

Phytoplankton Fractionation Studies in Great Central Lake, British Columbia: A Nutrient- enriched Sockeye Salmon (*Oncorhynchus nerka*) Nursery Lake

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May 1979

PHYTOPLANKTON FRACTIONATION STUDIES IN
GREAT CENTRAL LAKE, BRITISH COLUMBIA: A NUTRIENT-ENRICHED
SOCKEYE SALMON (Oncorhynchus nerka) NURSERY LAKE

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ABSTRACT

Costella, A.C., K.S. Shortreed, and J.G. Stockner. 1979. Phytoplankton fractionation studies in Great Central Lake, British Columbia: a nutrient-enriched sockeye salmon (*Oncorhynchus nerka*) nursery lake. Fish. Mar. Serv. Tech. Rep. 880: 27 p.

Primary production, chlorophyll a and species composition of three phytoplankton size groups and of the total phytoplankton community were investigated from May to December, 1978, in an oligotrophic lake receiving weekly additions of nitrogen and phosphorus fertilizer. Considerable temporal variation occurred in the net plankton ($> 54 \mu\text{m}$) but nanoplankton ($3 - 54 \mu\text{m}$) and ultraplankton ($0.45 - 3 \mu\text{m}$) showed only moderate variation throughout the sampling period. The nanoplankton contained 63% of all epilimnetic chlorophyll a and assimilated 72% of the total carbon. The predominance of the nanoplankton is assumed to be a result of their greater ability to utilize the low concentrations of available nutrients. A four-day experiment was conducted to determine when each size fraction attained their maximum carbon uptake after a fertilizer application. The ultraplankton peaked on the first day after fertilization, nanoplankton on the second day and net plankton on the third day. By day 4, primary production in all size fractions had diminished markedly. Despite weekly additions of nitrogen and phosphorus fertilizer, Great Central Lake remained in an oligotrophic state and optimal conditions for growth of nanoplankton, the primary food source for zooplankton, were maintained.

Key words: primary production, chlorophyll a, species composition, ultraplankton, nanoplankton, net plankton, oligotrophic, fertilizer, zooplankton.

RÉSUMÉ

Costella, A.C., K.S. Shortreed, and J. G. Stockner. 1979. Phytoplankton fractionation studies in Great Central Lake, British Columbia: A nutrient-enriched sockeye salmon (*Oncorhynchus nerka*) nursery lake. Fish. Mar. Serv. Tech. Rep. 880: 27 p.

La productivité primaire, la chlorophylle a et la variété des espèces de trois classes de phytoplancton déterminées par la taille et de l'ensemble de la communauté phytoplanctonique ont été étudiées de mai à décembre 1978 dans un lac oligotrophe que recevait un apport hebdomadaire de fertilisant azoté et phosphoré. On a noté des variations temporelles considérables dans la classe du microplancton ($>54\mu$), mais le nanoplancton ($3-54\mu$) et l'ultra-

plancton (0.45 - 3 μ) n'ont présenté au cours de la période d'échantillonnage que des variations modérées. Le nanoplancton contenait 63 % de toute la chlorophylle a de l'épilimnion et assimilait 72 % de l'ensemble du carbone. La prédominance du nanoplancton semble être liée à sa plus grande aptitude à utiliser les éléments nutritifs présents en faible concentration. Une expérience de quatre jours a permis d'observer quand chaque absorbe son maximum de carbone après un déversement de fertilisant. L'ultraplancton atteint son maximum le jour qui suit le déversement, le nanoplancton le deuxième jour et le microplancton le troisième jour. Le quatrième jour, la productivité primaire des trois classes diminue nettement. Malgré des apports hebdomadaires de fertilisant azoté et phosphoré, le Grand lac Central est resté oligotrophe, et les conditions sont demeurées optimales pour la croissance du nanoplancton, qui est la principale source de nourriture du zooplancton.

Mots clés: productivité primaire, chlorophylle a, variété des espèces, ultraplancton, nanoplancton, microplancton, oligotrophe, fertilisant, zooplancton.

INTRODUCTION

Great Central Lake has undergone intensive study since the early 1970's when the lake was fertilized artificially for the first time (Parsons et al. 1972; Takahashi and Nash 1973; LeBrasseur et al. 1978). It was fertilized again as part of the Federal-Provincial Salmonid Enhancement Program in 1977 - 1978 (Stockner et al. unpublished data) in an effort to increase the numbers of anadromous sockeye salmon (*Oncorhynchus nerka*). In May, 1978, a program was initiated to determine the relative importance of several size groups of phytoplankton and to determine if the appropriate food sources for zooplankton were enhanced by the application of commercial fertilizer.

Many workers have studied the different size components of the phytoplankton using filter fractionation procedures (Gelin 1971; 1975; Kalff 1972; Berman 1975; Bothwell 1975) but little work has been done on the fractionation of phytoplankton in a nutrient-enriched oligotrophic lake.

This report describes results of a study conducted from May to December, 1978, to determine the importance of several size components of the phytoplankton and their response to nutrient enrichment in terms of rates of production, biomass (chlorophyll a), and species composition in the fertilized region of Great Central Lake. Problems associated with phytoplankton fractionation procedures are discussed (see Appendix).

DESCRIPTION OF STUDY AREA

Great Central Lake is located in the cool Mediterranean climate of Vancouver Island (49°22' N, 125°15' W) (Fig. 1). It is a large lake with a mean depth of 212 m, lake area of 45 km², drainage area of 308 km², and a residence time (the time required for the whole lake volume to replace itself) of 34 years (Duval and Murray 1976). There is extensive logging in the watershed, with some fishing, several cabins and one resort located on the lake. The station sampled was in the middle of the fertilized region of Great Central Lake (Fig. 2).

METHODS

A portion of Great Central Lake was fertilized once weekly with dissolved ammonium nitrate (NH_4NO_3) and ammonium phosphate ($(\text{NH}_4)_3\text{PO}_4$) in an atomic ratio of 10:1 (N:P), from April 19 to October 9, 1978, using a DC-6 (water bomber) aircraft. The specific surface loading of phosphorus (L_p) was calculated to be $225 \text{ mg P}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$ using Vollenweider's (1976) equation (Stockner et al. unpubl. data). Fertilization increased this load by 40%, resulting in a loading of 78% of the critical load (L_c) ($402 \text{ mg P}\cdot\text{m}^{-2}\cdot\text{y}^{-1}$) calculated for Great Central Lake. Great Central Lake was sampled on the day of fertilization or the day after from May to December, 1978. In August, 1978, the lake was sampled each day for four days after fertilization to determine when the maximum in production in each phytoplankton size group occurred relative to the day of fertilizer application.

