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BIOLOGICAL OCEANOGRAPHY OF THE GAMAGYANG BAY–THE YEOJA BAY WATER SYSTEM(I)

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ABSTRACT

The major source of nutrients in both the Gamagyang Bay and the Yeoja Bay is mixing. However, water discharges also seem to contribute significant quantities which may influence local phytoplankton growth. Data collected in the study area shows that natural fluctuations in the environmental conditions of the entire area play a dominant role in determining the phytoplankton populations of the two Bays. The predominating phytoplankton forms are neritic diatom species including some dinoflagellate species in summer. Neritic groups are relatively more abundant in inner areas of the Bays. The oceanic groups and species are seasonal, and associated with advective effects. One neritic species is of overwhelming numerical importance and occurs when a specific seasonal condition is formed. Species cycles in the two Bays may be regarded as largely the result of successional changes or cycles of autochthonous species introduced by advective processes.

INTRODUCTION

The coastal waters in the vicinity of Yeosu is a system which is composed of two semi-closed bays, the Gamagyang Bay and the Yeoja Bay, and off the Bays. In the geomorphological point of view, the two Bays provide very good sites for mari-culture. Nevertheless, no comprehensive biological oceanographic research has been done in this area.

Traditionally, one of the important uses of coastal waters for man has been as a repository for his wastes. Although the ocean is vast, its ability to assimilate these waste without significant environmental degradation is limited and is sometimes disastrous especially in shallow coastal waters.

The basic goal of this study is to increase understanding of the ecology of the coastal waters near Yeosu area and of the possible effects of wastewater discharge on the marine environment. The study aims at encouraging the conservation and enhancement of local marine resources by providing baseline scientific insight.

Biological Oceanographic field work in the study area (Fig. 1) was conducted during five

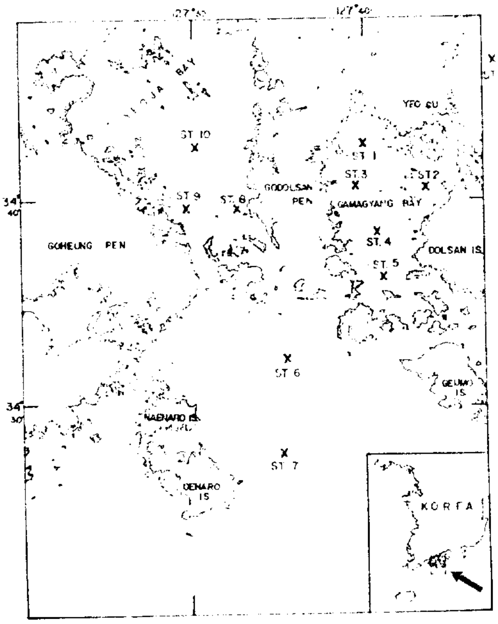

Fig. 1. A map showing sampling stations at study area.

Table 1. Oceanographic cruises to the study area

Cruise No.	Cruise data	Cruise duration (days)
1	1~4 Aug. 1979	4
2	7~9 Sep. 1979	3
3	24~26 Oct. 1979	3
4	21~23 Nov. 1979	3
5	17~19 May 1980	3
	Tota numbers of cruise days	16

METHODS AND MATERIALS

separate cruises aboard chartered vessel. Dates of these cruises were scheduled once a month so as to allow collection of information from the area.

The 11 oceanographic stations were geographically located to yield maximum data including 5 stations in the Gamagyang Bay, 3 in the Yeoja Bay, 2 off the Bays and 1 in the Yeosuhae Bay (Fig. 1).

The individual cruises varied in length from 3-4 days (Table 1) and variations in curise duration were due to primarily weather conditions.

Collection of Physical Data

Temperature and salinity data were obtained at all stations from Van Dorn Bottle casts. Surface temperatures were measured with a bucket thermometer at all stations on every cruise. A detailed methods for the measurements of temperature and salinity should be referred to the report of the physical oceanography of the study area.

Transparency was measured by Secchi disc. Depending upon the depth of water column two or three or three depth intervals were chosen to measure environmental parameters and to collect samples. Light intensity was measured by KAHLSICO Submarine Photometer and calculated in mW/cm^2. This irradiometer consists of two meters which provide simultaneous measurements from both the Deck and Sea Cells, assuring more reliable data when cloudy sky conditions cause rapid changes in the ambient light.

