



Periodic changes of the phytoplankton assemblages in the estuary of Tansui River, Taiwan

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Abstract. The periodic changes in the quantitative and qualitative characteristics of phytoplankton in the Tansui estuary were studied. The samples were collected on May 23-24, 1989, October 10-11, 1989, and May 2-3, 1990 for a duration of 24 h, at 3 h intervals. The results show that there were marked changes in the species composition and structure of phytoplankton assemblages during a tidal cycle. There was a succession of dominance: green algae at ebb tide, and diatoms at flow tide. The index values of the species diversity of phytoplankton assemblages fluctuated with the change of tide stand, and is revealed to be related to water quality, which also fluctuated during each tidal cycle. This implies that, like the physicochemical parameters of the water, the diversity index of phytoplankton can be used as an indicator of water pollution in the estuary. Further analysis points out that nitrogen plays a more important role than does phosphate in influencing the succession of phytoplankton assemblages during a diurnal tidal cycle.

Key words: Diversity index; Phytoplankton; Periodic succession; Species composition; Tansui estuary; Water quality.

Introduction

The Tansui River (Fig. 1) is one of the most heavily polluted rivers in Taiwan. The estuary of this river

(Lin and Lee, 1991; Tzeng and Wang, 1992; Wang and Hwang, 1992), of heavy metals (Chiu and Chou, 1991), and of the distribution of nutrients and the variation of environmental factors in mangrove forest areas (Chou

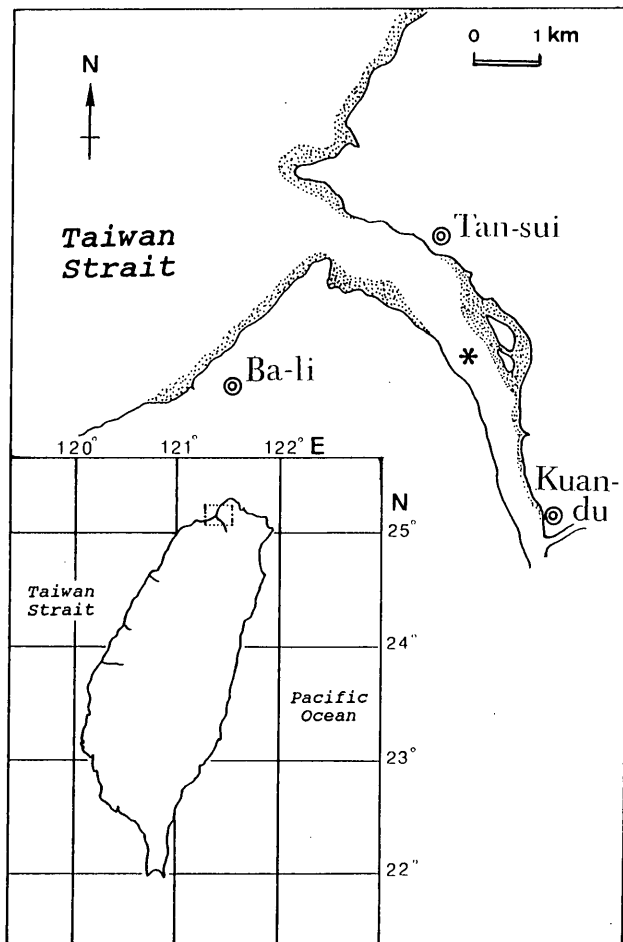


Fig. 1. Map of the Tansui estuary, showing the location of sampling station (*).

Materials and Methods

Sampling and Counting of Phytoplankton

Phytoplankton samples were collected from a station situated in the Tansui estuary. The sampling was carried out on May 23–24, 1989 (Sampling A), October 10–11, 1989 (Sampling B), and May 2–3, 1990 (Sampling C). The samples were taken over a 24 h period, at 3 h intervals. The collected samples were preserved by the addition of 5 ml of Lugol iodine solution to 1 liter of sample. The preserved samples were concentrated by centrifugation ($3000\text{ g} \times 10\text{ min}$) and prepared for microscopic observations.

The samples were filtered through a cellulose nitrate membrane (pore size $0.45\ \mu\text{m}$) under reduced

pressure ($<50\text{ mmHg}$) and then stained with Coomassie blue (0.1% in phosphoric acid (85% in ethanol)). Phytoplankton on the membranes were counted using phase contrast microscopy. The frequency of presence of each species in the estuary was estimated on the basis of the number of cells encountered in one thousand counts per sample.

