Primary production by various size classes of phytoplankton

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PRIMARY PRODUCTION BY VARIOUS SIZE CLASSES OF PHYTOPLANKTON IN LAKE GEORGE, N.Y.

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ABSTRACT

Primary production was measured using the ^{14}C carbon fixation method at four sites in Lake George, New York, an oligotrophic Adirondack region. Size fractionation was done subsequent to incubation to give fractions of >8, >5, >3, >1 and >0.4 μm. All samples tested had from 23-40% (mean 30.5% ± 8) of the net primary productivity in the < 3 μm fraction.

INTRODUCTION

The contribution of various size classes of phytoplankton to total primary productivity has been investigated by several groups. Studies in marine ecosystems have documented the importance of the smallest size fractions of phytoplankton (<3 μm) to total primary production (Holmes and Anderson, 1963; Derenbach and Williams, 1974; Berman, 1975; Durbin et al., 1975; and Johnson and Sieburth, 1979). Recent work by Tison and Wilde (1981) determined contributions of 15-40% to net primary productivity by plankton <3 μm in three South Carolina reservoirs. Paerl and Mackenzie (1977) found that 36-65% of the net productivity was due to this size class in an oligotrophic lake in New Zealand. This subject has not to our knowledge been addressed for natural lakes in the northeastern United States.

Planktonic organisms less than 3 μm in size have been referred to as ultraplankton, nannoplankton or picoplankton (Wetzel, 1975). This size class, which will be referred to here as ultraplankton, is difficult to identify and enumerate using routine light microscopic methods. Direct methods for measuring biomass, biovolume and cell counts may seriously underestimate the importance of the ultraplankton. Tison and Wilde (1981) using epiflorescence microscopy found that the ultraplankton comprised less than 5% of the total biovolume while contributing 15-40% of the total net primary productivity. In the present study the contribution of various size classes of phytoplankters to net primary production was determined for a number of sites in a natural lake in the northeastern U.S.

Lake George is a softwater, oligotrophic lake located in the southeastern corner of the Adirondack region of New York State (Fig. 1). The lake is 51 km long and 2.3 km wide with a mean storage volume of 2.1 km^3 (Colon, 1972). The lake is divided into two distinct basins, North and South, by an island-studied, narrow channel. Four sampling sites were chosen, two in the North Basin and two in the South Basin.

MATERIALS AND METHODS

Primary production measurements were made at each station (within a one week period) during the first week of July, 1980 using the ^{14}C light and dark bottle technique reviewed by Vollenweider (1974). Two light bottles and a dark bottle of 500 ml volumes were spiked with 20 µCi carrier free (^{14}C) $NaHCO_3$ (New England Nuclear Corporation, Boston, MA) and resuspended at the collection depths of 1 m or 6 m and incubated for 4h between 1000 and 1300h.

Filtration onto membrane filters (Nuclepore Corporation, Pleasanton, CA) was used to separate the size fractions. This technique has been shown to accurately separate particles of different sizes (Azam and Hodson, 1977; Sheldon, 1972) with little damage to cells (Tison and Wilde, 1981; Paerl and Mackenzie, 1977). One 80 ml aliquot from each bottle was filtered through one of the following nuclepore filters, 8, 5, 3, 1 and 0.4 µm so that fractions of >8, >5, >3, >1 and >0.4 µm were obtained and from these size classes were calculated.

Radioactivity on each filter was determined using a Beckman LS-133 liquid scintillation counter with external standardization used to correct for quench. Net production for each size fraction was then calculated. The difference in ^{14}C uptake between each consecutive size yielded the net productivity for the fraction of organisms in that size class.

RESULTS AND DISCUSSION

The means values for replicate samples for each size fraction are shown in Table 1. A two-way analysis of variance with size and location as variables demonstrated very highly significant differences ($P<.01$) in the amount of ^{14}C uptake between size classes and between locations. The interaction component for the two variables was also highly significant ($.005 < p > .01$). The variation in net productivity between sites was partly due to the much higher rate of carbon fixation at Warner Bay. This is very likely due to the higher nutrient concentrations which have been found in this bay, particularly in comparison to the northern stations.