Collection of Chemical Data

Measurements of pH were made with a model Photovolt 126A Portable pH Meter using combination glass-calomel electrode. Seawater samples were collected in 150 ml pyrex beakers promptly upon retrieval of Ban Dorn bottles from hydrographic cast. The pH meter was standardized with Merck buffers of pH 8.00 controlled to the same temperature as the samples. Biological activity would tend to change the pH, however, and all samples were therefore analyzed within 30 minutes after collection.

Dissolved oxygen measured with KAHLSICO Model TDO-2 Oxygen-Temperature Meter. In the course of making measurements with this model, it was maintained that time was allowed for the probe to reach equilibrium,as evidenced by stable meter readings.

Water samples for nutrients and chemical oxygen demand were taken in polyethylene bottles. The water samples were then placed in an ice chest in which the samples were frozen by dry ice. The samples stayed frozen during our return and were placed in the freezer of the Fisheries Research and Development Agency in Yeosu. The samples were analyzed at the laboratory of the Agency for NO_2, PO_4 and SiO_2 according to the methods Strickland and Parsons (1968), and for COD according to the $KMnO_4$ consumption method.

Biological Sampling

Seawater samples for chlorophyll were collected with Van Dorn Bottle and were transferred into 1-liter polyethylene sample bottle, filtering the water with 342μm meshed nylon cloth. One milliliter of $MgCO_3$ suspension was added to each bottle, and the contents were then filtered through Millipore filter(HA: 0.45μm).The filter containing the particulate matter was folded in half, inserted into a small petridish and kept frozen in the dark until extraction could be carried out. In the laboratory the filters were added to 10ml of top-grade acetone(95% v/v) and vigorously agitated until the filters were pulverized. The tubes containing the acetone mixtures were next placed in a refrigerator for 24 hours, removed and allowed to come to room temperature, then centrifuged above 3000rpm for 15min. The clear supernatant liquid was pipetted into a 1cm-path-length spectrophotometer cell and analyzed in a SHIMADZU UV-180 Double-Beam Spectrophotometer.

Phytoplankton samples for qualitative use were collected at 11 stations during 5 cruises. Phytoplankters were collected by oblique net haul from near bottom to surface at each station. The net used for this study was made of synthetic nylon with mesh size of 53μm and the diameter of net ring was 50cm. Neutralized formalin was added so that each sample contained a final concentration 5% formalin.

Phytoplankton for standing stock determinations were collected in Van Dorn Bottles. Subsamples were drained into 24 ml-glass bottles and 1 ml of Lugol solution was added to each sample. In order to prevent oxidation, the sample bottles were then wrapped with aluminium foil and kept in the dark. Following McAlice's treatment(1971) of this counting device, the Sedgwick-Rafter cell method was used to determine phytoplankton standing stock. The major taxonomic literatures are listed in the reference section.

RESULTS AND DISCUSSION

Water Characteristics

The major water quality characteristics for which data are available throughout the study area are temperature, salinity, dissolved oxygen, light intensity, transparency, selected nutrients, and chemical oxygen demand(Shim, Kim and Chough, 1980). These parameters do not provide, of course, a complete description of the waters. However, they do serve to describe and differentiate between different water environments that can be associated with identifiable biological regimes. Of the parameters measured temperature and salinity should be referred to Kim's report of Physical Oceanography of the study area.

Dissolved Oxygen

Table 2 shows the ranges of dissolved oxygen concentrations found in the waters of the study area. Surface concentrations are usually high and dissolved oxygen decreases with depth.The concentrations in October and May are higher than those found in August and November. This indicates that seasonal fluctuations in oxygen concentration are affected by phytoplankton growth which will be discussed later. The average concentration of dissolved oxygen tends to be lower than those found in the other area of the southern sea(Park, 1980). However, the concentrations did not fall below 4ml/1 which is about 50% of saturation and is adequate for the

Table 2. Monthly changes of Dissolved Oxygen in coastal waters of study area (ml/1).

