*Mar. Res. Indonesia Vol.23, 1984: 1-11*

# PHYTOPLANKTON AND ZOOPLANKTON ABUNDANCE IN AMBON BAY

by

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**ABSTRACT**

**Ambon Bay has a shallow neritic inner bay and a deep oceanic outer bay. Net hauls suggest the inner bay has a large population of large phytoplankton cells but a small population of macrozooplankton. In the outer bay the opposite situation exists, with a greater population of macrozooplankton and smaller population levels of small phytoplankton. The differences might be caused by nutrient pollution and siltation in the inner bay.**

**ABSTRAK**

**Teluk Ambon terdiri atas teluk bagian dalam yang merupakan perairan neritik dangkal dan bagian luar yang merupakan perairan oseanik dalam. Pengambilan contoh plankton dengan mempergunakan jaring plankton menunjukkan bahwa teluk bagian dalam mempunyai kandungan fitoplankton berlimpah tetapi mempunyai kandungan makrozooplankton sedikit. Di teluk bagian luar terjadi keadaan yang sebaliknya. Perbedaan ini mungkin disebabkan oleh terjadinya pencemaran zat hara dan siltasi di teluk bagian dalam.**

## INTRODUCTION

Ambon Bay, on Ambon Island in the eastern archipelago of Indonesia, has two distinct environments, a shallow neritic inner bay and a deep oceanic outer bay that opens on to the Banda Sea. In this paper we report on some features of the plankton communities, and discuss possible reasons for the differences in the two bays.

The inner bay is small (area 6 sq km, depth 20 m) and the circulation is restricted by a narrow 10 m deep sill that connects it to the outer bay. Inner bay surface waters are replaced by tidal action, and the deep waters are renewed between March and August when upwelling, during the southwest monsoon, brings outer bay thermocline water up over the sill and into the inner bay (ANDERSON & SAPULETTE 1981,

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*DOI: 10.14203/mri.v23i0.393*

WENNO & ANDERSON in press). The outer bay bottom, slopes from the sill region to a depth of 800 m at the opening to the Banda Sea, and with this geometry the outer bay freely exchanges water with the Banda Sea (Figure 1).

A human population of about 100,000 lives in Ambon city. The outer bay population is on the order of 15,000. Untreated sewage enters the bay, and during the rainy season there is a considerable erosion of top soil into the bay. The erosion is most visible near the city of Ambon, were after a rain a large plume of silt can be observed extending hunderds of meters out into the bay.