The changes in the structure of phytoplankton assemblages was indicated by changes in the diversity index. The Shannon diversity index (DI) (Shannon and Weaver, 1949) was employed: $DI = -\sum P_i \log_2 P_i$, where P_i is the percentage abundance of the i th species.

Analysis of Water Quality

The quality of the water in the samples was analysed immediately after sampling. The concentration of nutrients, such as nitrate, nitrite, ammonium, phosphate, and silicate, and the alkalinity of the water were determined with spectroquant reagents purchased from Merck (Darmstadt, Germany). The dissolved oxygen was measured by iodometry, the salinity was measured by hydrometry, and the chlorophyll content was measured by spectrophotometry, as have been described by standard methods (Greenberg *et al.*, 1985). The electrical conductivity was measured with a conductometer.

Results

During each tidal cycle the density of phytoplankton fluctuated markedly. The maximum density was measured at ebb tide and the minimum was measured at flow tide. The fluctuation in cell number matched well with the changes in the concentration of chlorophyll in the water (Fig. 2).

The species composition of phytoplankton altered when the tide stand changed. (Figs. 4 and 5). It was found that there was a succession of green algae and diatoms during each tidal cycle. Green algae were found to be dominant at ebb tide stand. *Pediastrum duplex* predominated in samplings A and C. *P. simplex* predominated in sampling B. Diatoms were the dominant algae at ebb tide stand. The recurring succession of these two groups of algae was independent of the light-dark cycle of the day (Figs. 3, 6, and 9).

In diatom assemblages, the dominant species was different at each sampling time. *Melosira sulcata*, *Chaetoceros* div. sp. and *Coscinodiscus* div. sp. were the

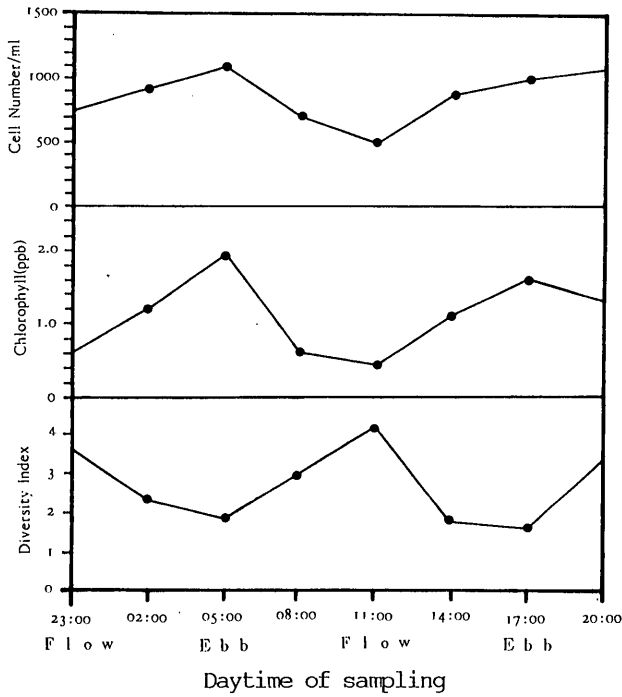


Fig. 2. Fluctuations of the phytoplankton density, chlorophyll content in waters, and diversity index of phytoplankton assemblages at sampling station in the Tansui estuary during May 23-24, 1989.