St. \ Mon.	Aug. 1979	Oct. 1979	Nov. 1979	May 1980
1	4.55~5.67	6.65~6.83	4.34~6.30	5.69~6.09
2	5.46~6.83	5.49~5.53	4.81~4.83	5.74~5.84
3	5.67~5.81	6.09~6.13	5.81~5.95	5.53~5.88
4	4.10~4.73	4.23~5.39	—	5.54~5.66
5	4.69~4.73	5.81~6.02	—	5.53~5.67
6	4.62~4.83	—	—	—
7	4.69~5.22	6.02~6.37	4.27~5.39	5.45~5.73
8	4.33~5.05	5.60~5.81	5.32~5.46	—
9	4.70~4.84	5.78~5.85	2.73~3.99	—
10	4.73~5.04	5.78~6.23	5.52~5.60	—
11	4.38~5.57	5.83~6.22	4.50~4.62	5.36~6.09

Table 3. Monthly changes of pH in coastal waters of study area.

St. \ Month	Aug. 1979	Sep. 1979	Oct. 1979	Nov. 1979	May 1980
1	8.10~8.25	8.14~8.20	8.10~8.12	8.13~8.24	8.13~8.16
2	8.15~8.25	8.20~8.31	— 8.22	8.13 —	8.07~8.16
3	8.10~8.15	8.10~8.28	8.20~8.21	8.13 —	8.14~8.17
4	8.15 —	8.13~8.18	8.18~8.21	8.21~8.23	8.08~8.09
5	8.10~8.15	8.12~8.20	8.24~8.28	7.93~7.97	8.06~8.07
6	7.60~8.20	8.23~8.31	8.04~8.06	—	—
7	7.75~8.05	8.30~8.35	8.16~8.25	8.03~8.05	8.06~8.13
8	8.08~8.26	8.15~8.20	8.07~8.12	8.07~8.16	—
9	7.97~8.16	8.18~8.27	8.04~8.09	8.20~8.23	—
10	8.06~8.13	8.17~8.22	8.14~8.15	8.18~8.20	—
11	7.99~8.26	8.15~8.29	8.20~8.23	8.28~8.30	7.96~7.98

support of marine life (Wallen and Hood, 1968).

It seems to be apparent from these data that replenishment of oxygen in the study area occurs probably throughout the year; otherwise, more conspicuous seasonal depletion would be expected. These results agree with those obtained from other coastal area of the southern sea(Park, 1980).

Hydrogen Ion Concentration

Table 3 shows the change of pH at each station with time of five months. The values in pH varies little, as is typical in sea waters. The pH decreased slightly with depth and this decrease may be caused by carbon dioxide produced by the biodegradation of organic matter. Minimum values below 8.0 were found in the bottom waters. However, the data indicate that the bottom water pH values did not undergo significant seasonal fluctuations.

Chemical Oxygen Demand

The Measurements of COD vary from 0.173 to 2.043 ppm(Table 4) comparing with the data obtained from the Kwang Yang Bay where the COD values were near 2.0 (Lee *et al.*, 1978), the COD values of the study area are slightly low.

In general, COD value more than 8.0 indicates polluted sea water and the value should be below 3.0 for marine life. Together with the data of DO and pH, COD data indicate that the waters of the study area remains unpolluted

Table 4. Monthly changes of C.O.D. in coastal waters of study area (p.p.m)

St. \ Month	Aug. 1979	Sep. 1979	Oct. 6979	Nov. 1979	May 1980
1	0.8870~1.0929	0.5386~1.0138	0.6272~0.9480	0.6040~1.0560	0.480~1.168
2	1.5365~2.0434	0.4910~0.8712	0.4704~0.7056	0.7544 —	0.960~1.408
3	0.9346~1.2514	1.0454~1.2672	0.7056~0.9408	0.4526~0.6035	0.800~0.848
4	0.4277~1.4098	0.8870~1.2672	0.7056~0.7848	0.4526~0.7544	0.672~1.040
5	0.3168~0.3485	0.7603~0.9662	0.6272~0.9408	0.3018~0.7544	0.960~1.440
6	0.6019~1.2197	1.1563~1.2038	— —	— —	— —
7	0.2851~0.6178	0.5702~1.1880	— 1.1760	0.6035~0.9050	0.960~1.280
8	0.0475~0.380	0.5861~0.9821	0.6272~0.7848	0.4530~1.2070	— —
9	0.0173~0.3485	1.0138~1.0454	0.7848~1.0976	0.3020~0.7540	— —
10	0.0475~0.2693	0.8870~1.2672	0.7848 —	— 0.7540	— —
11	0.0634~1.2514	0.4118~1.3622	0.4704~0.7848	0.7540~0.9050	0.800~1.248

condition.