Total incident solar radiation ($\text{joules}\cdot\text{cm}^{-2}$) was recorded on a Belfort pyrheliometer at the east end of the lake. Extinction of total surface light with depth was measured using a Montedoro-Whitney (Model LMT-8A) light meter, and photosynthetically available radiation (PAR: 400 - 700 nm) was measured with a Lambda Li-Cor Quantum/Radiometer/Photometer (Model Li-185A). Light data were plotted on a Hewlett-Packard Calculator Plotter (Model 9820A) as a function of depth, and the slope of the line regressed through the points gave the mean extinction coefficient (k). Compensation depth was calculated as the depth at which 1% of the surface light remained. A 30-cm white Secchi disc was used to measure water transparency.

Temperature profiles to a depth of 50 m were obtained with a bathythermograph (BT), and a YSI Tele-thermometer (Model 43TD) was used to measure surface temperatures for BT calibration.

Water samples were collected from the surface, 1, 2, 3, 5, 7.5, 10, 20 and 30 m with a 6-L polyvinylchloride Van Dorn water sampler. From 1, 3, 5 and 20 m, 250 mL were stored in dilute H_2SO_4 acid-rinsed polyethylene bottles and analyzed for total phosphate-phosphorus ($\text{TPO}_4\text{-P}$), nitrate-nitrogen ($\text{NO}_3\text{-N}$), reactive silicate ($\text{SiO}_4\text{-Si}$) and total alkalinity. Twenty-five mL of water were removed and filtered through an ashed Sartorius glass fiber filter into a clean screw-cap test tube for analysis of soluble reactive phosphorus (SRP). The nutrient samples were frozen until analysis at the Pacific Biological Station, Nanaimo, B.C. Methods for nutrient analysis were as described by Traversy (1971).

The standard ^{14}C method for measuring primary production was used as initially proposed by Steemann Nielsen (1952), with some modifications. Four light productivity bottles (125-mL Pyrex) were filled from each depth (2 for a total sample and 2 for a fractionated sample) plus 2 dark bottles from depths of 1, 5 and 20 m (1 for a total sample and 1 for a fractionated sample).

Each bottle was inoculated with 1 mL of sodium bicarbonate carbon-14 radioisotope stock (approximately $2 \mu\text{Ci}\cdot\text{mL}^{-1}$ or $74 \text{ kBq}\cdot\text{mL}^{-1}$), using an Oxford automatic pipet. The number of disintegrations per minute (dpm) was determined by inoculating three scintillation vials filled with 15 mL of a toluene-based fluor (Amersham Spectrafluor, 2-ethoxyethanol and toluene). Samples were incubated for 4 h in situ, normally from 0930 to 1330 h, and then retrieved. The samples for total carbon assimilation were filtered through 0.45- μm Sartorius cellulose-nitrate membrane filters and the filters placed in 15 mL of fluor. During the first part of the study (May to August), the fractionated samples were filtered sequentially through a 54- μm Nitex screen, a 3- μm and a 0.45- μm Sartorius filter, resulting in three size groups of phytoplankton ($> 54 \mu\text{m}$, 3 - 54 μm , and 0.45 - 3 μm). In October and December the fractionated samples were also filtered through a 25- μm Nitex screen, resulting in the 3 - 54 μm group being divided into 3 - 25 μm and 25 - 54 μm . Size groups were similar to those described by Wetzel (1975):

Size Group	Wetzel	Present Study
net (micro) plankton	50 - 500 μm	$> 54 \mu\text{m}$
nannoplankton	10 - 50 μm	3 - 54 μm
ultraplankton	0.5 - 10 μm	0.45 - 3 μm

After filtration, each filter or screen was placed in a scintillation vial with 15 mL of fluor, and all samples were analyzed for activity in a Packard Tri-Carb Liquid Scintillation Spectrometer (Model 3375). The equation of Strickland (1960) was used to convert counts per minute (cpm) to $\text{mg C}\cdot\text{m}^{-3}\cdot\text{h}^{-1}$. Primary production rates were integrated with depth using a Hewlett-Packard Calculator Plotter (Model 9820A) to give $\text{mg C}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$. Daily rates ($\text{mg C}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) were computed using data from the Belfort pyrheliometer.

Five samples were taken from each depth for phytoplankton counts (1 for total counts and 4 for the fractionated samples). The fractionated samples were filtered using the same filters as for primary production and the filtrate fixed with Lugol's solution. Phytoplankton samples were examined to assess species composition, predominance of major taxa, differences among fractionated samples and to determine filter efficiency. Phytoplankton were counted in 25-mL settling chambers under x175 and x700 magnification using a Wild M40 inverted plankton microscope (Utermöhl 1958). Volumes were estimated by equating phytoplankton cells to known geometric shapes and results were expressed as number and volume of cells $\cdot\text{m}^{-3}$.

Of the 400 mL of water taken from each depth for chlorophyll a determination, 200 mL were filtered onto a 0.45- μm Sartorius filter to determine total chlorophyll a. The remainder was filtered sequentially to determine the amount of chlorophyll a in each size group. Filters were frozen until analysis. Samples were soaked in the dark in 90% acetone at 4°C overnight and chlorophyll a determined using a Turner fluorometer (Model 111) and the SCOR-UNESCO equation (Strickland and Parsons 1968).

RESULTS

The mean seasonal values for extinction coefficient (k), Secchi depth, compensation depth and thermocline depth were 0.27, 10.4 m, 17.3 m and 13.5 m, respectively.

Epilimnetic values of total alkalinity remained relatively constant throughout the sampling period with a mean of $11.7 \text{ mg} \cdot \text{L}^{-1} \text{ CaCO}_3$. Mean epilimnetic silicate concentration was $667 \text{ } \mu\text{g Si} \cdot \text{L}^{-1}$, well above the limiting concentration for diatom growth (Wetzel 1975). Mean epilimnetic concentrations of SRP ranged from undetectable levels ($< 1.0 \text{ } \mu\text{g L}^{-1}$) to $2.3 \text{ } \mu\text{g L}^{-1}$. Details of seasonal variation of $\text{NO}_3\text{-N}$, $\text{TPO}_4\text{-P}$, SRP and $\text{SiO}_4\text{-Si}$ are reported in Stockner et al. (unpubl. data).

