PHYTOPLANKTON STUDY OF RARITAN BAY

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INTRODUCTION

Abnormally low concentrations of oxygen, especially at certain times of the year, have been noted repeatedly in the western reaches of Raritan Bay. Such low concentrations of oxygen, besides indicating and undesirable degree of pollution, are certain to have a deleterious effect on fish and other aquatic animals of the bay (Hynes, 1960). A thorough understanding of oxygen levels in the bay requires not only an extensive sampling program to determine the actual levels of oxygen from day to day, but also an equally detailed study of oxygen consumption and production in this water (Westlake, 1959; Wheatland, 1959; Gameson, 1959). Such a comprehensive study was conducted by the Interstate Sanitation Commission from June to October, 1963. The results of this survey have not yet been fully analysed, but it seems worthwhile to give a preliminary report on one part of the total program -- a study of phytoplankton in Raritan Bay.

Since the bay is lacking in submerged vegetation, oxygen production is entirely due to microscopic plants (algae) floating in the water, and referred to collectively as phytoplankton. It was the purpose of the phytoplankton part of this survey to determine the quantity and type of

phytoplankton present. Once this information is had, it is then possible to correlate phytoplankton abundance with oxygen levels, and see how the growth (or senescence) of phytoplankton influences the abundance (or depletion) of oxygen. This relationship will be presented in a later report. But further experimental work would be required to understand the factors which are responsible for the number and types of phytoplankton present.

METHODS

Field

Water samples were collected at two points in the bay, the Victory Bridge and the Pennsylvania R. R. Coal Dock. Samples were collected Monday through Friday at both stations as follows: from a depth of one foot at 9:30 A.M. and 1:30 P.M.; from a depth of five feet at 9:30 A.M., 11:30 A.M., and 1:30 P.M. Samples were kept cool in transit to the laboratory, where they arrived at about 4:00 P.M.

Laboratory

Upon arrival, 40 ml of each sample were preserved with 2 ml of formalin for subsequent counting. Unpreserved samples were regularly studied to aid in identification of organisms and to detect delicate flagellates which would not withstanc fixation. The presence of chlorophyll in

the smallest forms was confirmed with fluorescence microscopy (Young, 1961; Wood, 1962).

Counts of the smallest and most abundant phytoplanktonts were made using unconcentrated samples. Where more accurate counts of larger and less abundant phytoplanktonts were desired, preserved samples were concentrated by passage through a 0.30 or 0.45 μ pore membrane filter (Gelman or Millipore), or by centrifugation for 15 minutes at 3000 r.p.m. (Ballantine, 1953). At the beginning of the study some samples were concentrated following the Sedgwick-Rafter sand filtration method with applied suction of 2 p.s.i. (Amer. Public Health Assoc., 1960).

Plankton counts were made by placing 0.1 ml of sample or concentrate in a Palmer nannoplankton cell (A. H. Thomas Co., Philadelphia) which has a cell depth of 0.4 mm. Field counts were made using a 44X objective and 12.5Xocular containing a Whipple-Hausser eyepiece micrometer. Strip counts were made using the 44X objective and the 10X objective. Units counted represent individual cells except in the case of the smallest form (Nannochloris) where counts represent two- or four-celled groups.

Counts were also made with an electronic particle counter (Coulter Electronics, Hialeah, Fla.; Model B). This is a later and more versatile model than the one used by Hastings et al. (1962). Particles were counted in three size categories: 25 to 125 μ^3; 125 to 500 μ^3; and

500 to 8000 μ^3. The orifice used had a diameter of 100 μ, and the volume of the individual samples counted was 0.5 ml.

