Introduction

Diatom community structure changes quickly in response to changes in environmental conditions, and it is sometimes used to examine the link between long-term variations in a marine ecosystem and its physical/chemical environment (Chiba & Saino 2002, Chiba et al. 2004). Rapid industrial development enhanced eutrophication of the inner part of Tokyo Bay during the early 1960s and 1970s. Nutrient concentrations did not limit phytoplankton growth after this period (Yamaguchi & Shibata 1979, Han et al. 1989), and Tokyo Bay became one of the most contaminated regions in the world (Ishimaru 1991). The species diversity of diatoms decreased considerably after eutrophication. Compared to before the 1940s, most offshore species disappeared and coastal species occurrence declined (Marumo & Murano 1973). The dominant species in the 1940s (e.g., Chaetoceros affinis Lauder, C. decipiens Cleve, and Thalassionema nitzschioides (Grunow)) were replaced in the 1970s by Eucampia zodiacus Ehrenberg, Rhi-


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Abstract: Temporal variation in the wintertime diatom community structure in Tokyo Bay was investigated from 1981 to 2000 with respect to possible environmental influences. A previous study found that rapid industrialization around the 1960s altered the diatom community. We found that a similar eutrophic-type community with low species diversity dominated by Skeletonema costatum sensu lato (s.l.) still prevailed in 2000, despite recent relaxation of eutrophic conditions. When the cell density and carbon biomass of S. costatum s.l. declined from the mid 1980s to the late 1990s, diatom communities dominated by various species occurred sequentially and species diversity increased. Principal components analysis on environmental factors revealed that S. costatum s.l. favored typical wintertime conditions in the Tokyo district, sunny (less rain) and cold. In contrast, cloudy and warm conditions from the mid 1980s to the mid 1990s were responsible for the decline in S. costatum s.l., allowing other diatom species to grow. The second most important species, Eucampia zodiacus, favored windy years, presumably with strong advection and vertical mixing. The interannual variation of S. costatum s.l. and E. zodiacus populations was out of phase, suggesting that these species had responded to different climatic forcing at different temporal scales.

Key words: community analysis, diatom, long-term variation, Skeletonema costatum sensu lato, Tokyo Bay

Skeletonema costatum sensu lato (s.l.) was the dominant species throughout those decades (Marumo & Murano 1973).

Nomura & Yoshida (1997) and Nomura (1998) reported that the diatom species composition in the early 1990s was similar to that of the 1970s, with S. costatum s.l. dominant. However, most studies of diatom species occurrence in the Tokyo Bay were based on information obtained by sporadic observations (e.g., as a part of red tide observations) (Nomura & Yoshida 1997), and there are no reports about the relationship between phytoplankton community composition and environmental variation based on statistical analysis in Tokyo Bay.

In general, phytoplankton community is affected by physical (e.g. temperature, salinity and solar radiation) and chemical (nutrients) factors as well as biological factors such as allelopathy (Pratt 1966) and predation. However several reports supported that phytoplankton community in Tokyo Bay was barely affected by chemical factors due to high nutrient concentration (Han et al. 1989, Nomura & Yoshida 1997, Yu et al. 1995, Matsumura et al. 2001).
The Tokyo University of Marine Science and Technology conducted monthly routine observations, including phytoplankton sampling, at a fixed station in the inner part of Tokyo Bay from 1981 to the present. In the present study, using phytoplankton samples collected between 1981 and 2000, we analyzed diatom species composition during the winter months to investigate long-term variation in diatom species composition in relation to variations on the physical environment.

