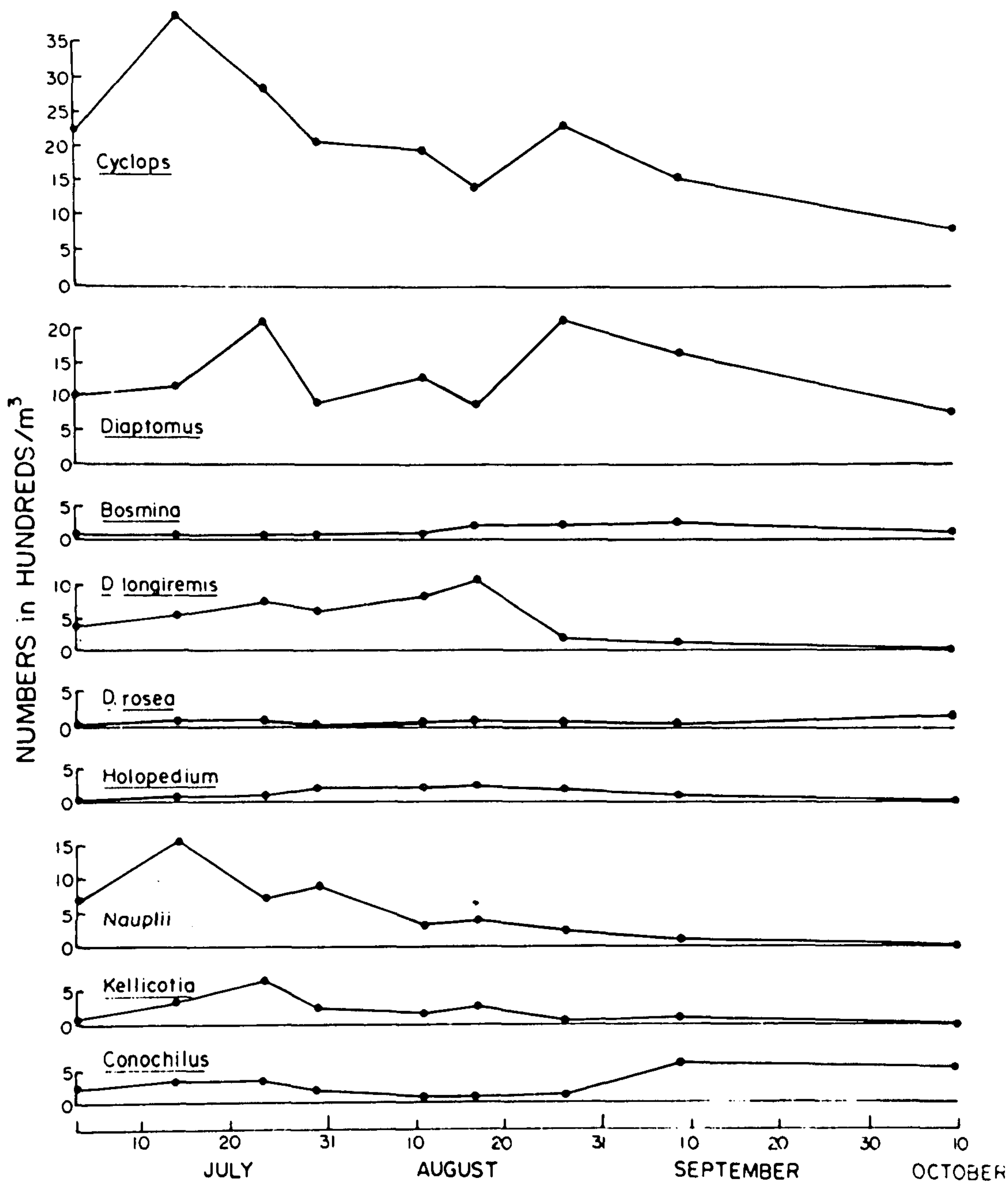

Figure 4. Seasonal changes of zooplankton in Brooks Lake during 1962 with all six sampling depths combined.

