The Journal of the Oceanological Society of Korea,
Vol. 17, No. 1, p. 1~11, June 1982.

THE COMMUNITY STRUCTURE AND DISTRIBUTION OF PHYTOPLANKTON OF THE KUM RIVER ESTUARY

Jae-Hyung Shim and Jae-Sam Yang
Department of Oceanography, Seoul National University

ABSTRACT

A study on the community and distribution of phytoplankton of the Kum River Estuary has been done in fall, 1980 and spring, 1981. One hundred and one taxa representing 22 families, 41 genera, 107 species, 2 varieties, and 2 forms were identified. The community of the study area composed mainly of diatom species including the very small fraction of dinoflagellates, blue-greens and greens. The dominant species were *Skeletonema costatum*, *Paralia sulcata*, and *Asterionella kariana*. The total standing crop of phytoplankton of winter samples was 115,000 cells/*l* in average and that of spring samples was 1,320,000 cells/*l* in average. Of the representative members, dominant species above appeared more than 10% of the total standing crop, *Skeletonema costatum* being maximized up to 46%. In spring *Asterionella japonica*, *Thalassionema nitzschioides*, and *Chaetoceros curvistetus* appeared 3~8%, and *Thalassiosira excentricus* 3% in winter. The distribution of marine forms showed negative correlation with that of fresh water forms, although the brackish-water forms showed no relationship. This change pattern of marine, brackish and fresh-water forms are discussed with the results of time series analysis. A list of phytoplankton species observed in this study is added.

INTRODUCTION

Estuaries are significant environments to human welfare with their production, waste disposal and recreational role. Many of the world's largest metropolitan areas have been developed near estuaries. However, the estuarine waters have adversely been affected by human activities. In this context understanding detailed information of estuarine circulation patterns, rates of exchange of materials with coastal and fresh waters, and the ecology of estuarine organisms would be crucial for management of estuaries in the future.

Phytoplankton organisms in estuaries are unable to maintain their distribution against the movement of water masses, and they take an important role as producers in estuarine ecosystems. Thus, the study of estuarine microflora and their ecology are the important parts of estuarine studies.

In 1960's studies on phytoplankton of the estuarine environments with ecological implications have been done by Chung, Shim and Lee (1965), Chung (1969), Chung and Shim (1969). Recently, Lee (1973) investigated the relationship between microflora and water quality in Nakdong River Estuary. In the study area Yoo (1960) reported the composition of microplankton of the Keum River Estuary and a few reports of the biological investigations have been presented by MOST (1967) and the Fisheries Research and Development Agency (FRDA, 1974).

The aims of this study are: (1) to clarify the change pattern of community structure using the time series analysis of phytoplankton data which were collected hourly for 25 hours, and (2) to characterize the spatial distribution of phytoplankton from the data of 8 sampling stations.

STUDY AREA

The study area covers the Keum River Estuary between from 35°50′ N to 36°05′ N and from 126°30′ E to 126°45′ E which is located mid-western coast of Korea (Fig. 1). The area is dominated by a semidiurnal tide having a ratio of amplitude (W_1+K_1/M_2+S_2) of approximate 0.2 and its direction of flood tide is 110° with maximum speed of 1.7 knot and the ebb tide has a direction of 219° with a current speed of 2.8 knots.

METHODS AND MATERIALS

Samples for this study were collected twice from November 30 to December 2, 1980 and April 24～25, 1981. Locations of sampling stations are as shown in Fig. 1.

Hourly samplings at stations A and B have been done for 25 hours during sampling period of time.

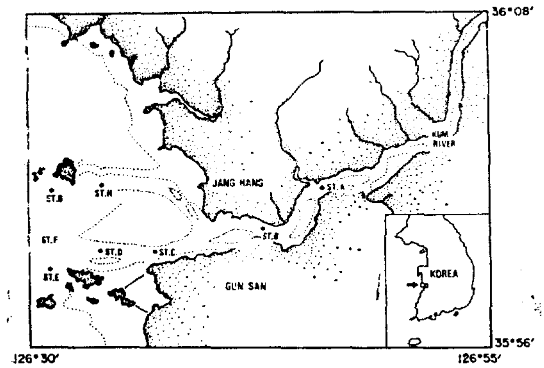

Fig. 1. Map showing the sampling stations

The plankton net used was synthesized nylon cloth with mesh size of 60μm. Samples after collecting were preserved by 5% neutralized formalin. For quantitative analysis 230ml water samples were collected at each station and fixed with Lugol solution. Before counting with Sedgwick-Rafter cell, the samples were well mixed to make organisms distribute evenly.