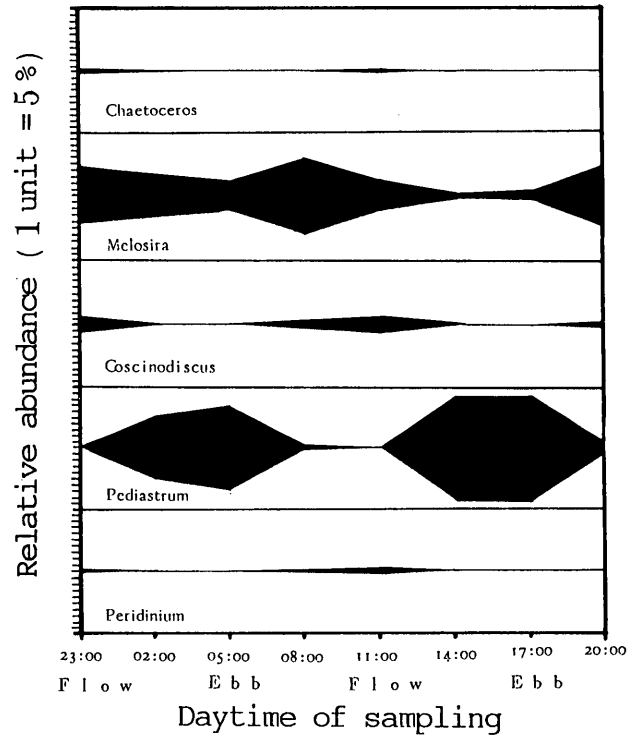


Fig. 3. Succession of dominant phytoplankton at sampling station in the Tansui estuary during May 23-24, 1989.

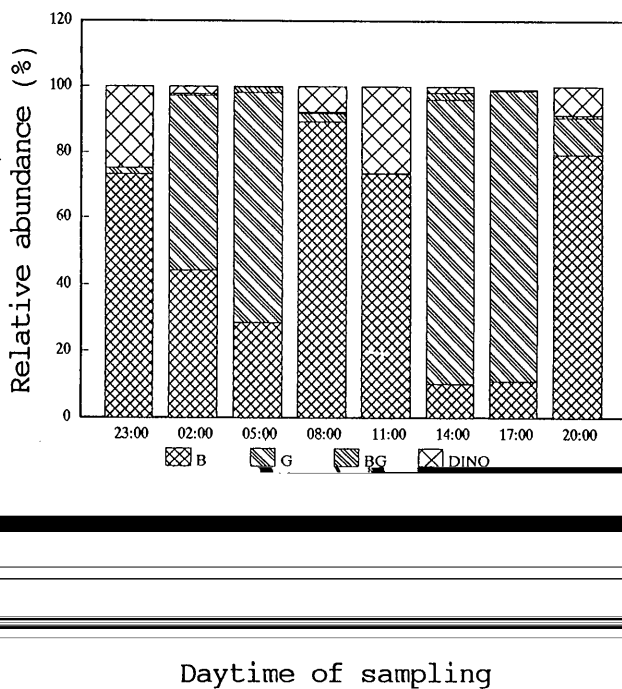


Fig. 4. Changes in the relative abundance of Bacillariophyta (B), Chlorophyta (G), Cyanophyta (BG) and Pyrrhophyta (DINO) at sampling station in the Tansui estuary during May 23-24, 1989.

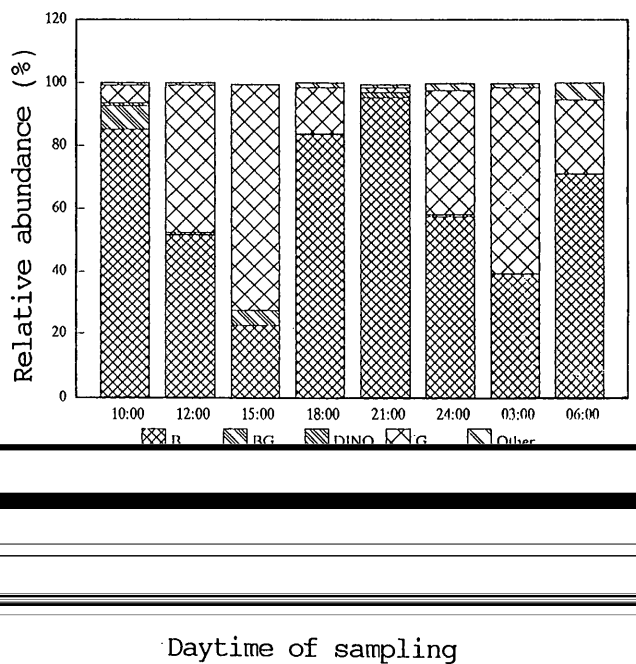
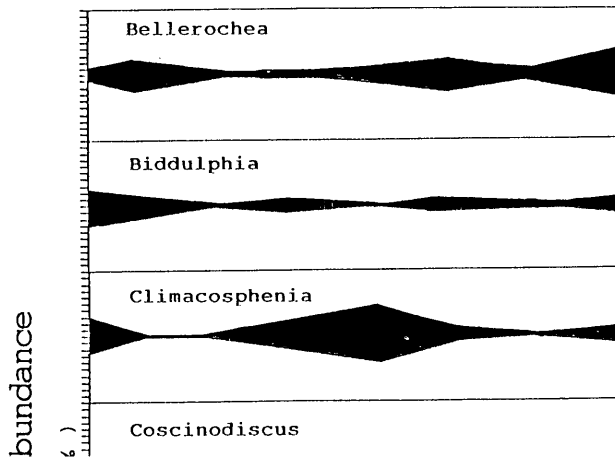