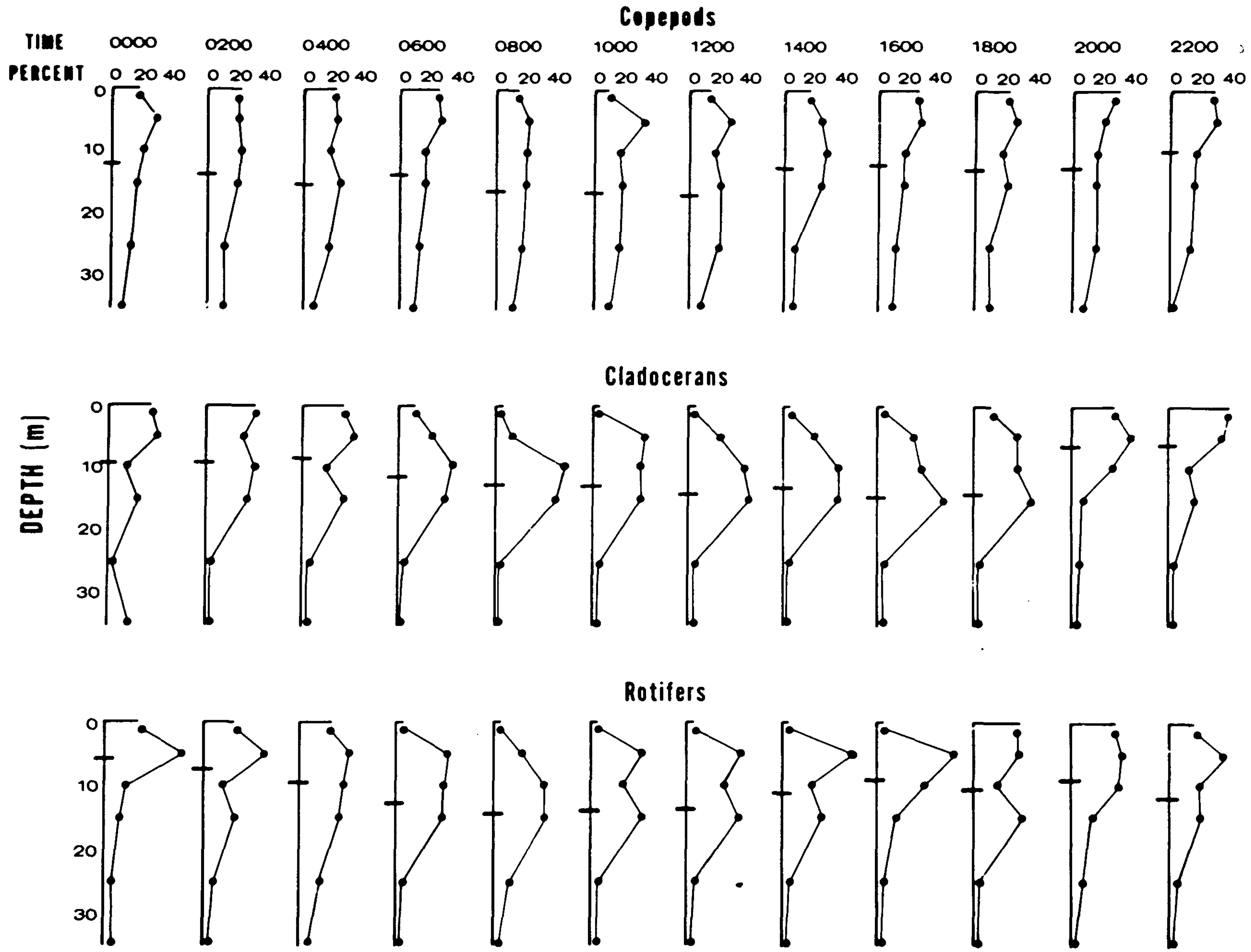

Figure 6. The diel depth distribution by percent of copepods, cladocerans, and rotifers in Brooks Lake on July 30, 1962.