Current velocity was determined by CM-2 Current Meter, and salinity by Autosal Lab Salinometer (Model No. 8400).

Identified phytoplankton organisms were grouped into fresh water, brackish water, and marine forms, respectively. The ratio of each group/total standing crop was analysed with stational, seasonal, vertical and horizontal differences.

For comparing the change patterns of community structure with hourly intervals at each station, time series analysis was introduced. This method was successfully used to identify the periodicity of insect population (Poole, 1974), and employed to interprete the heterogeneity of oceanographic data (Ibanez, 1981). According to Davis (1973), if two serial data are defined Y_1 i, Y_2 i, and if N^* is the match number, the cross-correlation of m (match position) is

$$r_m = \frac{N^*\sum Y_1Y_2 - \sum Y_1 \sum Y_2}{\sqrt{[N^*\sum Y_1^2-(\sum Y_1)^2][(N^*\sum Y_2^2-(\sum Y_2)^2)]}}$$

and also

$$= \frac{COV_{1.2}}{S_1 \cdot S_2}$$

When $COV_{1.2}$ is the covariance of matched positions of two serial data, and S_1 and S_2 are standard deviation of part 1 and 2. Confidence level of computed cross-correlation coefficient was compensated by

$$t = r_m\sqrt{\frac{N^*-2}{1-r^2_m}}$$

Where (N^*-2) is degree of freedom. Confidence level was checked 95% and 99% level, respectively. The results of this analysis were related to data of November-December, 1981.

RESULTS AND DISCUSSION

I. Water Characteristics

In general the salinity of estuarine environments is higher in lower water than in upper water (Perkins, 1974). In the study area the salinity data measured hourly at stations A and B for 25 hours shows similar tendency. At station A, the salinity of upper layer ranged 1.62~20.57‰ with the average value of 9.03‰, while that of lower layer 1.78~24.14‰, with the average value of 14.15‰. At station B the average salinity were 17.75 ‰ in upper layer and 18.52‰ in lower layer respectively. According to Venice System (Perkins, 1974) which classifies estuarine gradient on the basis of salinity, both stations A and B could be classified as a mixohaline zone.

The velocity and direction of tidal current in the estuarine environment are significant factors in studying the change pattern of community structure. In the study area the maximum velocity of waters at station A was 130 cm/sec with the average of 52cm/sec and at station B the maximum velocity was 187cm/sec with the average of 91cm/sec. The maximum value was measured 3 hours after low water at station A and 2.5 hours after high water at station B. In particular, a counter flow from high tide to HW+1h was observed at station B. In order to clarify this counter-flow bottom velocity of the water was measured at every 5 minute at station B. It was found that at low tide the counter-flow of the upper layer appears 40 minutes earlier than that of bottom layer (Fig. 2-1).

II. Community Structure and Abundance

From 122 samples total 101 species of phytoplankton organisms were identified. These are attributed to 22 Families and 41 Genera and arranged into a classification system following Simonsen (1974), Parke and Dixon (1976) and Shim (1977). The majority of phytoplankton community in the study area is Chrysophyta (98%) and the rest consist of Cyanophyta (1.2%), Dinophyta (0.4%), and Chlorophyta (0.4%), respectively. This combination is agreed with other studies (Lee, 1973; Kim and Cho, 1980; Song, 1980). A taxonomic list is presented in the Appendix below.

Predominating at all stations, diatom species are increased downward estuary and deacreased with upward part of the estuary, while the green algae show the opposite trend.

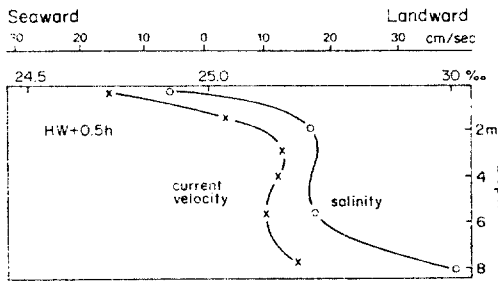

Fig. 2-1. Vertical current velocity and salinity profile at St. B. HW+0.5h means 30 min. after high water

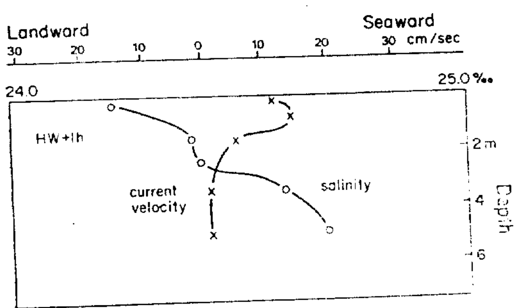

Fig. 2-2. Vertical current velocity velocity and salinity profile at St. A. HW+1h means an hour after high water

It is similar result to those of Chung, Shim, and Lee (1965), Carpenter (1971), and Song (1980).