Total primary production was highest during May ($358 \text{ mg C} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$), decreased to a low in July of 174 and increased to a high in October of 283 (Fig. 3). The nanoplankton exhibited a similar trend and production of net and ultraplankton remained relatively constant throughout the sampling period. During the study, the summed production of all size fractions averaged 73% of the total production, and of that amount 12% was assimilated by the net plankton, 16% by the ultraplankton and 72% by the nanoplankton (Table 1, Fig. 4). In terms of production, the net plankton decreased in relative importance in summer, while ultraplankton increased. Nanoplankton were most important in May, decreased in June and July, but increased again from July to October (Fig. 5). Maximum production for both total and fractionated samples throughout the season occurred at a depth of 2 - 5 m (Fig. 4).

Mean epilimnetic values of total chlorophyll a ($\text{mg} \cdot \text{m}^{-3}$) exhibited a bimodal pattern with peaks in June and October (2.11 and $2.45 \text{ mg Chl a} \cdot \text{m}^{-3}$, respectively), with the lowest values in July ($0.60 \text{ mg Chl a} \cdot \text{m}^{-3}$) (Fig. 6). Little temporal variation was apparent in ultraplankton chlorophyll a, nanoplankton chlorophyll a varied to a somewhat greater degree, and net plankton chlorophyll a showed a bimodal trend. The mean recovery of epilimnetic chlorophyll a from sequential filtration was 78%; of that 6% was attributable to the ultraplankton, 63% to the nanoplankton and 31% to the net plankton. A hypolimnetic plate composed mainly of *Rhizosolenia* spp. at a depth of approximately 25 m resulted in high chlorophyll a values at the 20-m sampling depth. Of the total chlorophyll a recovered in the hypolimnion, 6% was attributable to the ultraplankton, 42% to the nanoplankton and 57% to the net plankton.

Size composition of algal cells changed both with depth and time. While the lake was stratified, phytoplankton in the 25 - 54- μm group were dominant in the epilimnion and decreased markedly below the thermocline. The net plankton remained low in the epilimnion but rose sharply at the 20-m sampling depth. In most samples the number of cells in the ultraplankton remained below 10%. The net plankton were dominant in May but declined through the summer and fall. By October, dominance had shifted to the nanoplankton

(Fig. 5). Diatoms, chrysophyceans and cyanophytes were the major phytoplankton groups in Great Central Lake. Details of the phytoplankton species composition and seasonal succession are discussed in Stockner et al. (unpubl. data).

The 54- μm Nitex screen was effective in removing most cells larger than 54- μm across their largest dimension. However, the 54- μm Nitex screen also removed a number of smaller cells in the filtering process, possibly from clogging of the screens by the larger cells. The 25- μm Nitex screen appeared quite effective in screening out cells $> 25 \mu\text{m}$ across their largest dimension, but removed some smaller cells as well. The 3- μm Sartorius filter was effective only on small sample volumes as it tended to clog rapidly. The 0.45- μm Sartorius filter retained almost all remaining detectable phytoplankton.

In summer, assimilation ratios ($\text{mg C}\cdot\text{mg Chl a}^{-1}\cdot\text{h}^{-1}$) varied among size groups and with depth. They were low at the surface, increased to a maximum at 2 m, and decreased steadily to zero at 20 m for all size groups (Table 2, Fig. 4). The ultraplankton had the highest assimilation ratio followed by the nanoplankton and net plankton with mean epilimnetic assimilation ratios of 2.73, 1.52 and 0.44, respectively. The total phytoplankton community had a mean assimilation ratio of 1.26.

During the four-day experiment following fertilizer application, total primary production was highest on the second day after fertilization ($35.3 \text{ mg C}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$). The ultraplankton production was highest on the first day after fertilization, nanoplankton production on the second day and net plankton on the third day. By the fourth day, primary production in all size groups had diminished markedly (Fig. 7).

DISCUSSION

As a result of the nitrogen and phosphorus fertilizer additions, phytoplankton production in Great Central Lake has increased measurably, although species composition has not changed and the lake remains in an oligotrophic state (Stockner et al. unpubl. data). From this study, it was possible to quantify differences in the relative importance of net and nanoplankton groups in Great Central Lake with respect to carbon assimilation, chlorophyll a, and species composition. Birge and Juday (1922) were the first workers to quantify the biomass of net and nanoplankton. They found in Wisconsin lakes that net plankton showed pronounced seasonal trends but nanoplankton did not. Gelin (1975) also showed that the biomass of nanoplankton exhibited less temporal variation than net plankton (a tenfold variation compared to a 25-fold variation in the net plankton). Our results substantiate these observations; ultraplankton and nanoplankton biomass exhibited only moderate variations compared with the net plankton biomass, which showed substantial temporal variation (eightfold and 42-fold, respectively).

The net plankton contributed approximately 31% of the total chlorophyll a in the epilimnion but their low assimilation ratios ($\text{mg C} \cdot \text{mg Chl a}^{-1} \cdot \text{h}^{-1}$) indicate that this group is photosynthetically inefficient. The small surface area to volume ratios of the large diatoms appear to affect their ability to utilize basic nutrients (Rodhe et al. 1958; Findenegg 1965; Lean 1976). Kalff (1972) also found this to be true in his studies on Lac Hertel, a small, naturally eutrophic lake in the St. Lawrence Valley. There, the net plankton in August produced approximately 40% of the biomass but only 15% of the production at 2 m. In our study, the nanoplankton and ultraplankton consistently had higher assimilation ratios than the net plankton. McCarthy et al. (1974) obtained similar results in the Chesapeake Bay estuary as did Gelin (1975) in Lake Vombsjon, Sweden. Gelin and Ripl (1978) also reported in the case of Lake Trummen, Sweden, that the low supply of available nutrients was an important factor in nanoplankton development.

Results of the four-day experiment indicated that immediately following the application of liquid fertilizer the concentration of soluble reactive phosphorus (SRP) at 2 m was seven times higher than before fertilization. Within one day SRP concentrations had returned to pre-fertilization concentrations (Stockner et al. unpubl. data). However, maxima in primary production for each size fraction did not occur concomitant with high SRP concentrations. The ultraplankton attained their maximum carbon uptake rate one day after fertilization, nanoplankton on the second day and net plankton on the third day. The delay between fertilization and maximum carbon uptake increased with increasing cell size and appears to be a function of a cell's efficiency at utilizing basic nutrients (Fig. 7).