Silicate

The concentrations of SiO_2 are shown in Figure 2, ranging from 1.82-19.50 μg-at Si/1 in the study area depending upon station and month. The highest concentrations occurred inner area of the Gamagyang Bay receiving freshwater input. The seasonal cycle of SiO_2 in the study area shows that SiO_2 levels were

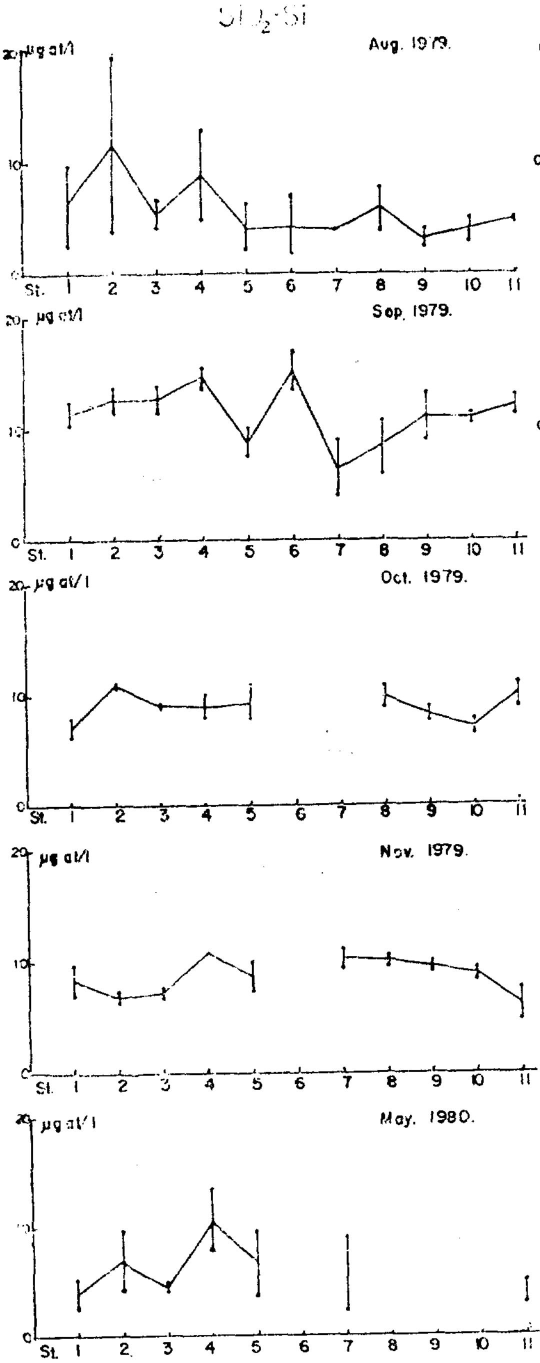

Fig. 2 The distribution of SiO_2-Si in coastal waters of study area.