Dominant species which indicate more than 10% of total standing crop are *Skeletonema costatum*, *Paralia sulcata*, and *Asterionella kariana*. *Asterionella japonica*, *Thalassionema nitzschioides*, *Chaetoceros curvisetus*, and *Thalassiosira rotula* showed 5% of total standing crop in April, 1981, while *Thalassiosira excentricus* showed 3% of total cell numbers during November-December, 1980.

It is well known that periodic tidal current dilutes the sea water and the change of salinity influences the community structure of phytoplankton (Hurlbert, 1963; Soeder and Stengel, 1974; Boney, 1975). In this study an analysis of relative abundance of some dominant species to salinity change indicates that *Skeletonema costatum*, *Paralia*, *sulcata*, *Thalassionema nitzschioides*, *Thalassiosira excentricus* and *Th. rotula* are euryhaline form, while *Asterionella kariana*, *A. japonica* and *Chaetoeros curvisetus* could be stenohaline forms which prefer to high salinity (Fig. 3). It is doubtless that this preference of plankters for salinity contributes to characterize the community structure. The upper area of the Kum River Estuary showed large fluctuations in standing crops which implies that phytoplankton biomass particularly varies with the location and sampling time in the estuarine environment (Table 1). This is agreed with the result elsewhere (Chung, Shim and Lee, 1965). Compared with other results in terms of standing crop (Kurasige, 1943; Cho, 1973), total standing crop in the study area shows approximately 1/2∼2/3 less abundances. It is unlikely due to poor nutrient concentration, but high turbidity caused by strong tidal effect. Yoo (1961) and Kim and Cho (1980) reported similar observations. In this context it is suggested that the higher standing crop in April is mainly caused by the extended radiation and warm temperature.

III. Spatial Distribution of Phytoplankton

Table 2 shows quite different features in distribution of phytoplankton of the Kum River Estuary as expected. At stations C, D and E, most of phytoplankton organisms are marine forms and the very small fractions share fresh-water and brackish-water forms. At stations F, G and H, however, freshwater forms did not occur. Thus, it seems that the study area could be divided into two domains in terms of community structure; the freshwater form-appearing area is with stations C, D and E, and the marine form-dominating area with stations F, G and H.

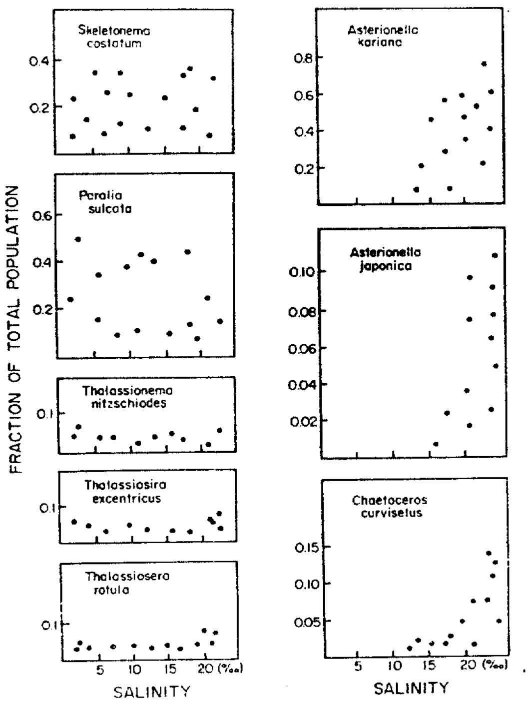

Fig. 3. The relation of the relative abundance of some dominant species to salinity

Table 1. Average standing crops of stations A and B (×1000 cells/l)