The zooplankton biomass maximum in the fertilized region of Great Central Lake ($15.9 \text{ mg} \cdot \text{m}^{-3}$) in July coincided with low phytoplankton biomass, particularly in the nanoplankton (Rankin et al. unpubl. data). The apparent inverse relation is presumably owing to grazing pressure. Gelin (1975) also found in Lake Vombsjon that zooplankton biomass was inversely proportional to nanoplankton biomass and Gliwicz and Hillbricht-Ilkowska (1972) reported that nanoplankton are more effectively utilized as food by zooplankton in oligotrophic than in eutrophic lakes.

In summary, weekly applications of low concentrations of nitrogen and phosphorus fertilizer to Great Central Lake have retained the conditions necessary for the growth of nanoplankton, and zooplankton in an oligotrophic environment appear to prefer algae in the nanoplankton size group (Gliwicz and Hillbricht-Ilkowska 1972; Gelin and Ripl 1978). Therefore we conclude that fertilization of Great Central Lake thus far has been successful in enhancing the appropriate food sources for zooplankton. Rankin et al. (unpubl. data), have reported substantial increases in zooplankton biomass since the start of fertilization of Great Central Lake; these increases benefit our target organism--juvenile sockeye salmon.

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TABLE 1. Primary production ($\text{mg C}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$) during the sampling period.

DATE (1978)	SIZE FRACTION (μm)			TOTAL	PERCENT RECOVERY	
	.45-3	3-54	>54			
May 23	24.19	197.55	46.75	358.10	75%	
June 26	30.45	108.61	40.46	283.12	63%	
July 25	26.09	72.32	22.53	173.65	70%	
Aug. 28	33.93	117.05	13.83	213.41	77%	
	.45-3	3-25	25-54	>54	TOTAL	PERCENT RECOVERY
Oct. 16	23.94	156.67	1.65	29.08	282.70	75%

TABLE 2. Values of primary production, chlorophyll *a* and assimilation ratios of each size fraction (μm) on June 26.

DEPTH (m)	PRIMARY PRODUCTION $\text{mg C}\cdot\text{m}^{-3}\cdot\text{h}^{-1}$			CHLOROPHYLL <i>a</i> $\text{mg Chl } a\cdot\text{m}^{-3}$			ASSIMILATION RATIO $\text{mg C}\cdot\text{mg Chl } a^{-1}\cdot\text{h}^{-1}$					
	.45-3	3-54	>54	TOTAL	.45-3	3-54	>54	TOTAL	.45-3	3-54	>54	TOTAL
0	0.20	0.89	0.22	2.58	0.09	0.59	0.93	2.07	2.22	1.51	0.24	1.25
1	0.09	1.42	0.36	2.70	0.15	0.76	0.59	1.62	0.60	1.87	0.61	1.67
2	0.31	1.53	0.55	3.86	0.07	0.63	0.72	2.19	4.43	2.43	0.76	1.76
3	0.20	1.43	0.88	3.14	0.13	0.82	1.48	2.54	1.54	1.74	0.59	1.24
5	0.73	1.00	0.78	2.90	0.11	0.56	1.09	1.81	6.64	1.79	0.72	1.60
7.5	0.15	0.68	0.11	1.64	0.05	0.86	0.92	2.07	3.00	0.79	0.12	0.79
10	0.10	0.47	0.04	1.20	0.14	0.90	0.87	2.44	0.71	0.52	0.05	0.49
20	0	0	0	0.31	0.23	1.73	1.89	3.78	0	0	0	0.08

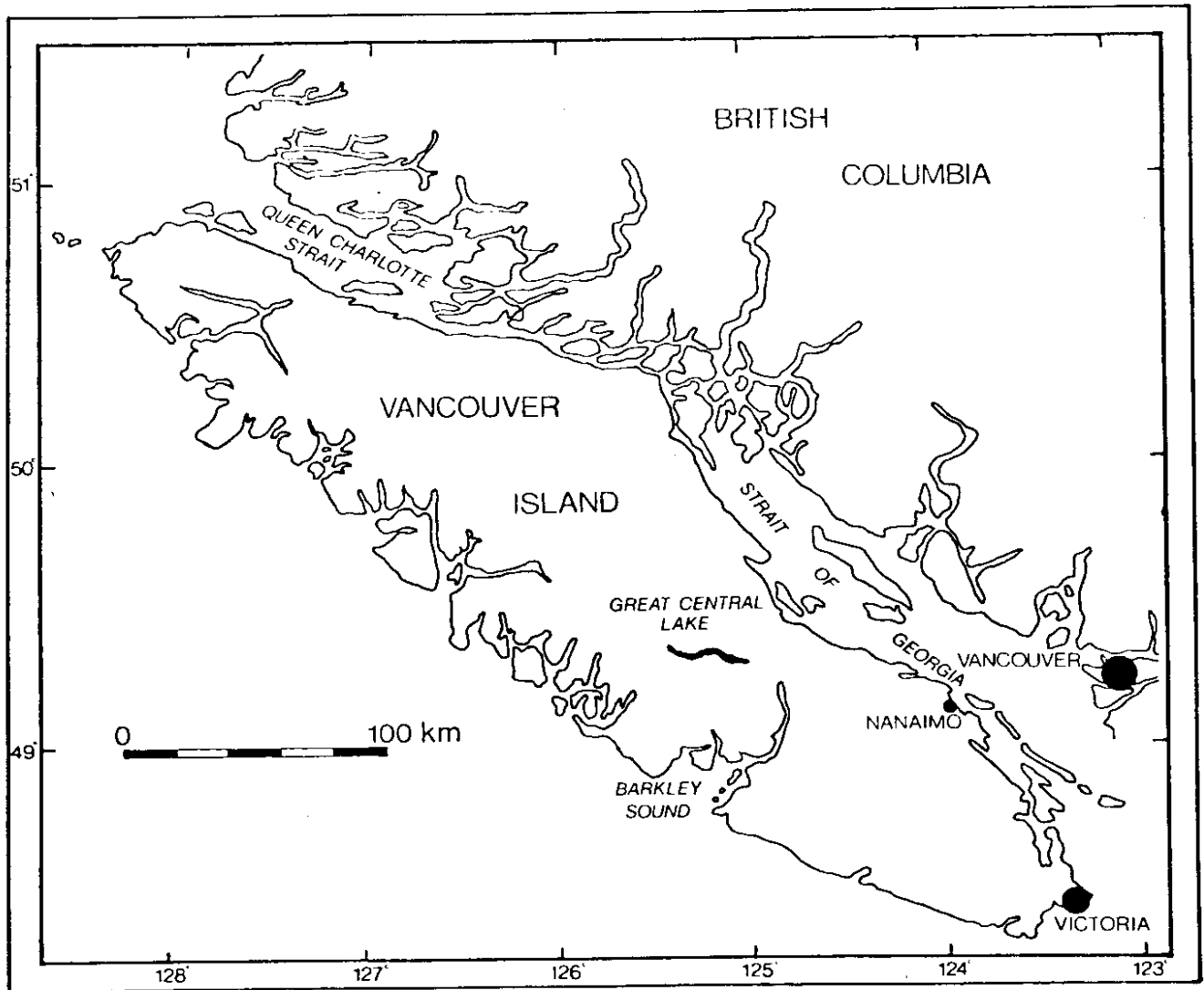


Fig. 1. Map of Vancouver Island showing location of Great Central Lake.