Materials and Methods

Diatoms were collected monthly at a station located in Tokyo Bay (35°25′N, 139°48′E; Fig. 1) from January to March during the period 1981–2000 by the R/Vs “Seiyo-Maru” or “Hiyodori.” Surface water (1 L) was sampled and phytoplankton in the seawater were fixed in 1% buffered formalin. After being precipitated in a tube, diatom species were observed under a differential interference contrast microscope, and when necessary, a scanning electron microscope. A minimum of 400 cells were identified to the species level or to the lowest taxonomic level possible for each sample, and cell density (cells mL$^{-1}$) was estimated for each species or taxon. Identification of diatoms was based on Kokubo (1960) and Hasle & Syvertsen (1996). Twenty cells per species were used for estimation of carbon biomass. Parts of each cell were measured following the methods of Kovala & Larrance (1966), and cell thickness was defined as the minor axis ×3/5 (Miyai et al. 1988) as an estimate of cell volume. For Eucampia zodiacus, which has a trapezoid shape, depth was defined as the length of the upper line ×2/3 to avoid overestimation of the volume. Community carbon biomass (μg L$^{-1}$) was estimated using the volume-carbon ratio (Strathmann 1967) and cell density (cells mL$^{-1}$). Menden-Deuer & Lessard (2000) pointed out that this equation leads to overestimate for large diatoms. However, subsequent researchers have continued to use this equation for carbon estimates (e.g. Chang et al. 2003, Bode et al. 2005, Bos et al. 2006, Sekino et al. 2007). In the present study, the overestimation for large diatoms is regarded to be negligible because small diatoms (e.g. Skeletonema costatum s.l.) dominated in terms of not only cell density but also carbon biomass.

We used a cluster analysis to investigate temporal variation in diatom community structure using R language (ver. 2.0.0). Each year-month sample was classified into several clusters based on similarity in diatom species composition (%) estimated from carbon biomass. Data for species whose occurrence never exceeded 20% of the total throughout the research period were eliminated from the analysis. A dissimilarity matrix was obtained using the Bray & Curtis method (Bray & Curtis 1957), and a dendrogram was drawn based on the unweighted pair group method using arithmetic mean (UPGMA) linkage. Species diversity was measured for each cluster group using the diversity index $H'$ (Shannon & Weaver 1949) based on average cell den-
Long-term variation of diatoms in Tokyo Bay

Sea surface temperature, sea surface salinity, solar radiation, precipitation, chlorophyll $a$ and wind speed data were used to examine the influence of environmental conditions on interannual variation in diatom community structure. Sea surface temperature and sea surface salinity were measured on each sampling occasion, except during January–March 1981, 1982, and 1986, and January 1983. For these dates, data were taken by the Kanagawa Prefectural Fisheries Technology Center at Station 112 (Fig. 1; Kanagawa Prefectural Government 1981–1983, 1986). We used monthly mean solar radiation data taken by the Tokyo District Meteorological Observatory (Fig. 1; Japan Meteorological Agency 1981–2000a), and precipitation and wind speed data taken by the Yokohama Local Meteorological Observatory (Fig. 1; Japan Meteorological Agency 1981–2000a). Because a north wind enhances horizontal water exchange between the offshore and inner bay areas, as well as vertical water mixing in Tokyo Bay (Nomura 1995, Nagashima & Matsuyama 1999), monthly mean wind direction from the Yokohama Local Meteorological Observatory was examined (Fig. 1; Japan Meteorological Agency 1981–2000b). Chlorophyll $a$ was measured on each sampling occasion during the period from 1983–2000 using the fluorescence method (Strickland & Parsons 1972).

Principal components analysis (PCA) was used to investigate interannual variation in environmental conditions in Tokyo Bay using SPSS ver. 14.0 (SPSS Inc., Chicago, IL). The monthly environmental data listed above were averaged yearly and normalized (mean = 0, standard deviation = 1) prior to the PCA. The correlations between the time-series of principal components (PCs) and each environmental variable, and between PCs and dominant species were examined with Pearson’s correlation coefficients.

Table 1. Species of diatoms that occurred in the central part of Tokyo Bay during the periods from January to March from 1981 to 2000.