Date	Station	Surface layer				Bottom layer			
		fresh forms	brackish forms	freshwater forms	total	fresh forms	brackish forms	freshwater forms	total
Nov. 28-	A	18.47	2.92	75.81	97.2	14.06	3.01	83.33	100.4
29, 1980	B	10.15	1.13	101.52	112.8	11.02	1.57	144.81	157.4
Apr. 24-	A	33.47	8.37	794.96	836.8	39.94	9.98	948.48	998.4
25, 1981	B	68.38	34.19	1607.02	1706.6	63.63	31.82	1495.35	1590.8

To support the above results a cluster analysis have been done with the most frequent species. The results of the cluster analysis show that the phytoplankton distribution of surface layer may be divided into three sections, while that of bottom layer consists of only one section except station G (Figs. 4-1 and 4-2). At high tide the water column may be divided into two sections (Fig. 4-3). The results together with those shown in Table 2 indicates that the community of stations G and H is moving down to station F at low tide and that the community structure of stations C, D and E area is showing no change with both tides. This suggests that distribution of phytoplankton is consistent with the flow pattern which have been reported by ERDA (1974). Table 3 also shows the spatial distribution of phytoplankton in terms of standing crop, indicating that marine forms in abundance are increasing downwards the Estuary, and the fresh-water forms decreasing. However, brackish-forms show no tendency. This results are in accordance with Chung and Shim (1965), and Lee (1973). Thus, it may be concluded that the main runoff route of the Kum River is the southwestern part of the study area and that the phytoplankton of the Kum River Estuary composed of two different communities.

Table 2. The composition of phytoplankton community at each station in the study area.

Station	Layer	Marine forms Species No.	Brackish forms Species No.	Fresh-water forms Species No.
C	Surface	94	2	4
	Bottom	89	5	6
D	S	87	7	6
	B	92	4	4
E	S	93	3	4
	B	93	3	4
F	S	90	10	0
	B	97	3	0
G	S	97	3	0
	B	100	0	0
H	S	93	7	0
	B	98	2	0
F′	S	95	4	1
	B	99	2	1
E′	S	92	4	4
	B	93	3	4
D′	S	91	5	4
	B	93	3	4
C′	S	91	5	4
	B	93	2	7

CDEFGH: Samples collected from outflowing waters
C′D′E′F′: Samples collected from inflowing waters

Table 3. The spatial distribution of three main forms by means of standing crop fraction

Station	Marine forms	Brackish forms	Freshwater forms
A	80	3	17
B	91	1	8
C	92	3	5
E	93	3	4

Ⅳ. The Change Pattern in Community Structure

The structure that results from the distribution of organisms in, and their interaction with, their environment is called pattern (Hutchinson, 1953). Estuarine environment varies with dual changes of physical and chemical properties, and is a transit zone where various different conditions are mixing. Thus, it is important to study distributional pattern of three main forms phytoplankton such as marine, brackish, and freshwater species.

The change pattern of communities which consist of three main groups are shown in Figs. 5-1, 2, 3, 4 where the three components fluctuate with tide variation for 25 hours at stations A and B. At station A, the maximum occurrence of freshwater forms is at 1600 hours and at 0500 hours in surface layer, while the marine forms reach maximum at 1500 hours and 0500 hours. In bottom layer the freshwater forms appear with maximum at 1600 hours and 0700 hours, the marine forms reaching minimum at the same time. Therefore, it seems that freshwater forms of the surface layer appear an hour earlier than those of bottom layer and the minimum appearance of marine forms occurs in surface layer 2 hours earlier than in bottom layer. The brackish forms show no regular pattern. As a whole the change pattern at surface

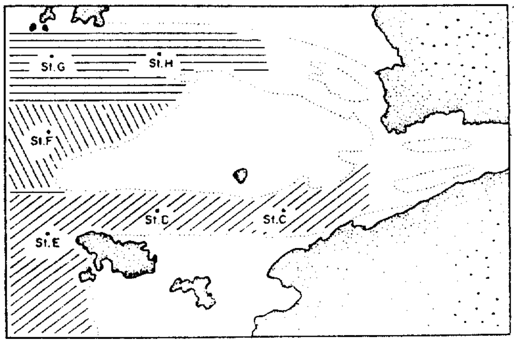

Fig. 4-1. Section of study area by cluster in surface layer (HW−HW+2.5h)

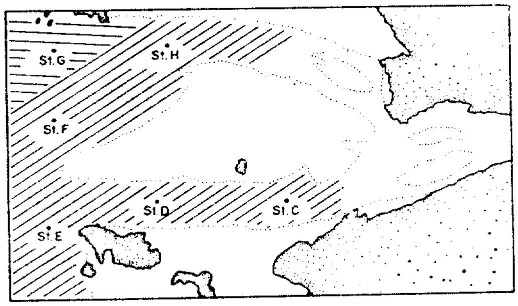

Fig. 4-2. Section of study area by cluster in bottom layer (HW−HW+2.5h)