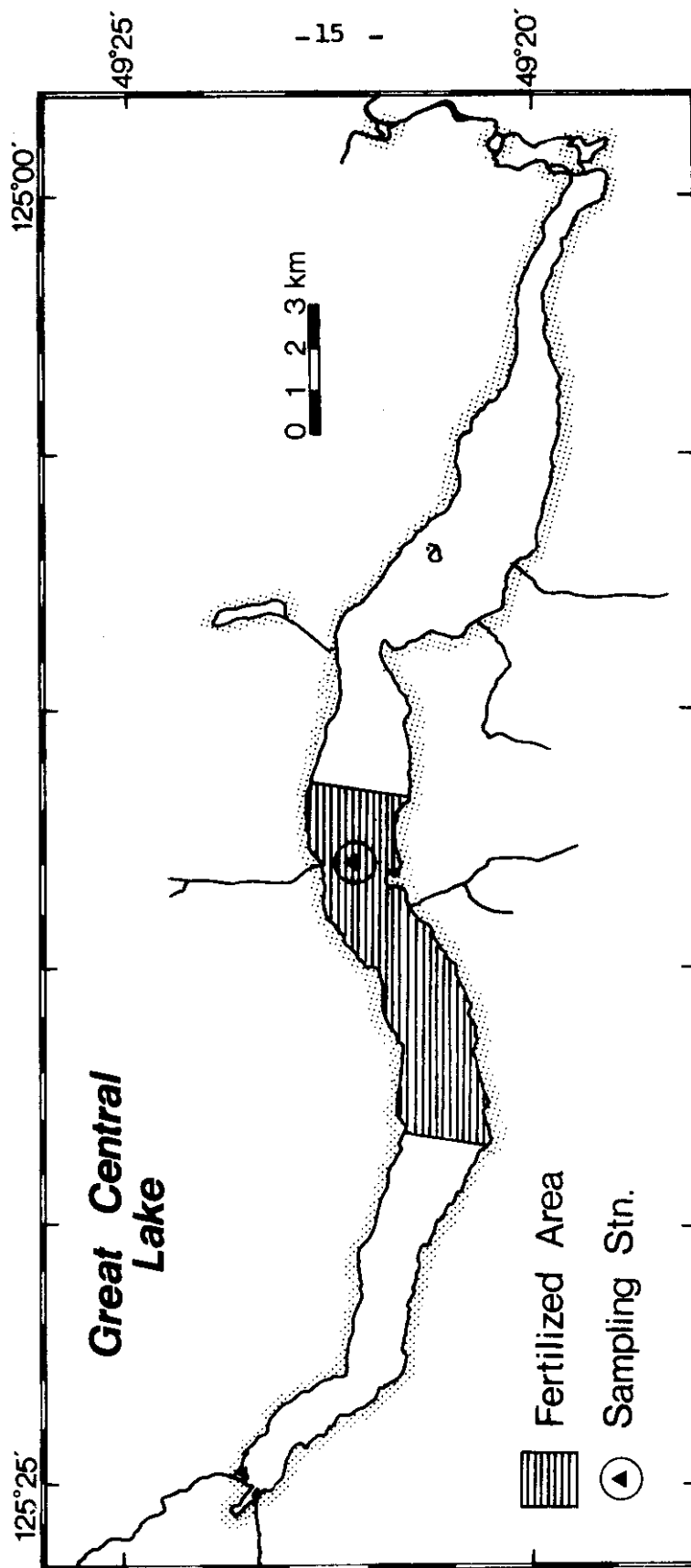


Fig. 2. Map of Great Central Lake showing location of fertilized region and sampling station.