RESULTS

Phytoplankton

The phytoplanktonic flora was found to be very rich in number of individuals (and total biomass) but correspondingly poor in species. The flora was overwhelmingly dominated by one small pale green alga, Nannochloris atomus Butcher (1952), which occurred mostly in two- and four-celled groups. The size variation in our samples

was somewhat greater than that described by Butcher, and our sample may have included N. maculatus Butcher. If so, both species were counted together because of their similar appearance. Their number varied from an average high of 822, 000 units per ml. (10 samples, July 7, 1963) to an average low of 161,000 units per ml. (10 samples, Oct. 25, 1963). A number of individual samples in early July had counts of 900,000 per ml or higher. And from the trend seen in October it is expected that even lower counts will be found later in the year. As can be seen from figure 1, the numbers of Nannochloris exhibit considerable cyclic fluctuation, but there is also visible a general trend of diminution from the high in early July to a low at the end of the sampling peried in October. This trend parallels in general the decline of oxygen concentration. A more detailed study of the correlation between oxygen levels and phytoplankton abundance is in preparation.

The other phytoplanktonts present can be grouped into two size categories. The smaller size, generally from 5 to 7 μ (occasionally to 10 μ, rarely to 15 μ) consisted of chlorophyceae, bacillariophyceae, and chrysophyceae,

with perhaps some xanthophyceae. Practically all the cells were solitary. There were very few motile forms, mostly some chlamydomonads. Especially rare were delicate small flagellates studied by Parke et al. (1955-1962) and abundant in some other localities. At some times an unidentified loricate chrysophycean reached densities greater than 10,000 cells per ml, but no motility was ever observed. The total number of individuals in this intermediate size category showed great variation with changes in tide, varying from less that 1,000 to more than 10,000 per ml. They seemed to be most abundant in the Raritan river above Victory Bridge. In numbers and in total biomass they did not equal the Nannochloris.

The largest size category includes all cells above 15 μ; but there were very few cells with bodies (exclusive of processes) larger than 30 μ. The category consisted of diatoms, dinoflagellates, and euglenoids. The number of individuals has not been accurately determined for all samples, but was generally less than 100 per ml. During the first week of the study, June 3 to 7, 1963, they averaged 10 cells per ml and consisted almost exclusively of pennate diatoms. Thus, despite the large size of the

cells, their total biomass was considerably less than the combined bulk of the smaller phytoplankton.

Seston

There was an abundance of particulate matter in all size categories. Particles from 500 to 8000 μ^3 numbered generally from 1000 to 3000 per ml. This was chiefly debris and detritus with few cells, and was subject to sharp increase in certain samples as a result of temporary local conditions which stirred up debris from the bottom or added it from the air. On such occasions counts reached more than 10,000 per ml, but subsided to normal levels within two hours. Particles from 125 to 500 μ^3 numbered generally 5,000 to 20,000 per ml, including both debris and phytoplankton (cells and cell groups). Numbers sometimes reached 50,000 per ml due to sudden increase of debris. Particles from 25 to 125 μ^3 numbered generally from 200,000 to 50,000 per ml, and although including some debris consisted mostly of phytoplankton, especially the larger four-cell groups of Nannochloris. Counts in this volume range were relatively insensitive to wide

fluctuations of debris in the larger size categories, and as can be seen in figure 1, the counts showed a general although not perfect correlation with optical counts of Nannochloris.

Procedures in Concentration and Counting

Plankton larger than 15 μ can be concentrated by Sedgwick-Rafter filtration, but smaller cells pass for the most part through the filter, depending on the size of the cells or cell aggregates, the degree of clogging of the filter by cells and debris, and the amount of suction applied. Using a suction of 2 p.s.i. there was about 50% retention of particles in the 5 to 10 μ range and less than 10% below the 5 μ size. Even with no suction applied the bulk of the smallest cells passes through the filter. A similar loss occurs in using a 10 μ pore membrane filter. Subsequent counts on such selectively concentrated samples are liable to give a misleading picture of the total phytoplankton, especially in water rich in small nannoplankton. Conveniently, such water often requires no concentration before counting.