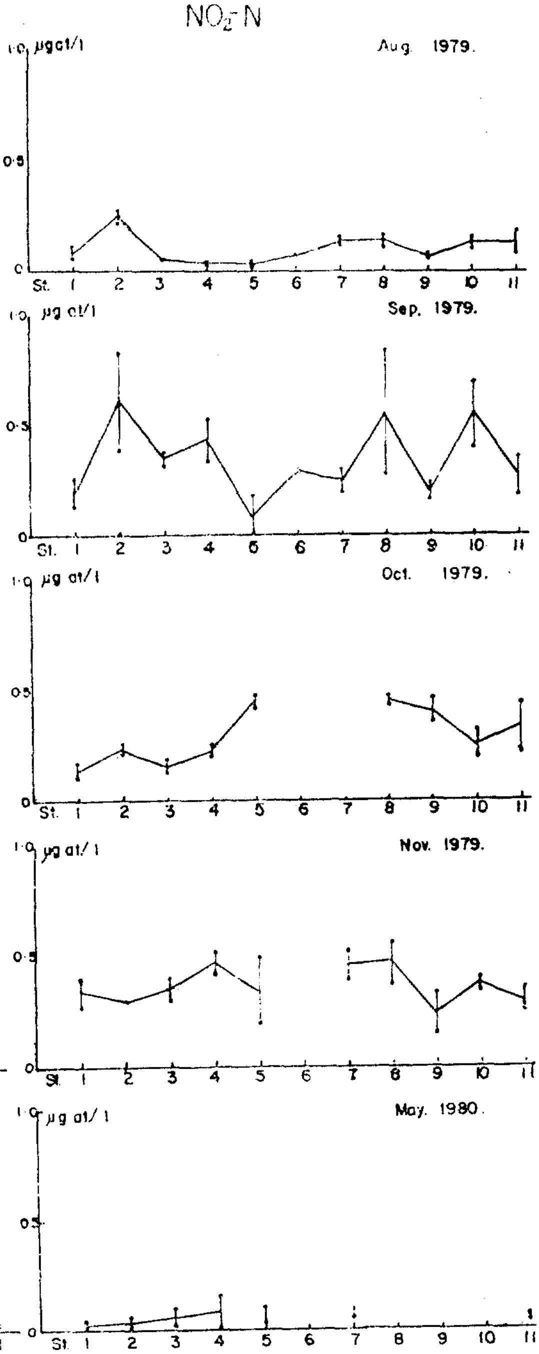

Fig. 3 The distribution of NO_2-N in coastal waters of study area.

lower in October and November than in the other two months; this might be attributed to the fall diatom growth. Concentrations were particularly elevated in August at station 2 near major freshwater inputs. Vertical mixing already started in September and markedly increased in October and November, reducing vertical differences in SiO_2 levels.

Nitrite

The concentration of NO_2 in the study area is shown in Figure 3, with NO_2 levels ranging from 0. 014-0. 836 ug-at/l depending upon station and month.

The NO_2 levels in the study area varied with station and especially with month. During summer and early spring (August and May), NO_2 levels were very low, a condition brought about by phytoplankton growth which typically begins in spring and in fall(October). Vertical mixing of the water is presumably the major force to replenish NO_2 levels in September. However, the big differences of the NO_2 levels between surface and bottom waters indicate that the concentration of NO_2 in surface waters in the study area was also increased by freshwater input.

Phosphate

The measured concentrations of phosphate in the study area are shown in Figure 4, ranging from 0. 039-2. 145 ug-at/1. These data are typical for those observed in other areas of the southern sea (Lee *et al.*, 1978). phosphate concentrations were high in August and September with maximum values in the Gamagyang Bay and gradually decreased in the fall months and in May.

As expected, the seasonal cycle of PO_4 in the study area was similar to that SiO_2 and NO_2. This suggests that phytoplankton growth is responsible for the major concentration alterations of these nutrients. As with the SiO_2 and NO_2 patterns, PO_4 levels remained low in fall and are approached values that are possibly limiting to phytoplankton growth. Freshwater