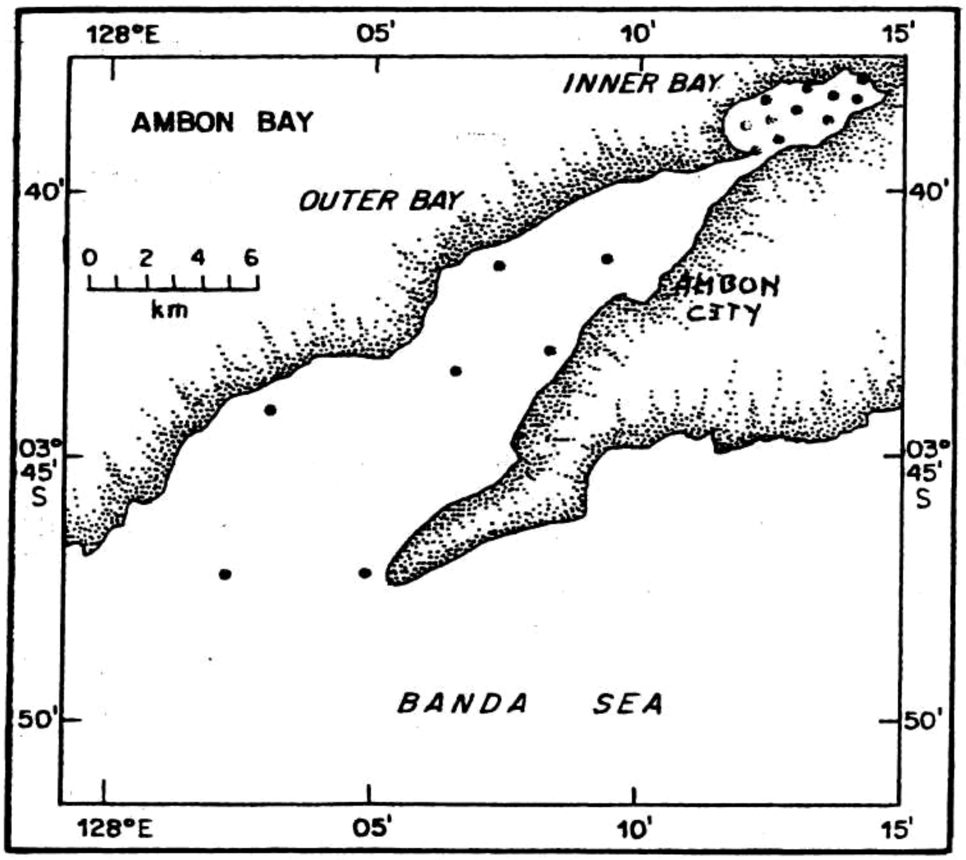


**Figure 1. Ambon Bay showing location of stations in inner and outer bay.**

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### METHODS

Between March 1980 and March 1981 net hauls were collected eight times at eleven stations in the inner bay, and seven stations in the outer bay (Fig. 1). Inner bay hauls were made to the bottom, between 15 and 30 m deep. The outer bay hauls were made to 100 m. Two nets were used: a Kitahara 30 cm diameter net with a 0.12 mm nylon mesh, and a NORPAC 45 cm diameter net with a 0.33 mm nylon mesh. Using the methods in WICKSTEAD (1965) plankton settling volume was determined for the Kitahara samples, and the displacement volume was determined for the NORPAC samples.

To compare the net samples, Kitahara settling volume was converted to displacement volume by multiplying by the conversion factor 0.042. This was determined by a regression of 21 Kitahara samples, where both displacement and settling volumes were measured. The standard deviation on the conversion is 30%.

To compare net hauls from the inner and outer bays we use settling volume per square meter of sampling area since the net haul depths were different in the inner and outer bays. ANDERSON & SUTOMO (submitted) demonstrated that sample volumes expressed per unit area are better for comparing hauls to different depths than are volumes expressed per cubic meter of water filtered.

Phosphate was measured in the surface waters using the method in STRICKLAND & PARSONS (1968). Samples were not cooled, but were generally analyzed the day of collection.

Chlorophyll was measured in April 1981 as part of a survey by the Centre ORSTOM vessel R/V Coriolis. Water was collected in plastic water bottles and phytoplankton, down to a size of 0.01 mm, were collected on glass fiber filters. Chlorophyll was determined by a fluorometer according to the methods of HOLM-HANSEN *et al.* (1965).

Monthly rainfall data was obtained from the weather bureau in Ambon City.

### OBSERVATIONS

The net plankton volume data had no well-defined seasonal cycle (Figure 2). The inner bay had greater Kitahara net volumes, while the outer bay had greater NORPAC net volumes (Table 1). For the outer bay the Kitahara and NORPAC samples were correlated and were about equal while for the inner bay the two net volumes were uncorrelated, and the Kitahara volumes were larger (Figure 3). The inner bay contained between