Small cells can be quantitatively concentrated by using a smaller pore filter. A 5 μ pore filter will

retain most of the nannoplankton and a 2 μ pore filter practically all. But an even smaller pore size (0.30 or 0.45 μ) is recommended in oreder to retain the plankton on the surface of the filter where it can be more easily removed and resuspended. But with Raritan Bay water, so rich in nannoplankton and detritus, the filter is quickly clogged, and filtration of much more than 100 ml can be prohibitively time consuming. Using a syringe assembly for concentration and a Palmer cell for counting, it is possible to work with small samples (10 ml). The method is fast, simple, fully portable, requires no power source (except a thumb of ordinary strength), and is thus adaptable to field prodecures.

Centrifugation at 3000 r.p.m. for 15 minutes will completely settly out (preserved) cells of the two larger size groups (down to about 5 μ) and most but not all of the smallest size group (Nannochloris).

In making counts, it is imperative to use sufficient magnification (Palmer, 1959). At 100X cells like Nannochloris can hardly be distinguished from dust and detritus. Using a 20X objective and 10X ocular Williams' group (Williams and Scott, 1962; Williams, 1963) was

able to count forms as small as 4 μ in a Sedgwick-Rafter slide. Thus it might be possible to count two- or four-celled groups of Nannochloris at 200X, but higher magnification is desirable. At 550X cells down to about 1 or 2 μ could be clearly discerned. The Sedgwick-Rafter slide is too thick to permit the use of the 44X objective, but the commercially available Palmer nannoplankton cell is quite satisfactory and allows routine counts of small nannoplankton with the high power objective.

A special problem was met in counting cells in the 5 to 10 μ range. Without concentration counting of these cells is tedious and time consuming because of the large area of the slide that must be examined for an accurate count. But in concentrating the sample, the Nannochloris cells were also concentrated to the point where they so covered the field that is was difficult for the eye to notice the 5 to 10 μ cells which were only slightly larger and far less numberous.

DISCUSSION

Phytoplankton

After a study during 1957 and 1958, Patten (1962) commented, "With respect to sheer number of cells, and possibly also with respect to contribution to total productivity of the estuary, the chlorophyte Nannochloris is probably the most important single phytoplanktont." Our present study certainly confirms this view with regard to the westernmost end of the bay. The dominance of Nannochloris throughout a large area of the bay is indicated both in Patten's study (1961, 1962) and in the survey conducted by the U.S. Public Health Service (1963) from September to December 1962.

The two counts made by Patten on raw samples, 406,000 per ml on July 7, 1958 (1961, p. 372) and 573,000 per ml on August 11, 1958 (1962, p. 64), fall within the values we have observed. Ryther's (1954) count of 1,000,000 per ml for both Nannochloris and Stichococcus in Moriches Bay, Long Island, is only slightly higher than our maximum count for Nannochloris alone.

The gradual decline of the population with the advancing summer and especially in mid-autumn might be due to any number of factors, e.g. depletion of certain nutrients, accumulation of toxic metabolites, change of temperature, etc. Data on periodicity of nannoplankton in oceanic and estuarine environments is extremely meager. Yentsch and Ryther (1959) found no obvious seasonal trend in the abundance of nannoplankton in Vineyard Sound. But the bulk of this consisted of small diatoms. In Moriches Bay, dominated by small green algae, seasonal periodicity was evident with a decline to minimum levels in mid-autumn, and lasting well into the following spring. Similar late autumn to mid-spring minima were found for nannoplankton in fresh water lakes by Birge and Juddy (Welsh, 1952, p. 259) and more recently for some μ-algae by Lund (1961). But the overall picture is complex, varying with the type of nannoplankton present, and the particular body of water. (For a general review on the abundance and productivity of nannoplankton in marine waters see Raymont, 1963.)

The low species diversity in net samples noted by Patten (1962) for the western end of the bay, appears

even more marked in our study of the total phytoplankton.