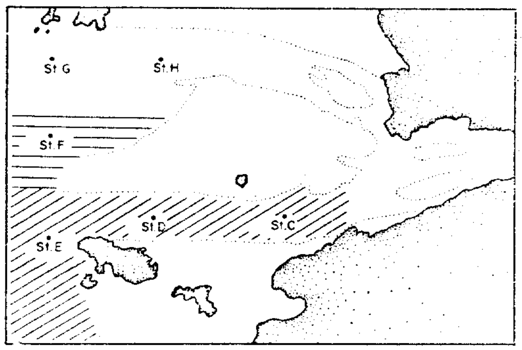

Fig. 4-3. Section of study area by cluster in total layer (HW+2.5h−HW+5h)

Table 4. Correlatition between surface and bottom layers at stations A and B

Group	Layer	Initial Time St. A	Initial Time St. B	Correlation coefficient	T. value
Freshwater	Surface	HW−0.5h	HW+1.5h	0.6985	4.5786*
		−0.5h	+0.5h	0.5943	3.5443*
	Bottom	HW+0.5h	HW−0.5h	0.5475	3.1380*
Brackish	Surface				under 95%
	Bottom				confidence level
Marine	Surface	HW−0.5h	HW+1.5h	0.6921	4.4981*
		−0.5h	+0.5h	0.6587	4.1986*
	Bottom	HW+0.5h	HW−0.5h	0.5224	2.9384*

*99% confidence level

layer is shifted an hour earlier than that of bottom layer. The percent ratio of marine forms reach two peaks, reflecting high waters.

For comparison time series analysis has been introduced. As shown in Table 4, it is evident that the change pattern of surface layer is shifting an hour earlier than that of bottom layer at station A. This suggests that phytoplankton is transported by waters and their distribution is closely related with the time of counter-flow at sampling site. In comparing horizontal variance there is one hour time lag between each layer of stations A and B (Table 5). This time lag is considered as the time for transforming the phytoplankton community between two domains discussed earlier. Comparing marine and freshwater forms, there is a sharp adverse correlation between the change patterns of the two groups. This is agreed with other studies (Chung and Shim, 1965; Lee, 1973).

In conclusion, the time series analysis for phytoplankton communities indicates that the change pattern in community structure could reflect the physical and chemical variables in estuarine environment and is a useful tool for estuarine phytoplankton study.