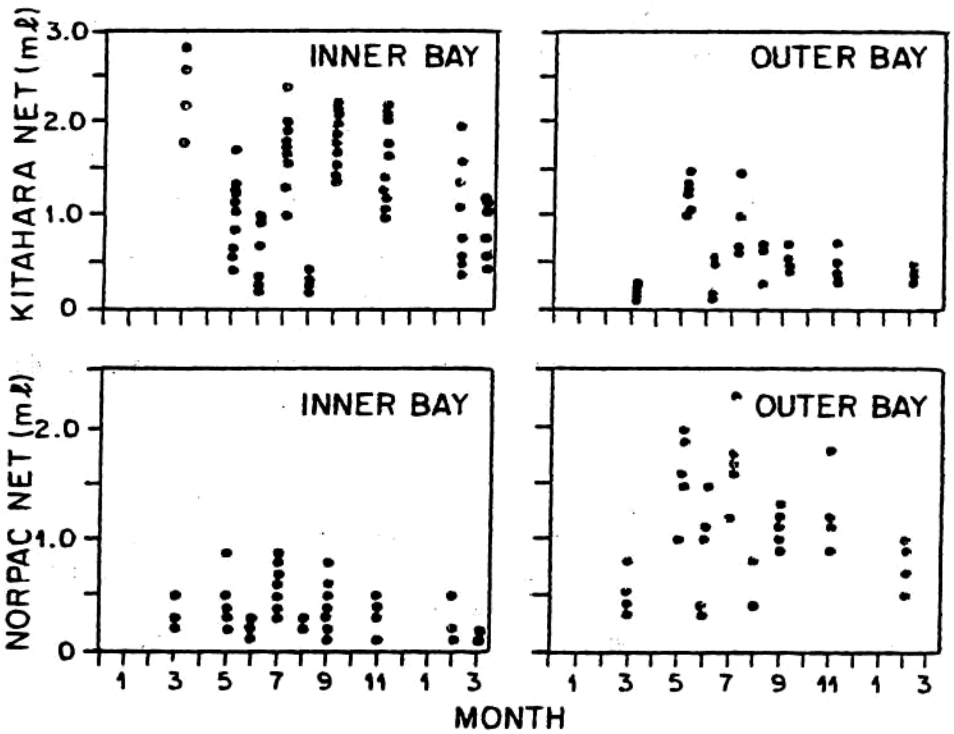


Figure 2. Plankton displacement volume vs. month, for inner and outer bay Kitahara and NORPAC net samples. Displacement volume is ml of material collected per $m^2$ of net front surface area.

Table 1. Average net plankton volumes for Kitahara and NORPAC nets. Both expressed in displacement volume with Kitahara displacement volume calculated from settling volume using factor 0.042. Volumes in ml/$m^2$.

| | **Kitahara** | **NORPAC** | **Kitahara-NORPAC** |
|---|---|---|---|
| **Inner Bay** | 16.4 | **1.9** | 14.5 |
| **Outer Bay** | **7.6** | **6.5** | **1.1** |

two and three times the concentration of chlorophyll that the outer bay did and the peak levels were three to five times greater in the inner bay (Table 2). The inner bay contained larger concentrations of phosphate than the outer bay, as exhibited by a larger modal value (0.4 vs. 0.2 ug-µg-at/1) and a larger average value (0.63 vs. 0.36 µg-at/1), where the sample size is 84 for the inner bay and 49 for the outer bay.

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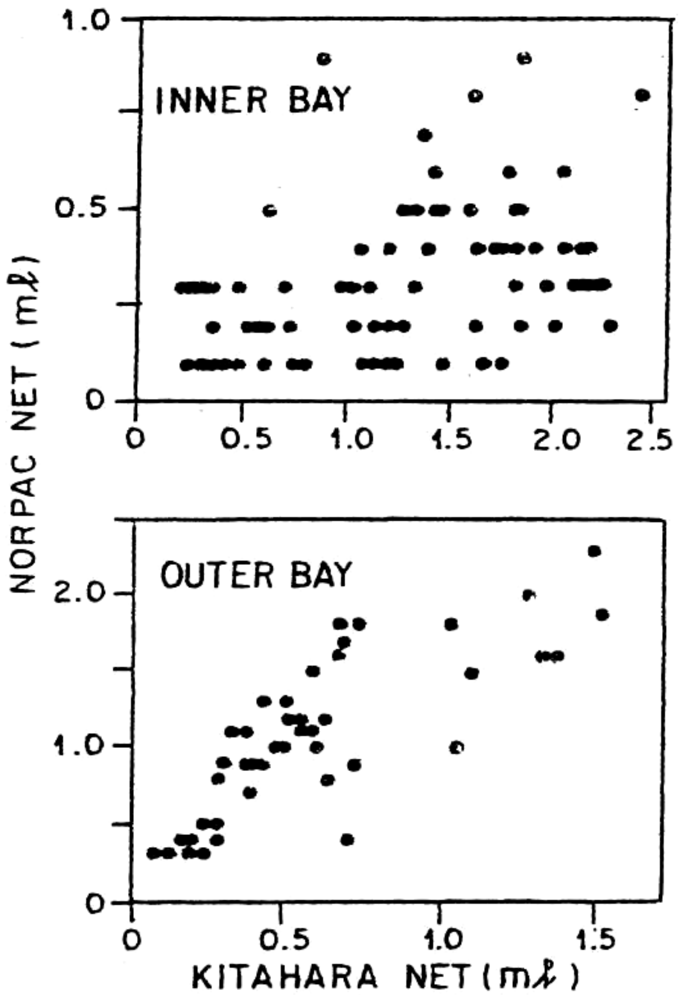