The general picture of the phytoplankton community in our study is strikingly similar to that found by Ryther (1954) in Moriches's and Great South Bay, Long Island, which is dominated from May to October (and even to February) by Nannochloris atomus associated with the equally small Stichococcus. By combining field studies with experimental cultures of the dominant organisms Ryther was able to elucidate certain basic features in the physiology of Nannochloris and Stichococcus, and relate the dominance of these algae to fecal pollution from nearby duck farms. In addition to imparting a pea-green color and a certain algal odor to the water, Nannochloris led to starvation of oysters in the area. "The ... oysters which had been thriving for years on a diet of the normal phytoplankton and supporting a profitable industry, were unable to utilize the new-comers as food and gradually disappeared; oysters were found starving to death with a gut full of undigested green [algae]. Other shellfish were also eliminated and all attempts to reintroduce them have failed." (Odum 1959, p. 97) The edibility of the phytoplankton is of paramount importance

for all organisms in higher trophic levels from protozoa and planktonic crustacea to fish and man; but it is a problem which until recently has received little attention.

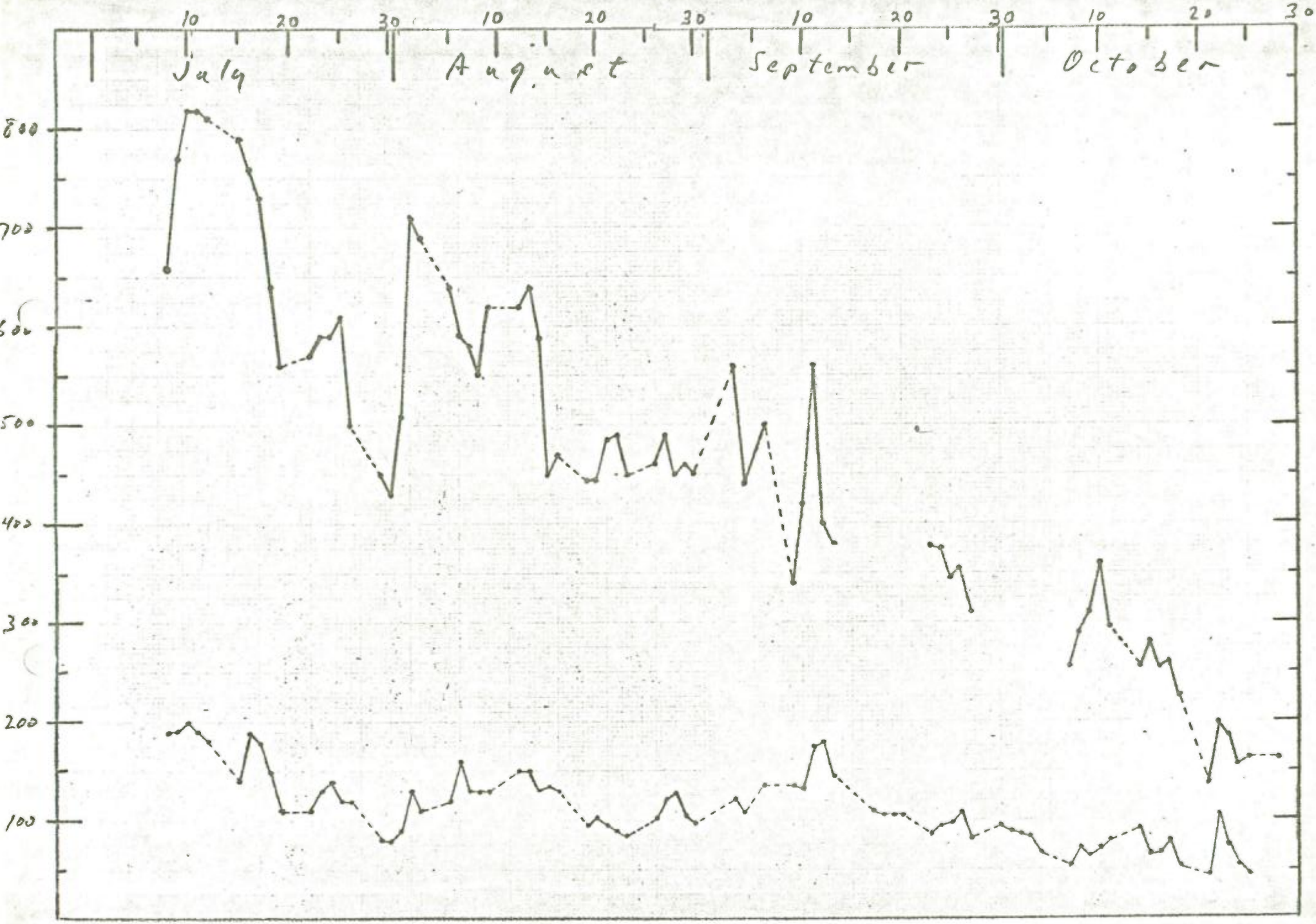
Nutrients

The general abundance of phytoplankton in the bay correlates well with the findings of Jeffries (1962) that "a combination of rich nutrient supplies arising from natural and domestic sources, plus a sluggish circulation, efficient nutrient regeneration mechanism and scarcity of macroscopic algae combine to form an estuarine environment capable of supporting extremely dense plankton populations." But mere abundance of nutrients does not explain the dominance of one organism. There would seem to be some toxic factor present which restrains other types of algae, or an imbalance in the nutrients which favors one form over all others. The abundance of pollution tolerant small green algae in streams below sewage outfalls (cf. references in Blum, 1956) and in experimentally enriched ponds (Margalef, 1955) is well known. But very little attention has been devoted to similar responses in marine and estuarine waters. The study of Moriches Bay was most enlightening, but the situation in the

(Legend to Figure 1)

Figure 1. Upper line: units of Nannochloris per microliter.

Lower line: particles, 25 to 125 u^3, per microliter.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Raritan Bay is not quite the same. For one thing, only traces of nitrate were found in ~~Great South~~ Moriches Bay whereas relatively high levels were generally found in Raritan Bay. Any true understanding of the factors involved in Raritan Bay will require experimental studies with cultures isolated from that area. Experimental cultures would also permit the study of oxygen production, not yet investigated for Nannochloris atomus; reveal factors affecting oxygen production; and give a firm basis for correlating oxygen production with cell numbers and amount of chlorophyll. let/le