Fig. 5. Changes in the relative abundance of Bacillariophyta (B), Chlorophyta (G), Cyanophyta (BG) and Pyrrhophyta (DINO) at sampling station in the Tansui estuary during October 10-11, 1989.



2 and 8).

The physicochemical character of the water altered when the tidal stand changed. The salinity of the water was found to range between 10‰ and 34‰ during the sampling time. The dissolved oxygen (DO) content of the water fluctuated in the same manner as did the salinity (Figs. 7, 8, and 10). Other factors such as the alkalinity, conductivity, and pH also fluctuated with the change of tide stand. The changes in these parameters were independent of the changes in water temperature.

The concentrations of nutrients, such as nitrate, nitrite, ammonia, phosphate, and silicate, were higher at ebb tide than at flow tide. This occurred in each tidal

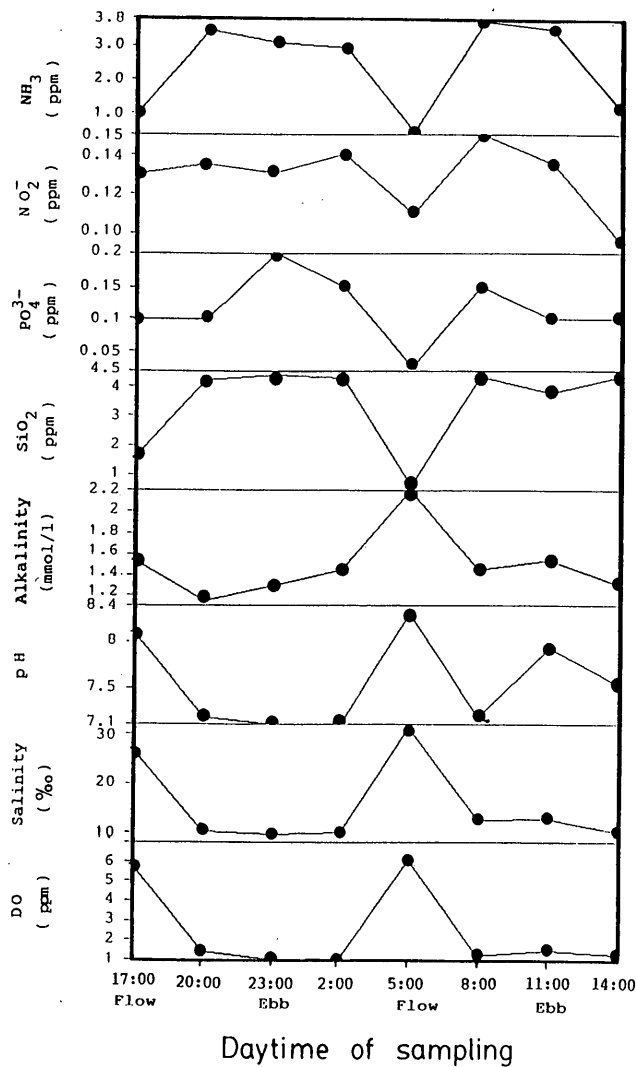


Fig. 10. Changes of the physicochemical environment and the diversity index of phytoplankton assemblages at sampling station in the Tansui estuary during May 2-3, 1990.

Table 1. Correlation coefficients between various physicochemical parameters of the water and the diversity index of phytoplankton assemblages at the sampling station in the Tansui estuary during diurnal tidal cycles of May 23-24, 1989, October 10-11, 1989 and May 2-3, 1990