**Figure 3.** Correlation of NORPAC and Kitahara net displacement volumes, for inner and outer bay data.

To estimate the volume of the microplankton size fraction, 0.12 to 0.33 mm, the NORPAC volume was subtracted from the Kitahara volume. The macroplankton volume is taken as the material caught in the NORPAC net and includes material greater than 0.33 in size, but excludes zooplankton that avoid the nets during the daylight hauls. The modal values were larger than the average values, such that the majority of the observations fall below the average value (Table 3).

| | Inner Bay | | | | | | Outer Bay | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | STA1 | STA2 | STA3 | STA4 | STA5 | STA6 | STA13 | STA14 | STA15 | STA16 | STA17 | STA18 | STA19 |
| 0 | .48 | .47 | .51 | .59 | .72 | .44 | .19 | .15 | .22 | . 14 | .12 | .21 | .10 |
| 5 | .27 | .16 | .63 | .55 | .76 | .36 | .15 | .14 | .27 | .20 | .17 | .27 | .12 |
| 10 | .30 | .27 | .87 | .80 | .75 | .64 | .15 | .12 | .30 | .28 | .23 | .33 | .15 |
| 15 | 1.03 | .42 | 1.27 | .92 | 1.52 | 1.55 | .17 | .20 | .32 | .28 | .27 | .33 | .16 |
| 20 | .92 | .75 | 2.34 | 2.44 | 1.82 | 1.60 | .18 | .37 | .34 | .28 | .31 | .33 | .17 |
| 25 | .70 | | 1.74 | 1.00 | | 1.00 | .25 | .36 | .34 | .34 | .25 | .34 | .17 |
| 30 | .45 | | | .63 | | .52 | .32 | .36 | .35 | .38 | .24 | .36 | .18 |
| 50 | .38 | | | | | | .34 | .25 | .22 | .20 | .17 | .36 | .22 |
| 75 | | | | | | | .20 | .13 | .06 | .12 | .08 | | .20 |
| 100 | | | | | | | .12 | .06 | | .09 | 0.7 | | 0.6 |
| 125 | | | | | | | .09 | .04 | | .09 | .06 | | .06 |
| 150 | | | | | | | .08 | 0.4 | | .07 | .06 | | .06 |
| Integration Interval | | | | | | | | | | | | | |
| 0 - 30 | 2075 | 1035 | 3680 | 3465 | 2785 | 3055 | 705 | 850 | 1070 | 950 | 795 | 1085 | 525 |
| 0 - 150 | | | | | | | 6880 | 5520 | 4680 | 5910 | 4610 | 5410 | 4850 |

Table 2. Chlorophyll (mg/m$^3$) at inner and outer bay stations. Integrated chlorophyll (mg/m$^2$) for 0 - 310 m and 0 -150 m depth intervals.

Table 3. Volume average and mode of plankton size fractions. Displacement volumes in ml/m$^2$.

| Location | Fraction | Average | Mode |
|---|---|---|---|
| Inner Bay | Microplankton (0.12 — 0.33 mm) | 14.5 | 14 — 17 |
| | Macroplankton (> 0.33 mm) | 1.9 | 0 — 3 |
| Outer Bay | Microplankton (0.12 — 0.33 mm) | 1.1 | 0 — 3 |
| | Macroplankton (> 0.33 mm) | 1.1 | 0 — 3 |

The inner bay microplankton had an inverse correlation with monthly rainfall (Figure 4). The macroplankton was not correlated with precipitation in the inner bay. In the outer bay neither microplankton or macroplankton were correlated with precipitation.

## DISCUSSION

The microplankton volume was seven times larger in the inner bay than in the outer bay, while the macroplankton volume was three times larger for the outer bay than for the inner bay. Chlorophyll measurements indicate that the inner bay contained about twice the phytoplankton that the outer bay did. Furthermore, the inner bay contained a well-defined chlorophyll maximum while the outer bay did not. The fact that the inner bay microplankton volume is seven times the outer bay volume, but the chlorophyll biomass is only two to three times larger, suggests that the inner bay phytoplankton cells were large and were retained by the Kitahara net, while the outer bay cells were generally smaller and passed through the net. A visual inspection of the Kitahara net material shows the inner bay material was green with phytoplankton chlorophyll, while the outer bay material was generally colorless.