Seston

As far as we know, no attempt has been made before to routinely count and size the total particulate matter in natural bodies of water, because of the lack of suitable instrumentation. It is known that many aquatic animals are able to feed on particles of non-living detritus, but the size of the particles is often of crucial importance. Our present experience with hundreds of samples indicates that such counting and sizing is feasable. It is necessary to use an aperature of sufficient size to avoid too frequent clogging, and we

In summary then, our experience would indicate that this electronic counter can be used not only for routine counting and sizing of the total seston, but also in some cases to measure the abundance of phytoplankton.

CONCLUSION

The western end of Raritan Bay is dominated by one minute pale green alga, Nannochloris atomus Butcher, to the virtual exclusion of all other forms. The population of Nannochloris shows cyclic variation with an overall decline from very high densities (over 900,000 units per ml) in spring and early summer to relatively low levels (less than 150,000 units per ml) in the fall. This variation in density correlates in a general way with the change in oxygen concentration.

Experimental work should be undertaken to determine:

1) the reasons for dominance of Nannochloris;
2) the reasons for gradual decline in the population of Nannochloris;
3) conditions affecting oxygen production by Nannochloris.

found that an aperture of 100 u was just large enough for our samples. Of course, bolting silk to suitable mesh could be used to remove the largest particles if these interfered with the method. The large size of the orifice limits the fineness of the particles which can be counted -- down to about 25 μ^3 or even 10 μ^3 depending on electrical interference.

For smaller particles, a smaller orifice must be used. And with our samples the material must be diluted to keep ~~the counting rate within the response time to the machine.~~ coincidence loss at a moderate level. Dilution also reduces the ~~incidence~~ frequency of clogging.

Estimation of what fraction of the particle count is due to phytoplankton depends on optical examination aided by machine measurement of pure cultures.

In situations where the plankton dominate a particular size category, the particle count will be a reflection of plankton abundance. This was observed in the 25 to 125 μ^3 range in these samples. It would probably be even more evident in the 5 to 25 μ^3 range but the necessity of routine dilution and change of orifice deterred us at this time from using the machine for this size range.