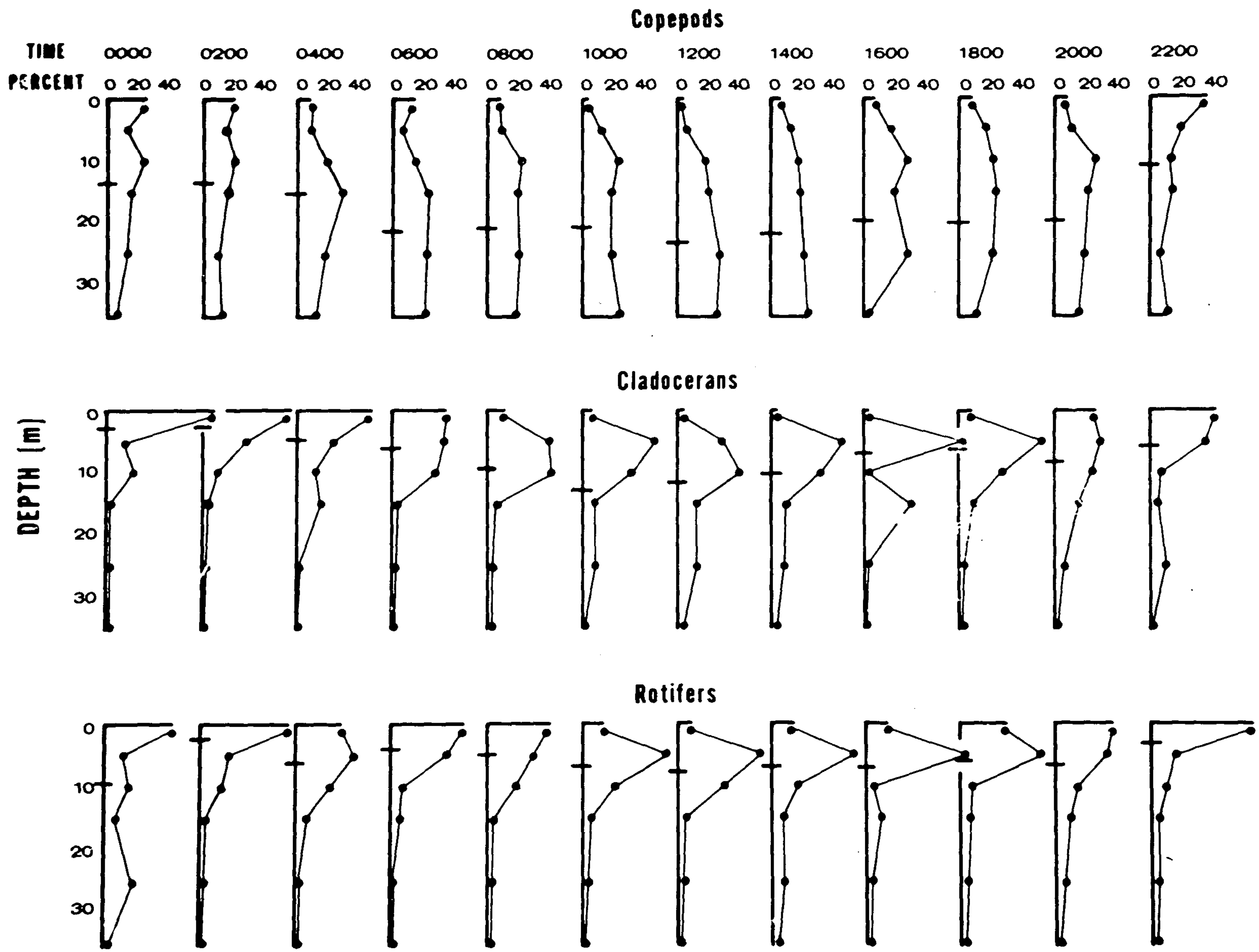

Figure 7. The diel depth distribution by percent of copepods, cladocerans, and rotifers in Naknek Lake on August 15, 1962.