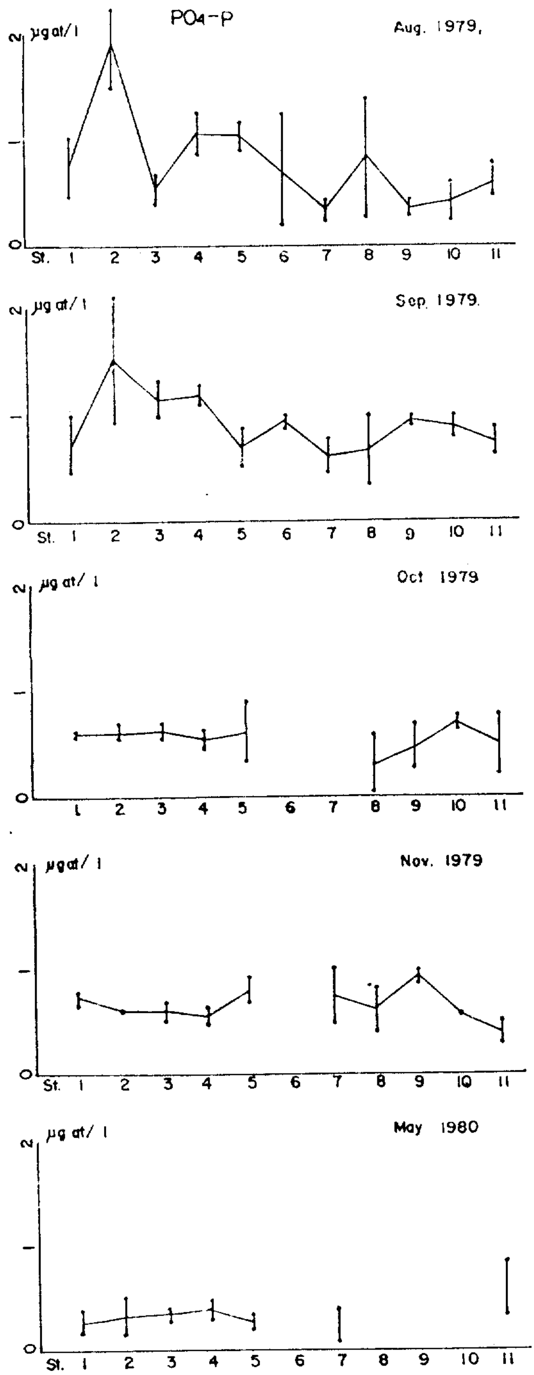

Fig. 4. The distribution of PO_4-P in the coastal waters of study area

input entering the study area is evident in inner area of the Gamagyang Bay, especially at station 2 near the river mouth.

Chlorophyll

The distribution of chlorophyll-a and total chlorophyll in the study area are given in Figures 5 and 6. Both exhibit generally the same pattern.

A typical flowering of phytoplankton in October and May represented by chlorophyll was closely related with the variations of nutrients and temperature. The temperature of the surface water was approached to similar level in two different seasons (Shim, Kim and Chough, 1980). Nutrients silicate, nitrite, and phosphate were at maximal concentrations prior to initiation of the bloom. The rapid phytoplankton growth (mainly diatom) in October was probably a result of decreasing daylight and abundant nutrient supply and was same pattern in May except increasing daylight. The extensive growth of phytoplankton soon depleted nutrients. Despite the favorable light condition in the study area the amount of phytoplankton growth could become limited by the shortage of nutri-

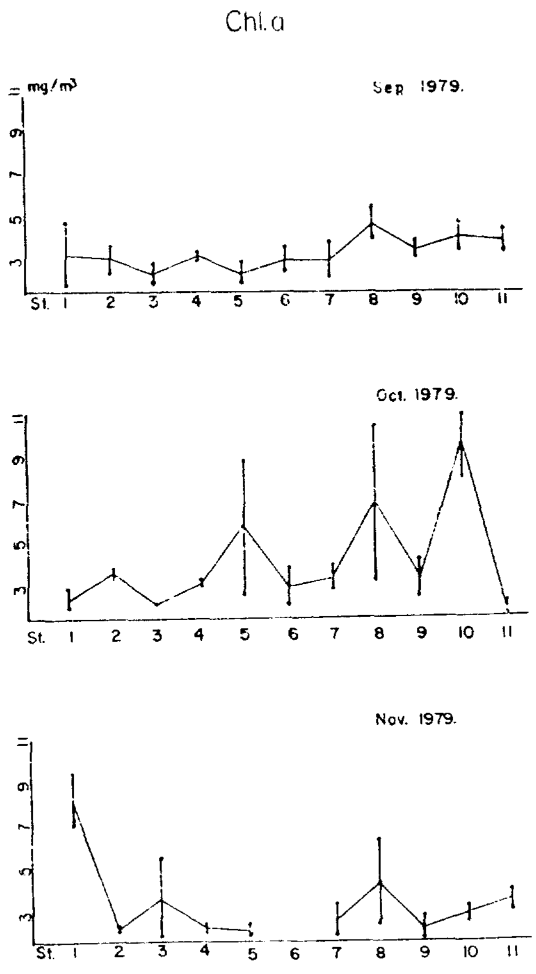

Fig. 5. The distribution of Chl.-a in coastal waters of study area.