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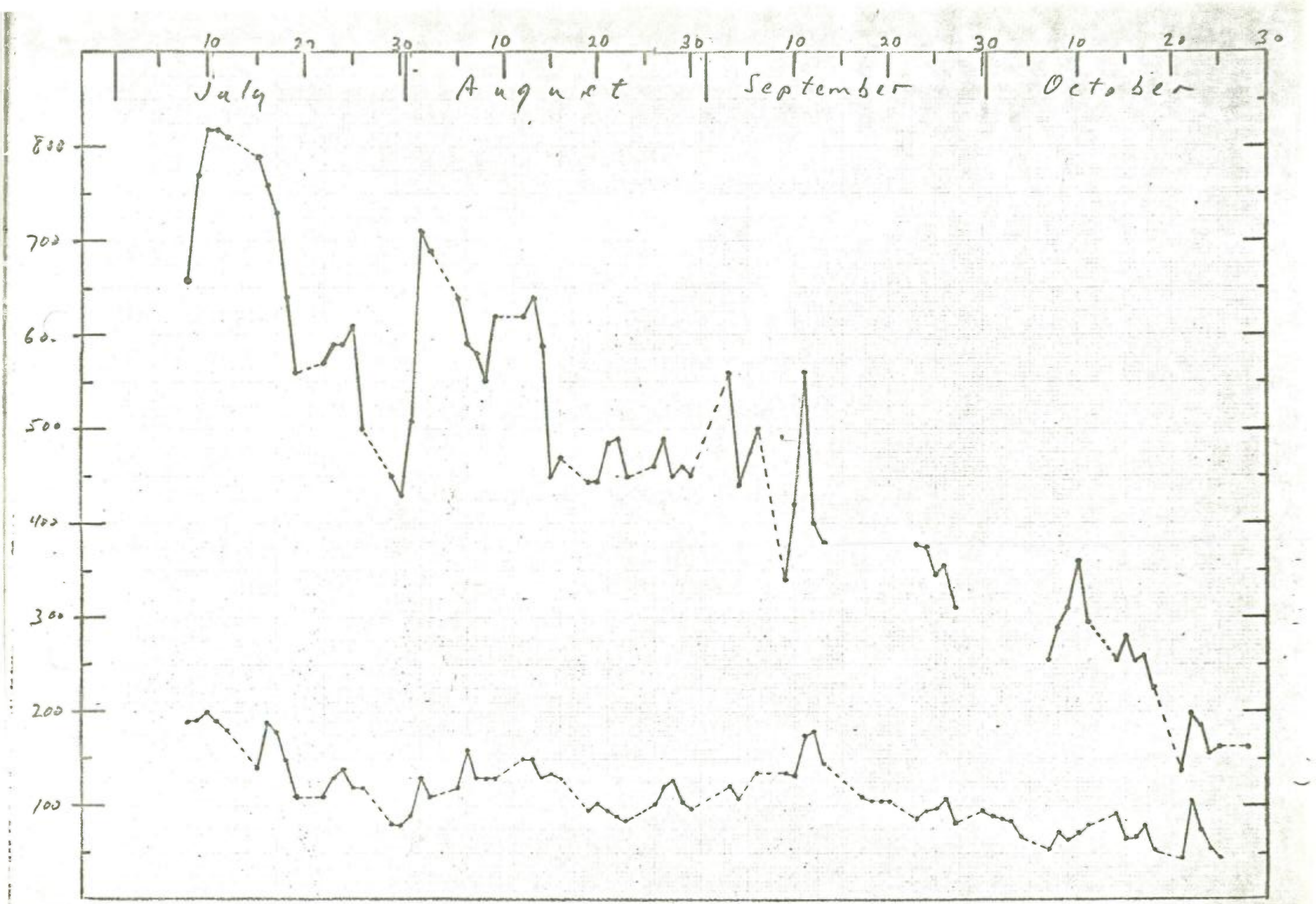
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