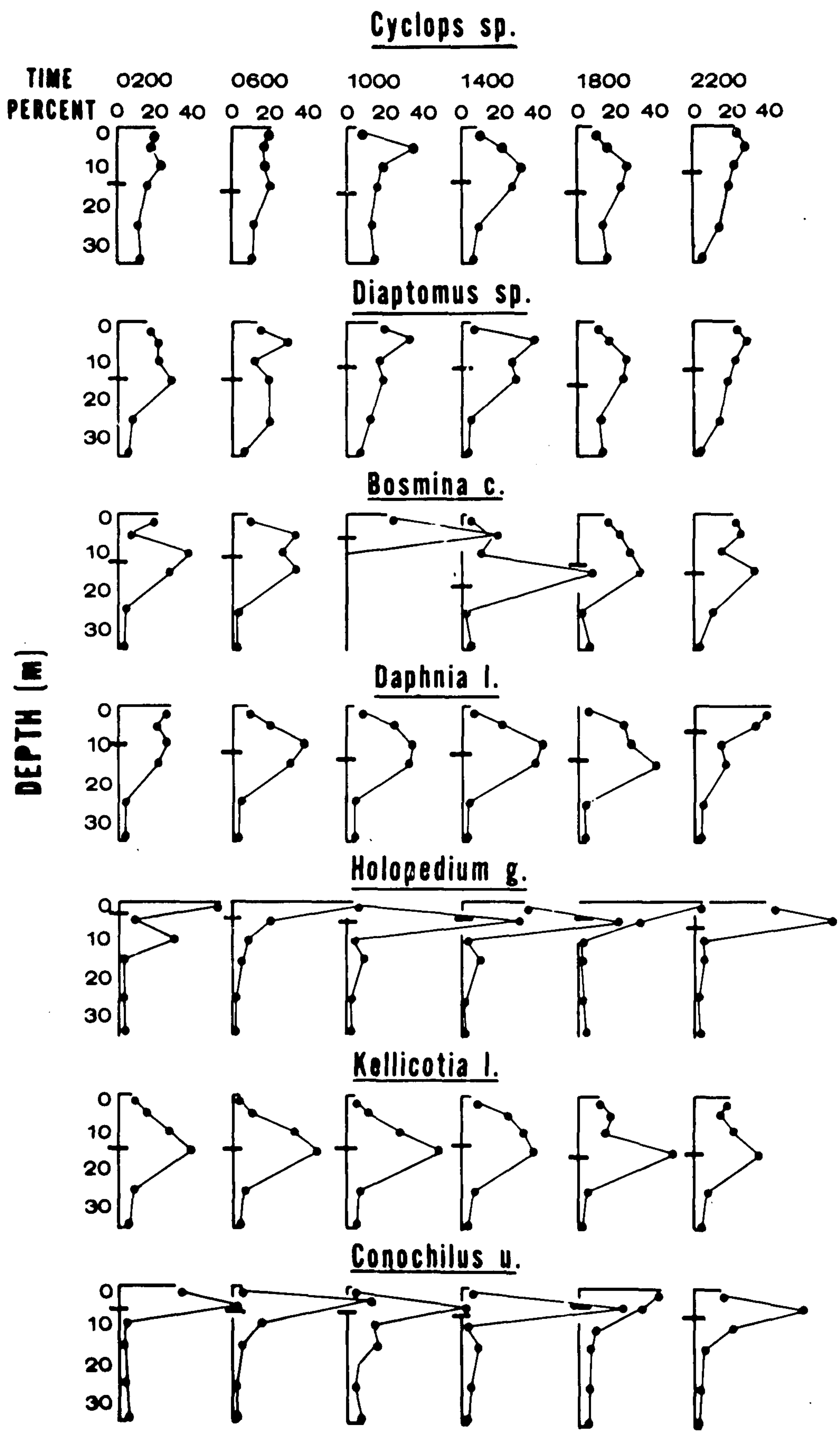

Figure 8. The diel depth distribution by percent of important species of zooplankton in Brooks Lake on July 30, 1962.