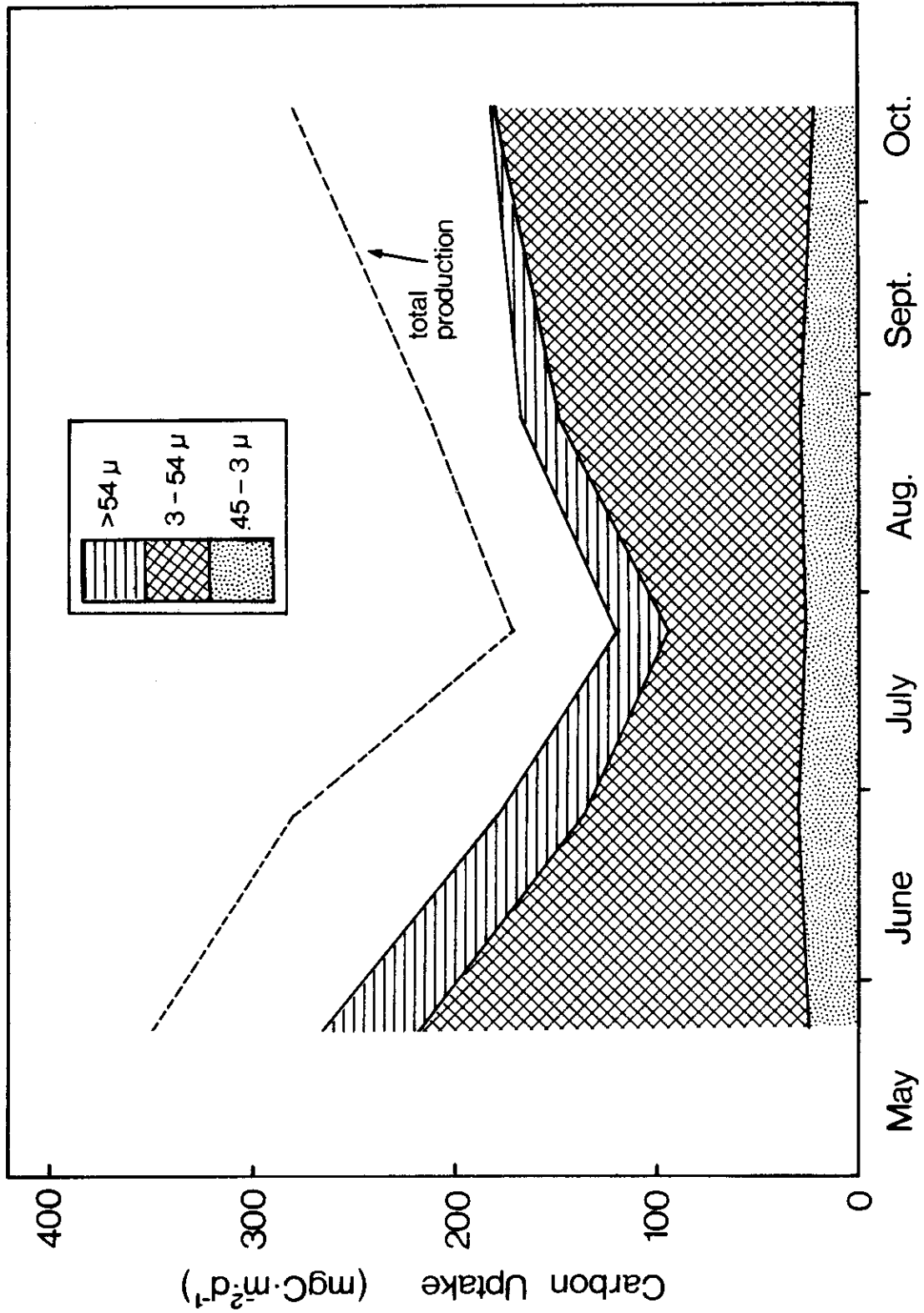


Fig. 3. Mean carbon uptake values ($\text{mg C} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$) of ultraplankton, nanoplankton and net plankton. Total production measured separately.

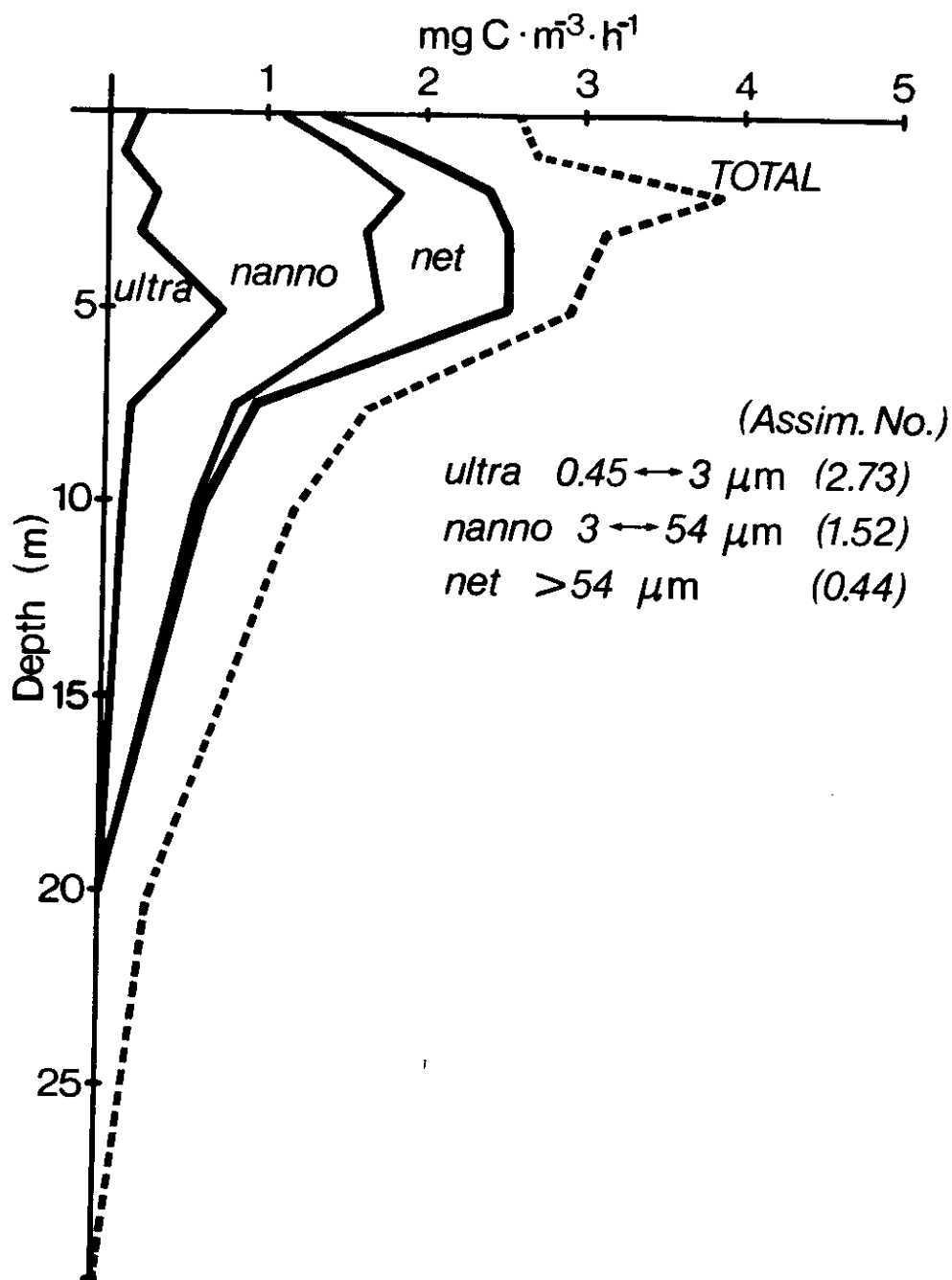


Fig. 4. Summer values of mean assimilation rates ($\text{mg C} \cdot \text{mg Chl a}^{-1} \cdot \text{h}^{-1}$) and depth profile of carbon uptake values ($\text{mg C} \cdot \text{m}^3 \cdot \text{h}^{-1}$) of ultraplankton, nanoplankton and net plankton. Total production was measured separately.