These observations suggest that the inner bay had a high population of large phytoplankton and a low population of zooplankton, while in the outer bay the situation was reversed. To consider a mechanism producing these differences, note that a similar pattern of phytoplankton and

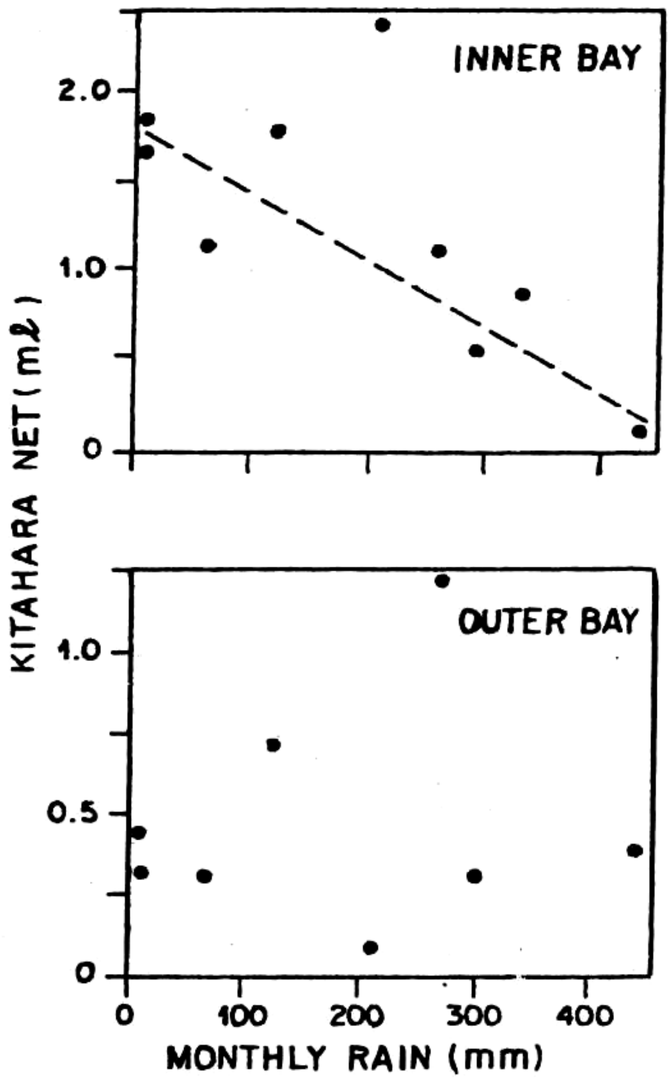


Figure 4. Correlation of microplankton volume with monthly rainfall, for inner and outer bay samples. Microplankton volume is defined at the volume collected in the size range 0.12 to 0.83 m.

zooplankton distributions is observed between coastal and oceanic environments. From a variety of studies (YENTSCH & RYTHER 1959, MALONE 1971, PARSONS & TAKAHASI 1973, 1974; STEEL & FROST 1977, and LANDARY 1977) a simple pairadigm has evolved that suggests: small phytoplankton cells grow in oceanic enviroments with low nutrient concentrations and low mixing, and larger phytoplankton cells grow in coastal environments with higher nutrient concentrations and greater mixing. In a model study, STEEL & FROST (1977) demonstrated that nutrients, turbulence, and the size of predators all affect the phytoplankton cell size. Our observations support this paradigm with higher nutrients and larger phytoplankton cells in the inner bay.

The inverse correlation between microplankton volume and rain in the inner bay suggests that phytoplankton growth might be light limited in the inner bay. Light could be limited by two mechanisms: directly by a decrease in the incident radiation, and indirectly by the decrease in light penetration from the silt loading in the water. These factors could both decrease the phytoplankton biomass during rains.

The reduced macroplankton biomass in the inner bay, as compared to the outer bay, might be the result of a limitation of zooplankton prey in the inner bay. The additional nutrient loading and siltation in the inner bay could both contribute to the condition. The nutrients could make phytoplankton cells too large to be efficiently consumed by zooplankton. Siltation could decrease the phytoplankton biomass through light inhibition.