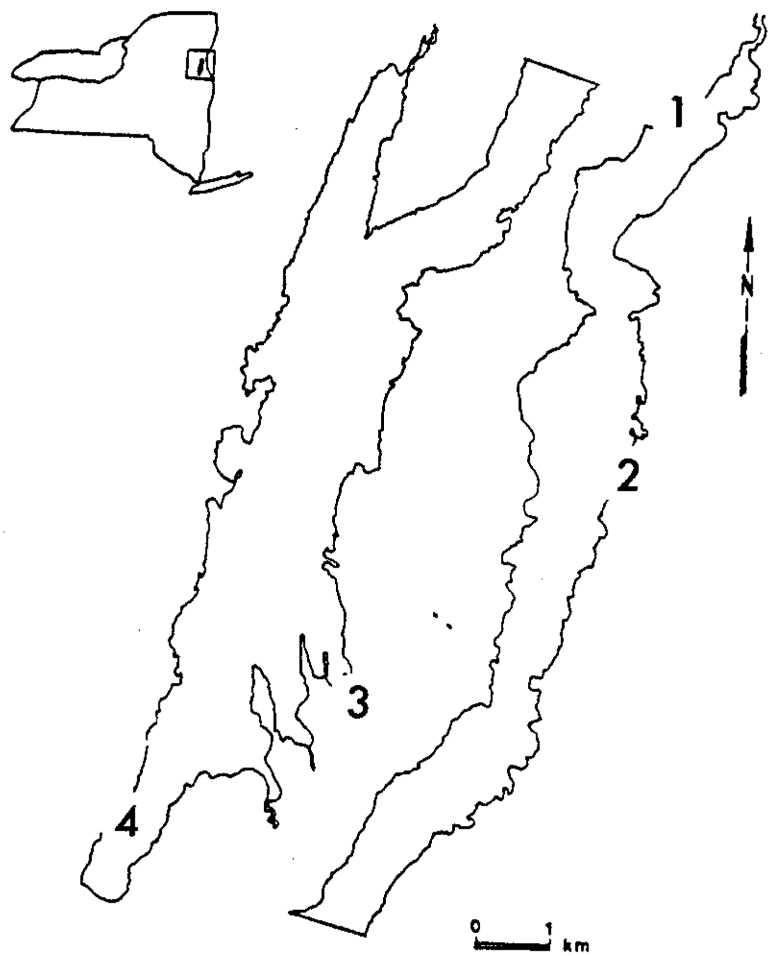

Figure 1. Map of sampling sites on Lake George.
1 - Hearts Bay
2 - Smith Bay
3 - Warner Bay
4 - Tea Island

Table 1

Net Primary Productivity (μg Carbon Fixed l^{-1} h^{-1}) by each Size Fraction

Site	Sample Depth	Date	Size Fractions (µm) >8	8>5	5>3	3>1	1>0.4
Smith Bay	1 M	7/14/80	0.59[a]	0.13	0.27	0.08	0.22
Warner Bay	1 M	7/15/80	3.92	0.26	1.02	1.56	0.74
Tea Island	6 M	7/15/80	1.11	0.38	0.02	0.35	0.54
Hearts Bay	1 M	7/16/80	0.31	0.10	0.06	0.13	0.11

[a]mean of duplicate samples.

The net primary productivity expressed as μg C fixed l^{-1} h^{-1} for each size class was transformed by dividing the productivity of a size class by the total net productivity on the 0.4 µm filter to produce a proportion of carbon fixation for each size fraction. This permits comparison between sites without considering differences brought about by variations in total productivity between stations.

A one way analysis of variance was performed on each size class and in all cases but one, no significant differences in percent productivity were found between locations for each size fraction. The one exception was the size fraction 3 < 5 µm which approached significance ($.05 < p > .10$) in the difference in percent production between sampling sites.

Since the percent contributions to net primary productivity from each size class were not found to vary between locales, they were lumped and confidence limits for their means were determined (Table 2).

Table 2

Mean Percent Net Primary Productivity for all Sampling Sites

with 95% Confidence Limits (n = 8 for each size class).

Size Fraction (µm)	Mean % Primary Productivity
> 8	48.2 ± 8.3
8 > 5	11.3 ± 6.6
5 > 3	11.2 ± 7.4
3 > 1	14.2 ± 8.0
1 > 0.4	16.4 ± 10.5
< 3	30.5 ± 8.0

The proportional contribution by each size class to net primary production at each site are seen in Table 3.

Table 3

Percent Contribution of each Size Fraction to Net

Primary Productivity at each Site

Size Class (μm)	Hearts Bay	Smith Bay	Warner Bay	Tea Island
> 8	42.6[a]	46.4	55.2	48.7
8 > 5	9.6	9.9	3.3	16.9
5 > 3	10.9	20.9	12.9	0.5
3 > 1	14.2	6.0	23.0	13.4
1 > 0.4	22.6	16.9	5.5	20.5

[a]Each value is the mean of the two replicates.

Although there were no statistically significant differences in percent primary productivity contributed by the same size class from different locales, the data set was small and additional sampling may tend to bring about significant levels of variation. Several factors extrinsic to the experimental design such as differences in water clarity, species composition, sample depth, and nutrient availability undoubtedly affected the results but were not quantified. Nonetheless, several conclusions are suggested by these results.

At four sites on Lake George, New York the size fraction of phytoplankton <3 μm contributed 23-40% (mean = 30.5% ± 8) of the total net productivity. This group obviously plays an important role as primary producers in freshwater systems. Because this size class is difficult to quantify or classify using routine light microscope techniques, they may have been ignored or at least understudied in the past. Indirect methods such as ^{14}C primary productivity measurements, chlorophyll a analysis or ATP biomass determinations incorporate all size classes and mask the contributions by particular components. This can lead to confusion when analysing data such as ^{14}C primary productivity. As discussed by Paerl and Mackenzie (1977) diurnal variations in rates of production by different size classes, with the smallest fraction having the highest rate earlier in the day, can cause a shift in plankton community structure to be interpreted as a change in overall plankton primary production. Conversely, an increase in the population of the smallest organisms may be missed in analyses of production rates, as determined by the ^{14}C fixation techniques, if measurements were only taken during the afternoon hours.

These considerations involving diurnal patterns of productivity, along with seasonal dynamics of the smaller size class, call for further investigation.

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