	NO ₃ ⁻	NO ₂ ⁻	PO ₄ ³⁻	Sil*	pH	Alk*	Cond*	Temp*	Sal*	DI*
NH ₃	-0.05	0.37	0.65	0.96	-0.82	-0.64	-0.27	0.24	-0.94	-0.58
NO ₃ ⁻	1	-0.50	0.01	-0.16	0.09	0.53	0.79	0.25	0.16	0.60
NO ₂ ⁻		1	0.55	0.35	-0.39	-0.35	-0.58	0.17	-0.28	-0.29
PO ₄ ³⁻			1	0.68	-0.80	-0.41	-0.24	0.23	-0.59	-0.19
Sil*				1	-0.88	-0.75	-0.37	0.17	-0.98	-0.68
pH					1	0.64	0.29	-0.14	0.83	0.62
Alk*						1	0.77	0.11	0.75	0.84
Cond*							1	0.16	0.37	0.68
Temp*								1	-0.09	0.12
Sal*									1	0.72

*Sil: silicate; Alk: alkalinity; Cond: conductivity; Temp: temperature; Sal: salinity; DI: diversity index.

trations of ammonium, phosphate, and silicate, and positively correlated with the pH and alkalinity. This indicates that these parameters are strongly affected by the stand of the tide. All of the present results infer a fluctuation in the quality of water during the tidal cycle, and are similar to the results of Chou and Bi (1990).

Hallegraeff and Reid (1986) indicated that nutrient enrichment plays an important role in the short term succession of phytoplankton in coastal areas. The results of this study show that the concentration of silicate in the water was rather high, and fluctuated during the tidal cycle, being higher at flow tide stand than at ebb tide stand. Such a change matches well with the succession of diatoms during a tidal cycle. Silicate is essential to the growth of diatoms. Undoubtedly, the concentration of silicate in the water strongly influences the distribution of diatoms in this area.

A striking fact is that the DI values of phytoplankton assemblages are negatively correlated with the concentration of ammonia, and positively correlated with that of nitrate. Higher concentrations of ammonia in the water indicate a greater degree of pollution. In general, species diversity in a community decreases with increasing pollution (Bahr *et al.*, 1972). Previous studies of the upstream regions of the Tansui River show that it is ammonium, rather than nitrate, which influences the phytoplankton communities (Wu and Suen, 1985; Wu, 1986). The results of our study imply that this is also true in the estuary of the river.

In the Tansui estuary, the DI of phytoplankton assemblages is found to be related more to the concentration of nitrogen sources such as ammonia and nitrate than to that of phosphate. Although the concen-

tration of phosphate in the water fluctuated with the changes in the concentrations of ammonia, nitrite, and silicate, and is related to water quality in the estuary, a very low correlation coefficient between phosphate concentration and DI was obtained. Apparently, the nitrogenous nutrients in this estuary play a more important role than does phosphate in the succession of phytoplankton assemblages. However, our results do not infer that nitrogen sources are the limiting factor for the growth of phytoplankton in this estuary.

The majority of phytoplankton species in the estuarine area usually have a broad tolerance to changes in salinity (Brand, 1984; Bonin *et al.*, 1986). Most of the diatoms found in the Tansui estuary are marine species, and dominate at flow tide stand when the salinity of the water may as high as 35‰. However, some of them also appeared at ebb tide stand, when the salinity might be as low as 10‰. It is likely that these species are tolerant of the changing salinity in the estuary. At ebb tide stand, the dominant species is *Pediasstrum*. The same species that dominate in the estuary also occur in the upstream freshwater region of the Tansui River. Culture study of the isolates of this species in the laboratory show that it can tolerate a salinity of up to 10‰ (data not published). The *Pediasstrum* found in the estuary are probably those originating in the freshwater area, and show tolerance of the brackish environment.

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淡水河口浮游藻類之週期性變化

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本研究在探討淡水河口浮游藻類之日週期變化情形。分別在 1989 年 5 月 23-24 日、1989 年 10 月 10-11 日和 1990 年 5 月 2-3 日三次，作二十四小時每隔三小時之採樣。結果顯示，隨著潮汐水位之日變化，藻類數量和種類有明顯之不同。在滿潮時，藻數量較少，矽藻為優勢種；在退潮時，藻數量較多，而以綠藻為優勢。藻類群落之種歧異度指數也隨著漲退潮而有明顯起伏，其指數值之在滿潮時較高和在退潮時較低，係與水質污染程度有關。從相關分析之結果顯示，水質理化參數中之氨氮、磷鹽、矽酸鹽、鹼度、酸鹼度和導電度等與藻類群落之種歧異度指數值有密切相關，而種歧異度指數可作為此環境之水質指標。分析結果同時顯示，水中之氮鹽比磷鹽對藻類之日消長影響較大。