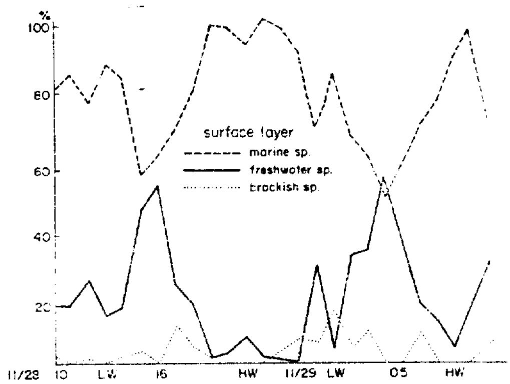

Fig. 5-1. The composition of 3 main forms at St. A in November, 1980

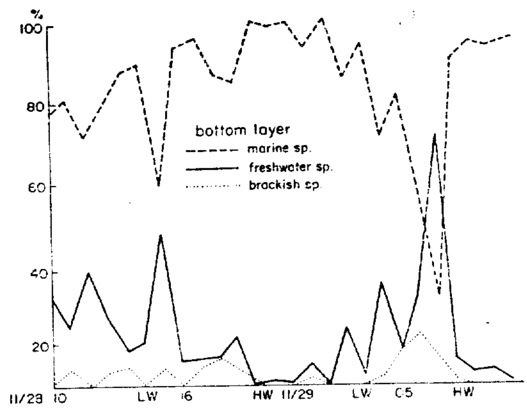

Fig. 5-2. The composition of 3 main froms at St. A in November, 1980

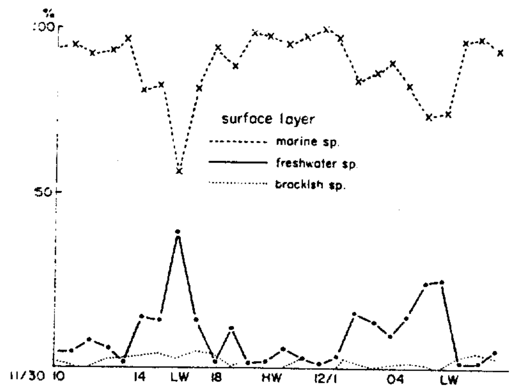

Fig. 5-3. The composition of 3 main forms at St. B in November, 1981

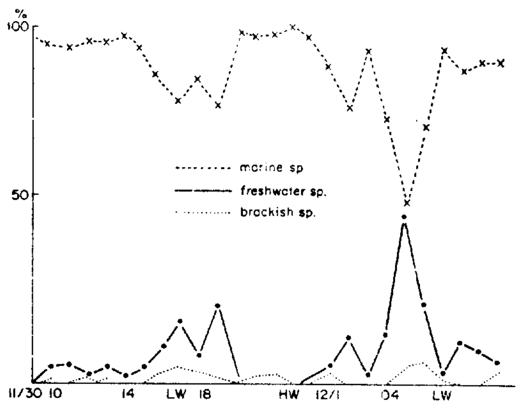

Fig. 5-4. The composition of 3 main froms at St. B in November, 1981

Table 5. Correlation between change patterns of freshwater and marine forms

Station	Layer	Initial Time Freshwater	Initial Time Marine	Correlation Coefficient	T. value
A	Surface	HW+0.5h	HW+0.5h	−0.9409	−13.6113*
	Bottom	HW+0.5h	HW+1.5h	−0.9822	−25.6305*
B	Surface	HW−1.0h	HW−1.0h	−0.7724	− 5.9579*
	Bottom	HW−0.5h	H−0.5h	−0.9644	−17.8676*

*99% confidence level

REFERESNCES

J.C. Davis. 1973. Statistics and Data Analysis in Geology. John Wliey & Sons, Inc. New York. 550pp.

Fisheries Research & Development Agency

1974 Survey of water pollution in surrounding waters of Korea, Technical Reports **23**:88-109

1975 Survey of water pollution in surrounding waters of Korea, Technical Reports **30**:89-100

1977 Survey of water pollution in surrounding waters of Korea, Technical Reports **34**:35-77

Hendey, N.I., 1964. "An Introductory Account of the Smaller Algae of British Coastal Water". In Fishery Investigation series Ⅳ, part Ⅴ, Her Majesty's Stationary Office, p.70-297

Hulburt, E.M. and J. Rodman, 1963. Distribution of phytoplankton species with respect to salinity between the coast of southern New England and Bermuda. Limnol. Oceanogr., **8**(2):263-269

Hutchinson, G.E., 1953. The concept of pattern in ecology, Proc. Acad. Nat. Sci. **105**:1-2

Hydrographic Office, 1978. Technical Reports **1101**: 55-77

Ibanez, F., 1981. Immediate detection of heterogeneities in continuous multivariate, oceanographic recordings. Application to time series analysis of changes in the bay of Ville franche sur Mer Limnol. Oceanogr., **26**(2):336-349

Kim, Y.K. and Y.S. Cho, 1970. Quantity and composition Change of microplankton in Kum River Estuary. (I) Bull. of Gunsan Fish. Coll. 23-26

Kurasige, H., 1943. Quantitative and qualitative characteristics of the marine diatom in the coastal waters of Taiyato at the Yellow Sea Side of Tyosen, in comparison with that of Tataho Bay at the southern coast of the Peninsula. Bull. of the Fisheries Experiment Station, No. 8, p.1-14. p.1

1-2

Lee, J.C. 1973. Studies on the influence of water quality of saline sensitive estuaries of Nak-dong River to microflora The Korean J. of Limnol., **6**, No. 12, p. 1-11

Lee, M.J., J.H. Shim and C.K. Kim, 1967. Studies on the planktonic of the neighboring Seas of Korea part 1: On the marine conditions and phytoplankton of the Yellow Sea in Summer. The Inst. Mar. Biol. SNU, **1**:6

Odum, E.P., 1971. Fundamentals of Ecology. 3rd Ed. W.B. Saunders Co., Philadelphia. 574 pp.