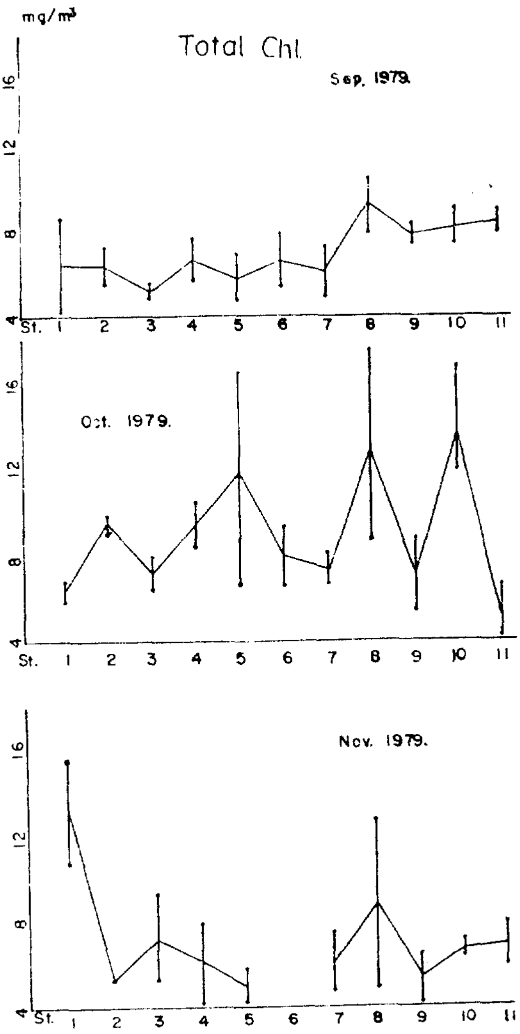

Fig. 6. The distribution of total Chl. at each station.

ents. After mixing occurred, the heavy sediment load reduced light penetration which might also affect phytoplankton growth.

In fall the distribution of chlorophyll within the Yeoja Bay was more pronounced than in the Gamagyang Bay. Such large variations suggest that freshwater and suspended sediments were significantly inhibiting phytoplankton production, particularly at stations of shallow area.

Phytoplankton

The tiny, single-celled free floating plants that constitute the phytoplankton provide a dominant link between the inorganic matter and living kingdom of the sea. They convert inorganic carbon, nitrogen, phosphorus, and a host of lesser elements into the reservoir of organic food upon which all animals of the sea subsist. In this role, the phytoplankton have developed powerful chemical mechanisms for the acquisition and concentration of a wide range of extremely dilute substances from sea water (Raymont, 1963).

The importance of the phytoplankton to the problems of the ecology of southern sea waters hence involves the following principle aspects for study. First, As the phytoplankton are the primary producers of food material, their general well-being and level of productivity are of concern, as are any profound alterations of species abundance or composition. Secondly, too much enrichment in coastal waters with limited circulation may result in excessive phytoplankton growth causing red tide.

Man's introduced material, waste water, contains an abundance of nutrients (particularly nitrogen). The investigations reported in this study have shown only modest and local increase in phytoplankton abundance associated with waste discharges. However, this investigations have also demonstrated an important result that one of phytoplankton increase involves the large proliferation of unusual species population. This result indicates that freshwater containing waste water greatly stimulated a specific algal species and led to a potential red tide.

Species Composition

The present study was originally designed to include a seasonal approach to phytoplankton. However, only five cruises could be done, and data obtained during each cruise has been listed accordingly.

There were 219 species of phytoplankton identified during the study (Shim, Kim, and Chough, 1980). Of the total number of species diatomaceous flora with 144 species predominated in the waters over the study arer. Major components of the phytoplankton communities of the study area are shown in Table 5. The majority of the diatoms are neritic and intermediate species. Diatoms representing oceanic or warm water origin probably came from Kuroshio current (Choe, 1966; Lee, Shim and Kim, 1967)

There were 70 dinoflagellate species identified in samples. Dinoflagellates were generally less abundant than diatoms over the study area. 2 silicoflagellates were noted infrequently and were never abundant. 1 euglenoid, 1 cryptomonad and 1 bule-green algae were also noted occasionally.

Abundance and Distribution

Figure 7 shows monthly variation of phytoplankton biomass at each station. Although these data are not completed throughout the year, the phytoplankton bloom and species succession in the study area seemed to follow a pattern of temperature of coastal zone. Summer phytoplankton bloom as experienced in other coastal area of the southern sea (Yoo and Lee, 1979) could be much more pronounced than fall maximum shown here. It is possible that a more pronounced summer maximum was not seen be-

Table 5. Major components of phytoplankton community of the study area observed in each month.