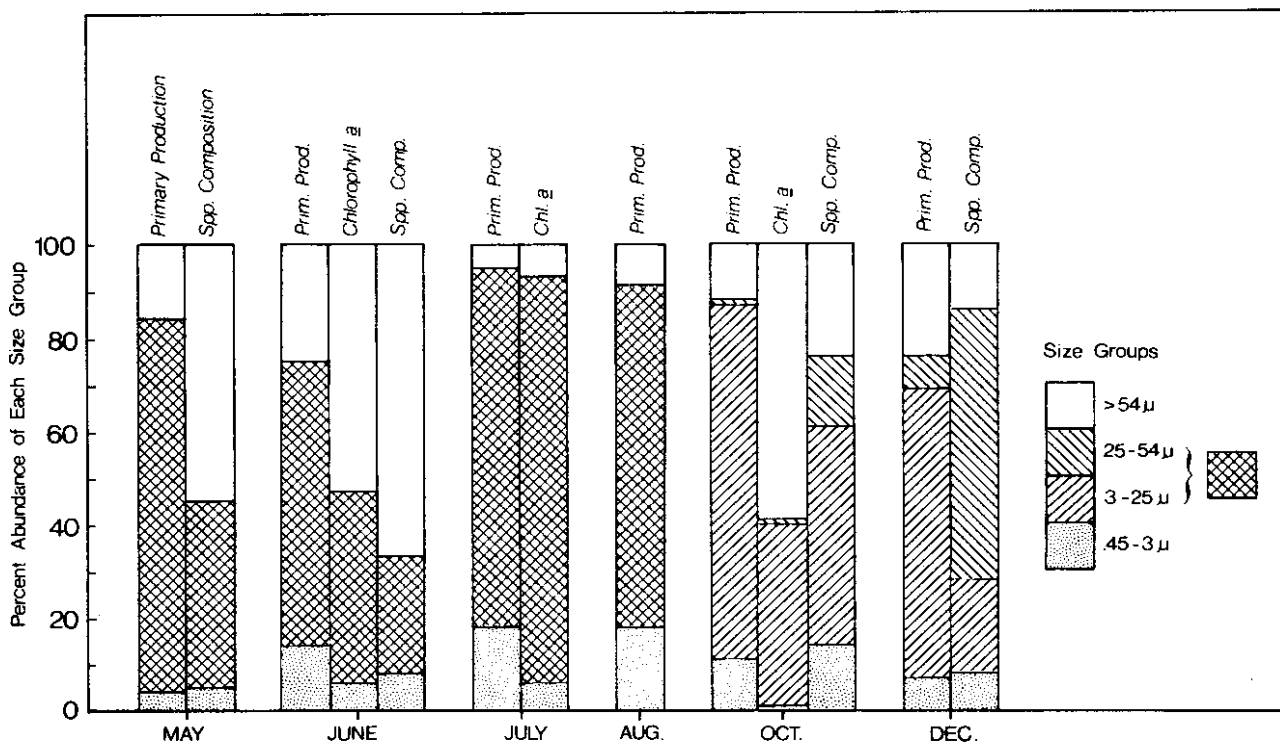


Fig. 5. Percent abundance of each size group with respect to mean epilimnetic values (0 - 10 m) of primary production ($\text{mg C}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$), chlorophyll a ($\text{mg}\cdot\text{m}^{-3}$), and species composition ($\text{no.}\cdot\text{m}^{-3}$).

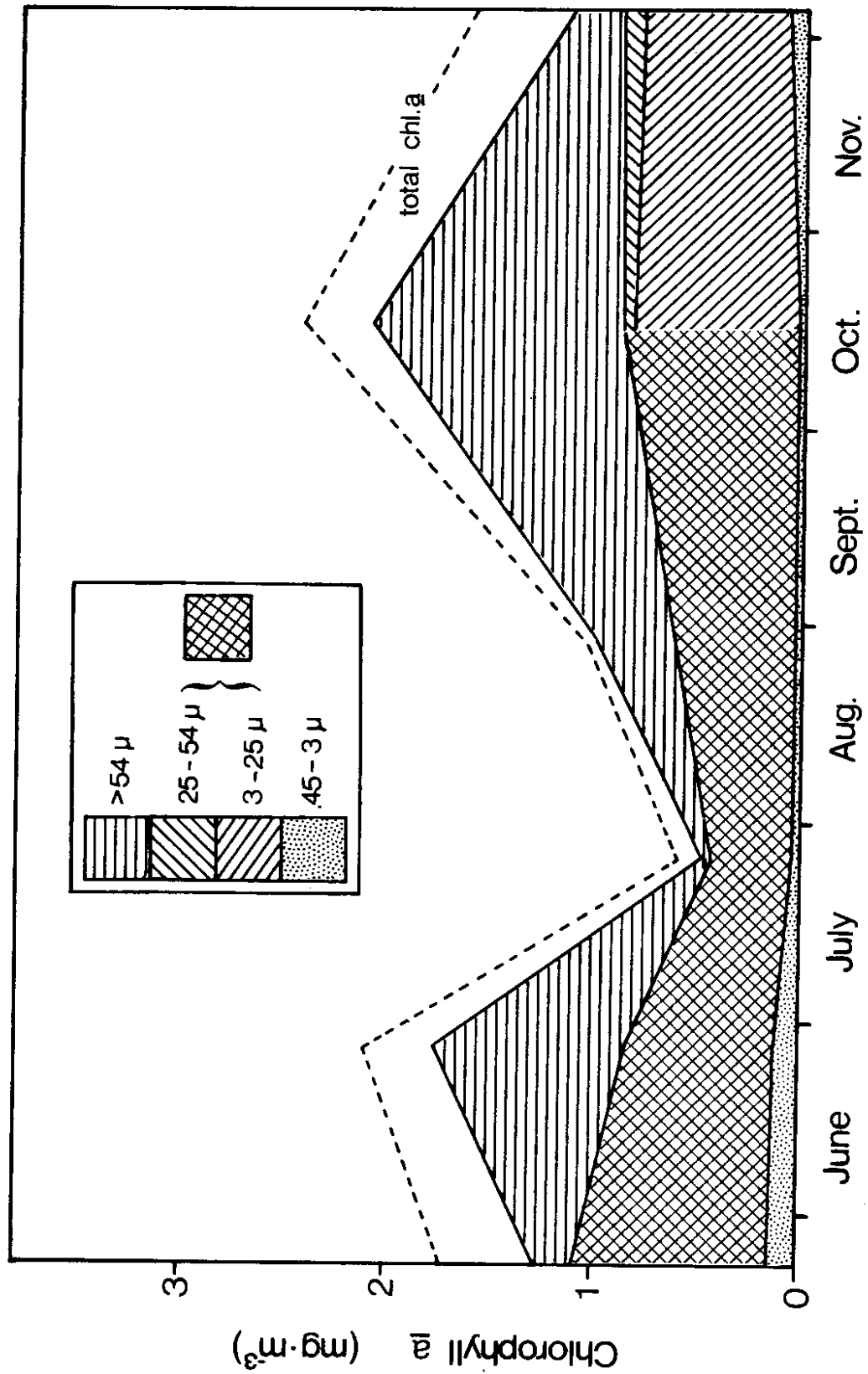


Fig. 6. Mean epilimnetic values (0 - 10 m) of chlorophyll a (mg·m⁻³) of ultraplankton, nanoplankton and net plankton. Total chlorophyll a measured separately.