Parke, M. and P.S. Dixon, 1976. Check-list of British marine algae, 3rd revision. J. mar. biol. Ass. U.K., **56**:527-594

Perkins, E.J., 1974. The Biology of Estuaries and Coastal Waters, Academic Press Inc. p. 25-39, 71-104

Poole, R.W., 1974. An Introduction to Quantitative Ecology, McGraw-Hill, Inc. p. 281-292

Pritchard, D.W., 1967. What is an estuary: A physical view point, "Estuaries" Amer. Assoc. Adv. Sci. p. 3-5

Prescott, G.W., 1951. Algae of the Western Great Lakes Area, Cranbrook Inst. of Sci. Bull. **31**: 946pp

Riley, G.A., 1967. The Plankton of estuaries, "Estuaries", Amer. Assoc. Adv. Sci. p. 316-328

Shim, J.H., 1977a. Distributional ecology of planktonic diatoms in the Strait of Georgia, B.C., Jour. of Oceanol. Soc. Korea **12**(1): 13-32

Shim, J.H., 1977b. A taxonomic study of marine planktonic diatoms of Vancouver Island coastal waters. Proc. Coll. Natur. Sci. SNU, **2**(2):79-184

Simonsen, R., 1974. The diatom plankton of the Indian Ocean Expedition of RV "Meteor" 1964~1965 "Meteor" Forschungesergebnissce Reihe D, No. 19, Gebruder Borntraeger, Berlin 61pp.

Smayda, T.J., 1957. Phytoplankton studies in lower Narragansset Bay. Limnol. Oceanogr., **2**:342-359

Soeder, C. and E. Stenge, 1974. Physico-chemical factors affecting metabolism and growth rate. In Algal Physiology and Biochemistry, WDP Stewart ed. Oxford. p. 714-740

Song, J.S. 1980. Standing crop and annual composition change of phytoplankton in Ulsan-Bay. Bull. Fisher. Res. & Dev. Agency **23**:159-169

Yamaji, 1966. Illustrations of the Marine Plankton of Japan, Hikusha Publishing Co. LTD, 369pp.

Yoo, S.K., 1962. A study on the quantity and composition of the microplankton in the coast of southern Chungchung Province in September of 1961. Reports of Tidal Flat Development Survey **2**:57-72

Appendix

CLASSFICATION OF THE PHYTOPLANKTON SPECIES OBSERVED FROM THE KUM RIVER ESTUARY

PHYLUM CHRYSOPHYTA
CLASS BACILLARIOPHYCEAE
ORDER CENTRALES
SUBORDER COSCINODISCINEAE
FAMILY MELOSIRACEAE

Leptcylindrus danicus CLEVE
Leptcylindrus minimus CLEVE
Melosira granulata (EHRENB.) CLEVE
Melosira nummuloides (DILLW.) AGARDH
Melosira varians AGARDH
Paralia sulcata (EHR.) CLEVE

FAMILY THALASSIOSIRACEAE

Thalassiosira baltica (GRUNOW) OSTENFELD
Thalassiosira decipiens(GRUNOW) JOERGENSEN
Thalassiosira hyalina GRUNOW
Thalassiosira rotula GRAN & ANGST
Cyclotella striata (KUETZING) GRUNOW
Skeletonema costatum (GREV.) CLEVE

FAMILY COSCINODISCACEAE

Coscinodiscus asteromphalus EHRENBERG
Coscinodiscus centralis EHRENBERG
Coscinodiscus commutatus GRUNOW

Coscinodiscus curvatulus GRUNOW
Coscinodiscus fimbriatus EHRENBERG
Coscinodiscus granii GOUGH
Coscinodiscus Jonesianus (GREV.) OSTENFELD
Coscinodiscus lineatus EHRENBERG
Coscinodiscus noduljfer A. SCHMIDT
Coscinodiscus oculus iridis EHRENBERG
Coscinodiscus perforatus EHRENBERG
Coscinodiscus radiatus EHRENBERG
Coscinodiscus rothii (EHRENB.) GRUNOW
Coscinodiscus stellaris ROPER
Coscinodiscus wailesii GRAN & ANGST

FAMILY EUPODISCACEAE

Triceratium favus EHRENBERG

FAMILY HELIOPELTACEAE

Actinoptychus splendens RALFS
Actinoptychus seranius EHRENBERG

FAMILY HEMIDISCACEAE

Actinocyclus ergenbergii EHRENBERG

SUBORDER RHIZOSOLENIINEAE
FAMILY RHIZOSOLENIACEAE

Ditylum brightwelii (WEST) GRUNOW
Guinardia flaccida (CASTR.) PERAGALLO
Rhizosolenia alata BRIGHTWELL f. *indica* (PERAG.) GRAM
Rhizosolenia calcar-avis SCHULTZE
Rhizosolenia delicatula CLEVE
Rhizosolenia hebetata (BAIL.) GRAN f. semis-pina (HENSEN) GRAN
Rhizosolenia robusta NORMAN
Rhizosolenia stolterfothii PERAGALLO