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Genus Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actinocyclus senarius (Ehrenberg)</td>
<td>D. sol Grunow</td>
</tr>
<tr>
<td>Cerataulina dentata Hasle in Hasle &amp; Syvertsen</td>
<td>Eucampia zodiacus Ehrenberg</td>
</tr>
<tr>
<td>Ce. pelagica (Cleve)</td>
<td>Nitzschia longissima (Brébisson in Kützing)</td>
</tr>
<tr>
<td>Ce. sp.</td>
<td>Pleurosigma affine Grunow</td>
</tr>
<tr>
<td>Chaetoceros affinis Lauder</td>
<td>Pseudo-nitzschia spp.</td>
</tr>
<tr>
<td>Ch. atlanticum Cleve</td>
<td>Rhizosolenia hebetata f. semispina (Hensen)</td>
</tr>
<tr>
<td>Ch. curvisetum Cleve</td>
<td>R. robusta Norman in Prichard</td>
</tr>
<tr>
<td>Ch. danicum Cleve</td>
<td>R. setigera Brightwell</td>
</tr>
<tr>
<td>Ch. debilis Cleve</td>
<td>R. styliformis Brightwell</td>
</tr>
<tr>
<td>Ch. decipiens Cleve</td>
<td>Skeletonema costatum (Greville) sensu lato</td>
</tr>
<tr>
<td>Ch. diadema (Ehrenberg)</td>
<td>Stephanopyxis palmeriana (Greville)</td>
</tr>
<tr>
<td>Ch. didymum Ehrenberg</td>
<td>Thalassionema frauenfeldii (Grunow)</td>
</tr>
<tr>
<td>Ch. lorenzianus Grunow</td>
<td>T. nitzschioides (Grunow)</td>
</tr>
<tr>
<td>Ch. paradoxum Peragallo</td>
<td>Thalassiosira angustelineata (A. Schmidt)</td>
</tr>
<tr>
<td>Ch. radicans Schutt</td>
<td>T. baltica (Grunow)</td>
</tr>
<tr>
<td>Ch. teres Cleve</td>
<td>T. decipiens (Grunow)</td>
</tr>
<tr>
<td>Coscinodiscus asteromphalus Ehrenberg</td>
<td>T. eccentrica (Ehrenberg)</td>
</tr>
<tr>
<td>C. concinnum Wm. Smith</td>
<td>T. hyalina (Grunow)</td>
</tr>
<tr>
<td>C. gigas Ehrenberg</td>
<td>T. mala Takano</td>
</tr>
<tr>
<td>C. grunii Gough</td>
<td>T. nordenskioeldii Cleve</td>
</tr>
<tr>
<td>C. radiatus Ehrenberg</td>
<td>T. oestrupii (Ostenfeld)</td>
</tr>
<tr>
<td>C. wailesii Gran &amp; Angust</td>
<td>T. rotula Meunier</td>
</tr>
<tr>
<td>Dactyliosolen fragilissimus (Bergon)</td>
<td>T. sp.</td>
</tr>
<tr>
<td>Ditylum brightwellii (West)</td>
<td></td>
</tr>
</tbody>
</table>
such as *Rhizosolenia setigera* and *Coscinodiscus wailesii* Gran & Angust. Of the 46 species, 19 were the dominant on at least one sampling occasion, and 10 species dominated only once.

Total cell density in the study period fluctuated between $0.76 \times 10^9 - 97.0 \times 10^2$ cells mL$^{-1}$ with a mean of $12.7 \times 10^2$ cells mL$^{-1}$ (Fig. 2). The maximum and minimum values were recorded in March 1998 and March 1989, respectively. Twenty-year mean values for each month were $10.7 \times 10^2$ cells mL$^{-1}$ in January, $11.2 \times 10^2$ cells mL$^{-1}$ in February and $16.2 \times 10^2$ cells mL$^{-1}$ in March. Total cell density in the study period fluctuated between $0.76 \times 10^9 - 97.0 \times 10^2$ cells mL$^{-1}$ with a mean of $12.7 \times 10^2$ cells mL$^{-1}$ (Fig. 2). The maximum and minimum values were recorded in March 1998 and March 1989, respectively. Twenty-year mean values for each month were $10.7 \times 10^2$ cells mL$^{-1}$ in January, $11.2 \times 10^2$ cells mL$^{-1}$ in February and $16.2 \times 10^2$ cells mL$^{-1}$ in March. No marked interannual tendency was observed. Chlorophyll *a* concentration also did not show any clear patterns of change over the study period (Fig. 4). This result mirrored the lack of decadal oscillation observed for carbon biomass. Meanwhile, the ratio of *S. costatum* s.l. biomass to total biomass exhibited a decadal oscillation with a decrease in the 1980s and an increase in the 1990s (Fig. 4).