August '79	*Amphiprora paludosa*	*Amphora* sp.
	Ceratium furca	*Ceratium fusus*
	Chaetoceros debilis	*Chaetoceros decipiens*
	Coscinodiscus concinnus	*Coscinodiscus gigas*
	Coscinodiscus megalomma	*Dictyocha fibula*
	Eucampia zodiacus	*Guinardia flaccida*
	Guinardia sp.	*Melosira* sp.
	Nitzschia longissima	*Navicula* sp.
	Nitzschia seriata	*Paralia sulcata*
	Rhizosolenia delicatula	*Rhizosolenia setigera*
	Skeletonema costatum	*Thalassionema nitzschioides*
	Thalassiosira sp.	
September '79	*Gonyaulax conpunctum*	*Melosira* sp.
	Navicula salinarum	*Nitzschia longissima*
	Nitzschia sigma	*Nitzschia longissima* v. *reversa*
	Peridinium catenatum	*Prorocentrum cornutum*
	Skeletonema costatum	*Thalassiothrix frauenfeldii*
October '79	*Actinoptychus undulatus*	*Bacillaria paxillifer*
	Chaetoceros affinis	*Chaetoceros curvisetus*
	Coscinodiscus sp.	*Gonyaulax conpunctum*
	Gonyaulax sp.	*Leptocylindrus danicus*
	Navicula salinarum	*Nitzschia longissima* v. *reversa*
	Paralia sulcata	*Rhizosolenia delicatula*
	Rhizosolenia stolterfothii	*Skeletonema costatum*
November '79	*Bacillaria paxillifer*	*Chaetoceros affinis*
	Chaetoceros curvisetus	*Chaetoceros debilis*
	Conscinodiscus sp.	*Eucampia zodiacus*
	Melosira nummuloides	*Nitzschia longissima*
	Nitzschia seriata	*Nitzschia longissima* v. *reversa*
	Paralia sulcata	
May '80	*Chaetoceros affinis*	*Chaetoceros curvisetus*
	Chroomonas sp.	*Guinardia flaccida*
	Leptocylindrus danicus	*Leptocylindrus minimus*
	Paralia sulcata	*Rhizosolenia hebetata*
	Rhizosolenia imbricata	*Rhizosolenia hebetata* f. *semispina*
	Rhizosolenia shrubsolei	*Rhizosolenia styliformis*
	Skeletonema costatum	*Thalassiothrix frauenfeldii*

cause of the timing of the cruise. Phytoplankton fluctuations with months and stations also suggest strongly that the environmental factors affecting plankton abundance in the study area. A small cryptomonad, *Chroomonas* sp., appeared with very high density (up to 4.6 millions cell/l) only at station 1 in May 1980, where the water was stagnant and the stratification of the water column already formed. This species could develop to a local red tide which may

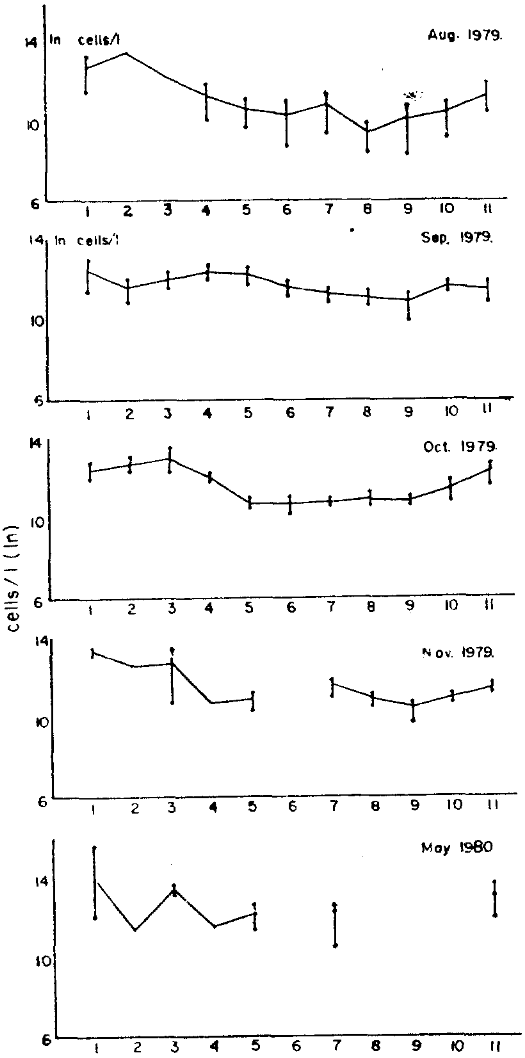

Fig. 7. Monthly Variation of phytoplankton density at each station.

affect seriously the fisheries in the study area.

The volume of plankton is the result of a complex balance between advection, growth, grazing, and a host of other factors. It is difficult to derive a coherent or consistent picture of changes in the concentration of plankton in the southern nearshore waters as they might be related to know environmental factors. The data from this study give some indication that waste water discharges, particularly shallow area, may enhance phytoplankton growth. However, this case occurred only at one area (station 1) and needs further study.

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