FAMILY CHAETOCERACEAE

Chaetoceros affinis LAUDER
Chaetoceros brevis SCHUETT
Chaetoceros curvisetus CLEVE
Chaetoceros danicus CLEVE
Chaetoceros debilis CLEVE
Chaetoceros decipiens CLEVE
Chaetoceros densus CLEVE
Chaetoceros diadema (EHR.) GRAN
Chaetoceros didymus EHRENBERG
Chaetocesos perviarus BRIGHTWELL
Chaetoceros radiaans SCHUETT
Chaetoceros setoensis IKARI
Bacteriastrum hyalinum LAUDER

SUBORDER BIDDULPHIINEAE
FAMILY BIDDULPHIACEAE

Biddulphia aurita (LYNGB.) BREBISSON
Biddulphia mobiliensis BAILEY
Biddulphia pulchella GRAY
Biddulphia reticulata ROPER
Biddulphia rhombus (EHRENBRG) W. SMITH
Biddulphia sinensis GREVILLE
Bellerochea malleus (BRIGHT.) VAN HEURCK

FAMILY EUCAMPIACEAE

Streptotheca thamensis SHRUBSOLE

ORDER PENNALES
SUBORDER ARAPHIDINEAE
FAMILY DIATOMACEAE

Asterionella kariana GRUNOW
Asterionella glacialis CASTRACANE
Fragilaria islandica GRUNOW
Synedra ulna (NITZ.) EHRENBERG
Plagiogramma vanheurckii GRUNOW
Thalassionema nitzschioides (GRUNOW) HUSTEDT
Thalassiothrix frauenfeldii GRUNOW

SUBORDER BIRAPHIDINEAE
FAMILY NAVICULACEAE

Neidium amphigomphus (EHRENBERG) PFITZER
Amphiprora alata (EHRENBERG) KUTZING
Amphiprora perudosa
Gyrosigma balticum (EHRENB.) CLEVE

Gyrosigma wansbekii (DONKIN) CLEVE
Navicula cari EHTENBERG
Navicula distans (Vm. SMITH) SCHMIDT
Navicula fortis (GREG.) RALFS
Navicula salinarium GRUNOW
Navicula (*Caloneis*) *westii* (Vm. SMITH) HENDEY
Pleruosigma angulatum (QUEDETT) W. SMITH
Pleruosigma elongatum W. SMITH
Pleruosigma fasciola (EHRENBERG) W. SMITH
Pleruosigma strigosum W. SMITH
Pleruosigma major (KUTZING) CLEVE
Pleruosigma ambigua CLEVE
Pleruosigma lata BREBISSON var. *minor* (GRUN.) CLEVE

DIVISION CHLOROPHYTA
CLASS CHLOROPHYCEAE
ORDER TETRASPORALES
FAMILY ULOTRICHACEAE

Ulothrix aequelis KUTZING
ORDER ZYGNEMATALES
FAMILY ZYGNEMATCEAE

Spirogyra mirabilis (HASS.) KYTZING
Spirogyra varians (HASS.) KYTZING

ORDER CHLOROCOCCALES
FAMILY SCENEDESMACEAE

Scendesmus dimorphus (TURPIN) KYTZING

FAMILY CHLOROCOCCACEAE

Nitzschia longissima (BREB.) RALFS
Nitzschia palea SMITH
Nitzschia paradoxa GMELIN
Nitzschia seriata CLEVE
Nitzschia sigma (KUETZING) W. SMITH

FAMILY SURIRELLACEAE

Surirella gemma EHRENBERG
Surirella robusta EHRENBERG var. splendida
Campylodiscus ralfsii W. SMITH

PHYLUM DINOPHYTA
CLASS DINOPHYCEAE
ORDER PERIDIALES
FAMILY CERATIACEAE

Ceratium bucephalum CLEVE
Ceratium fusus (EHRENB.) DUJARDIN

DIVISION CYANOPHYTA
CLASS CYANOPHYCEAE
ORDER OSCILLATORIALES
FAMILY OSCILLATORIACEAE

Lyngbya contorta LEMMERMANN