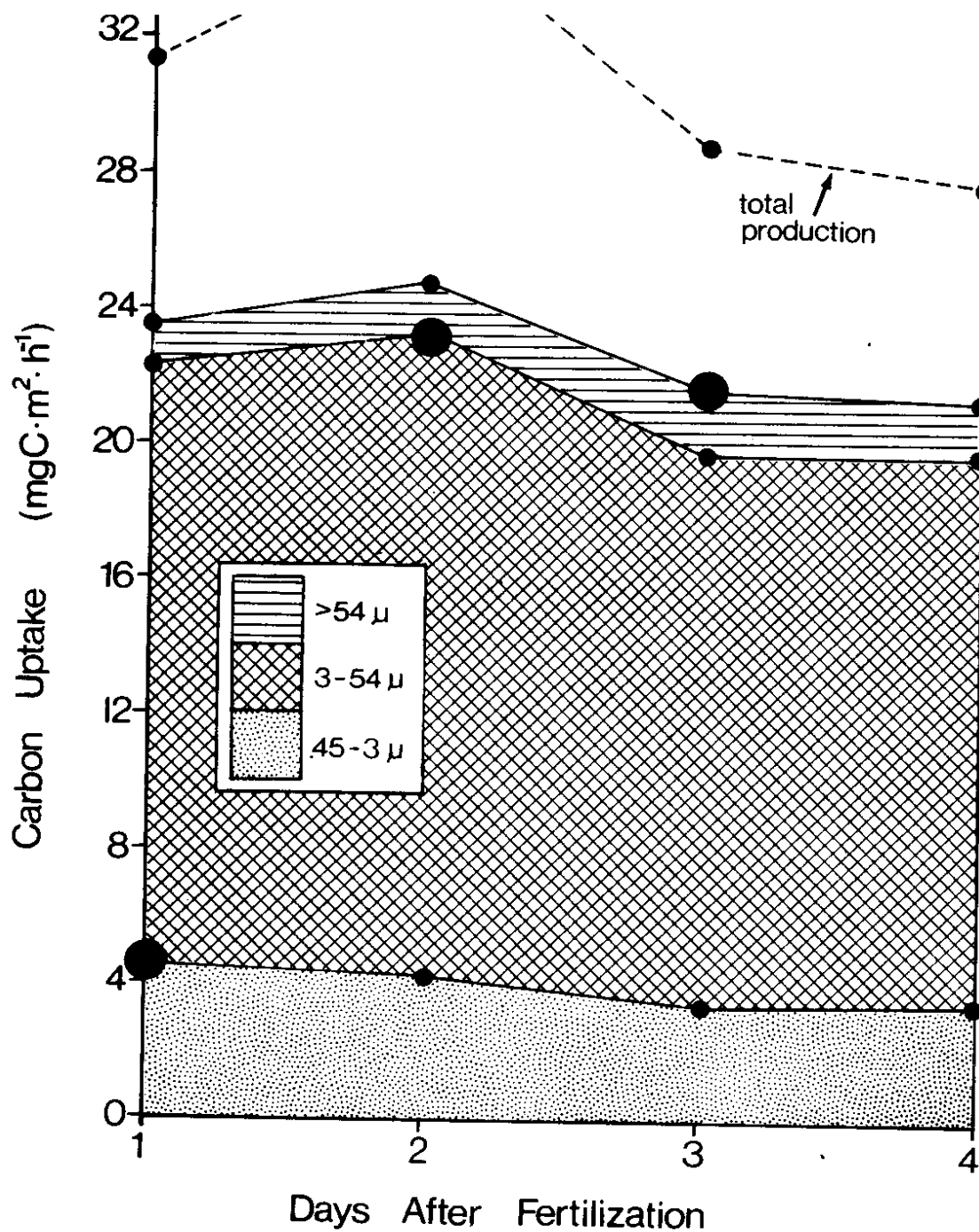


Fig. 7. Carbon uptake rates (mg C·m²·h⁻¹) of ultraplankton, nanoplankton, and net plankton on each of four consecutive days after fertilizer application. Total production measured separately. ● Denotes maximum carbon uptake rate attained.

APPENDIX

PROBLEMS ASSOCIATED WITH THE FRACTIONATION PROCEDURES

1. It is thought that some cells were damaged owing to their passage through the filters. Cell damage could be responsible for the discrepancy between the total production and chlorophyll a values measured separately and the summed values for the ultraplankton, nanoplankton, and net plankton. This could result in an underestimation of carbon uptake and chlorophyll a values.
2. Several phytoplankters can pass through a mesh with apertures smaller than the algal cells. The elasticity of some algal cells could result in overestimation of some of the smaller components of the phytoplankton (McCarthy et al. 1974).
3. Clogging of the Nitex screen or filters owing to heavy concentrations of cells in the sample may occur, as a result of larger cells blocking apertures, preventing smaller cells from passing. Hence the smaller size fractions may be underestimated.
4. When comparison is made of phytoplankton counts with primary production and chlorophyll a values it is important to use an identical technique for all fractionations. The phytoplankton samples passed through only one filter and the primary production and chlorophyll a samples passed through several; hence there could be a discrepancy in results owing to cell damage.
5. McCarthy et al. (1974) and Jackman and Lean (personal communication) recommend the use of 160- μm Nitex to screen out zooplankton before the commencement of fractionation as it is apparent that recently assimilated carbon can be lost due to zooplankton grazing. In Great Central Lake the low mean density of crustacean zooplankton ($9.5 \text{ animals}\cdot\text{L}^{-1}$) was such that pre-screening was unnecessary (Rankin et al. unpubl. data).