To put these observations in perspective we note that in 1857, WALLACE (1862) wrote: "There is perhaps no spot in the world richer in marine products, corals, shells and fishes, than the harbour of Amboyna". About ten years ago, TROOST *et al.* (1976) observed (fewer copepods in the inner bay than in the outer bay, and pointed out that significant degradation had occurred to the inner bay since Wallace's time. Our observations further document changes in the inner bay and indicate that differences in the size and abundance of plankton in the inner and outer bays also exist. A number of studies, and our data, suggest that both nutrient and .silt inputs might contribute of the difference between the two bays, and to the general alteration of the plankton communities over time.

Finally, as was pointed out by TROOST *et al.* (1976), the threat of increasing pollution will continue to alter the planktonic composition of Ambon Bay, and this may alter the fisheries. We expect similar situations exist in many tropical bays, and (suggest that further studies be conducted to determine the relative importance of nutrient and silt pollution in tropical bays.

## ACKNOWLEDGMENTS

This work was supported by the U.S. Agency for International Development Contract No. AID-497-79-100 and by LIPI, the Indonesian Institute of Sciences. We wish to thank Dr. Aprilani Soegiarto, Director of the National Institute of Oceanology and Mr. Atjep Suwartana, Director of the National Institute of Oceanology Ambon Research Station for their support during this project.

## REFERENCES

ANDERSON, J.J. and D. SAPULETTE 3981. Deep water renewal in inner Ambon Bay, Ambon, Indonesia. *Fourth Internat. Coral Reef Symposium,* 1: 369 - 374.

HOLM-HANSEN, O.; C.J. LORENZEN; R.W. HOLMES and J.D.H. STRICKLAND 1965. Fluorometric determination of chlorophyll. *J. Cons. perm. int. Explor. Mer.* 30: 3-15.

LANDRY, M.R. 1977. A review of important concepts in trophic organization of pelagic ecosystems. *Helgolander wiss. Meeresunters* 30: 8-17

MALONE, T.C. 1971. The relative importance of nannoplankton and netplankton as primary producers in tropical oceanic and neritic phytoplankton communities. *Limnol Oceanogr.* 16: 633 - 639.

PARSONS, T.R. and TAKAHASHI 1973. Environmental control of phytoplankton cell size. *Limnol. Oceanogr.* 18 : 511-515.

PARSONS, T.R. and M. TAKAHASHI 1974. *Biological Oceanographical Processes.* Pergamon Press, Oxford: 186 pp.

STEEL, J.H., and B.W. FROST 1977. The structure of plankton communities. *Phil. Trans. Roy. Soc. of London Biol. Sci.* 280: 485-534.

STRICKLAND, J.D.H. and T.R. PARSONS 1968. A practical handbook on sea water analysis. *Fish. Res. Bd. Canada Bull.* 162: 311 pp.

SUMADHIHARGA, O.K. 1978. Some biological aspects of ikan puri, *Stolephorus heterolobus,* in Ambon Bay (in Indonesia). *Oseanol. Di Indonesia,* 9: 29-41.

SUTOMO and J.J. ANDERSON In press. A comparison of unit volume and unit area expressions of vertical plankton hauls. *Mar. Res. Indonesia.*

TROOST, D.G.; A.B. SUTOMO and L.F. WENNO 1976. Distribution and abudance of major zooplankton groups in Ambon Bay (Maluku, Indonesia) during a Salp swarming, with notes on Chaetognatha and Pteropoda Species. *Mar. Res. Indonesia. W:* 31 - 43.

**PHYTOPLANKTON AND ZOOPLANKTON**

WENNO, L.F. and J.J. ANDERSON. In press. Evidence for upwelling across the sill of Ambon Bay. *Mar. Res. Indonesia.*

WICKSTEAD, J.C. 1965. *An introduction to the study of tropical plankton* Hutchinson Trop Monogr. London: 1-160.

YENTSCH, C.S. and J.H. RYTHER 1959. Relative significance of the net phytoplankton and nannoplankton in waters of Vineyard Sound. J. *Cons. perm. int. Explor. Mer.* 24: 231-238.