Interannual variation of major diatom species

The total cell density was high during the early 1980s, started declining in the late 1980s, remained low in the early 1990s, and recovered to the early 1980s level in the late 1990s. This interannual variation in total cell density was mainly determined by the abundance of *S. costatum* s.l. (Fig. 2). Cell density of *S. costatum* s.l. fluctuated between $0$ and $95.2 \times 10^2$ cells mL$^{-1}$ with a mean of $0.92 \times 10^2$ cells mL$^{-1}$. The maximum value was recorded in March 1998 (Fig. 2). Its carbon biomass fluctuated between $0.0 – 402.1$ μg L$^{-1}$ with a mean of $61.6$ μg L$^{-1}$ and the maximum was recorded in March 1998 (Fig. 3).

Dominance of *S. costatum* s.l. was especially high during

![Fig. 2](https://example.com/fig2.png)  
*Fig. 2.* Cell density (cells mL$^{-1}$) of the major diatom species during the winter (January–March) from 1981 to 2000 in Tokyo Bay. N.D. indicates that no data are available.

### Table 2. Dominant species and their dominance ratio (D.R.), which means a ratio of the number of the samples in which the species was the first dominant in terms of cell density (left) and carbon biomass (right) to the total number of the samples examined.

<table>
<thead>
<tr>
<th>Dominant species</th>
<th>D.R. (%)</th>
<th>Dominant species</th>
<th>D.R. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Skeletonema costatum</em> s.l.</td>
<td>59</td>
<td><em>Skeletonema costatum</em> s.l.</td>
<td>38</td>
</tr>
<tr>
<td><em>Eucampia zodiacus</em></td>
<td>9</td>
<td><em>Pseudo-nitzschia</em> spp.</td>
<td>10</td>
</tr>
<tr>
<td><em>Pseudo-nitzschia</em> spp.</td>
<td>5</td>
<td><em>Eucampia zodiacus</em></td>
<td>7</td>
</tr>
<tr>
<td><em>Chaetoceros debilis</em></td>
<td>3</td>
<td><em>Rhizosolenia setigera</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Chaetoceros radicans</em></td>
<td>3</td>
<td><em>Coscinodiscus wailesii</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Thalassiosira decipiens</em></td>
<td>3</td>
<td><em>Thalassiosira decipiens</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Thalassiosira rotula</em></td>
<td>3</td>
<td><em>Ditylum sol</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Thalassiosira angustelineata</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Thalassiosira eccentrica</em></td>
<td>3</td>
</tr>
</tbody>
</table>
the early 1980s and the late 1990s, occasionally accounting for more than 90% of the total cell density. The carbon biomass of \textit{S. costatum} s.l. declined in the late 1980s as cell density decreased. However, the decline in \textit{S. costatum} s.l. abundance during this period influenced the total carbon biomass less than the cell density because other diatom species occasionally replaced \textit{S. costatum} s.l. as the dominant species (Figs. 2, 3).

Cluster analysis

Year-month diatom communities were classified into eight clusters (Groups I–VIII) with distinctive diatom species compositions at the 83% dissimilarity level (Fig. 5). Dominant species and the species diversity of each cluster are listed in Table 3. Group I, the largest group, was characterized by low species diversity (0.76) and a marked dominance of \textit{Skeletonema costatum} s.l. (54.0%). Group I frequently occurred in the early 1980s and the late 1990s (Fig. 6), as indicated by the variation in \textit{S. costatum} s.l. biomass (Fig. 3). This group especially dominated in March. When Group I did not appear, mostly in January and February from the mid 1980s to the mid 1990s, diverse community groups appeared in turns. Group II, the second largest group, was characterized by the dominance of \textit{Eucampia zodiacus} (42.2%) and higher diversity (1.32). Group II appeared in 1984, 1986, 1990, 1995, and 2000. Groups III and IV were high diversity (≥1.40) communities dominated by \textit{Ditylum} spp. and \textit{Thalassiosira angusti-lineata} (A. Schmidt), respectively. Groups V and VII were dominated by \textit{Thalassiosira} spp., had moderate diversity (1.25–1.31), and appeared only occasionally. Groups VI and VIII were low diversity (<1.13) groups characterized by a marked dominance of a single large species, \textit{Rhizosolenia setigera} and \textit{Coscinodiscus wailesii}, respectively. These groups appeared on only a few occasions.
Interannual variation in environmental conditions

The mean sea surface temperature was 10°C (range: 6.5–12.5°C), with a decadal oscillation and a significant increase of 0.08°C year\(^{-1}\) \((p<0.05;\) Fig. 7a\). The mean sea surface salinity was 32.2 (range: 28.3–34.2) with low values in the mid 1980s, but neither a distinct oscillation nor any other significant trends were observed (Fig. 7b). The mean solar radiation was 10 MJ m\(^{-2}\) day\(^{-1}\) (range: 6.5–14.7 MJ m\(^{-2}\) day\(^{-1}\)) with low values from the mid 1980s to the early 1990s and high values during the early 1980s and after the mid 1990s (Fig. 7c). Precipitation (mean: 3.0 mm day\(^{-1}\), range: 0.1–16.0 mm day\(^{-1}\)) showed an out-of-phase interannual variation pattern with solar radiation: high from the mid 1980s to the early 1990s and low during the early 1980s and after the mid 1990s (Fig. 7d). The mean wind speed was 3.7 m s\(^{-1}\) (range: 2.2–4.5 m s\(^{-1}\); Fig. 7e) and wind direction was exclusively southward (north wind) throughout the study period.

Characteristics of the first to third PCs from the PCA based on environmental variables are listed in Table 4. The first, second, and third PCs (PC1, PC2, and PC3, respectively) explained 43, 27, and 19%, respectively, of the variation. PC1 had a significant negative correlation with precipitation and sea surface temperature \((p<0.01)\), and a positive correlation with solar radiation and sea surface salinity \((p<0.01\) and \(p<0.05,\) respectively). PC2 had a significant negative correlation with wind speed \((p<0.01)\). PC3 had a significant positive correlation with wind speed \((p<0.05)\) and a negative correlation with precipitation \((p<0.05)\). The PC1 time series showed a quasi-decadal oscillation with negative values from the mid 1980s to the early 1990s but positive around the mid 1990s (Fig. 8). PC2 also oscillated...
but its period was shorter than PC1, with a base around the mid 1980s and peaks in the early 1980s and the early 1990s. PC3 had the highest frequency variation, showing a 3–4 year oscillation (Fig. 8).

Relationships between major two species and environmental factors

Interannual variation in cell density of *Skeletonema costatum* s.l. and *Eucampia zodiacus* was compared to the PCs. We considered *E. zodiacus* to be one of the most important species because it was dominant in the second largest community (Group II) and its occurrence was relatively large both numerically and quantitatively (Table 2). Neither *S. costatum* s.l. nor *E. zodiacus* had a significant correlation with any PC (*p* > 0.05), although a weak correlation was detected between *S. costatum* s.l. and PC1 (*N* = 20, *r* = 0.386, *p* = 0.09). However, comparison with 5-year running mean showed a positive correlation between *S. costatum* s.l. and PC1 (*N* = 15, *r* = 0.737, *p* < 0.01; Fig. 9a), and a negative correlation between *E. zodiacus* and PC2 (*N* = 15, *r* = −0.619, *p* < 0.05; Fig. 9b), suggesting influences of environmental forcing with a 5-year or longer period on diatom community structure in Tokyo Bay.

### Discussion

This study examined variation in the diatom community structure of Tokyo Bay for 20 years since the 1980s. The diatom community in Tokyo Bay consisted of offshore and coastal species in the 1940s, when 35 species were identified (Marumo & Murano 1973). Marumo & Murano (1973) reported that the number of species had declined to 21 following the development of eutrophic conditions. We observed the greater species number of diatoms (more than 46 species), partly because our study period (20 years) was much longer than in their studies (few years). However, the community in the present study was domi-
nated by a few very abundant species such as *Skeletonema costatum* s.l., *Eucampia zodiacus*, *Chaetoceros debilis* Cleve, and *Thalassiosira decipiens*, and species diversity was generally low. These were the common species that dominated in Tokyo Bay after the 1970s.

*Skeletonema costatum* s.l., the most dominant species in this study, is an indicator species for coastal eutrophic wa-

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**Fig. 7.** Annual mean of environmental factors during the winter (January–March) from 1981 to 2000 in Tokyo Bay: (a) sea surface temperature, (b) sea surface salinity, (c) solar radiation, (d) precipitation, and (e) north–south component of the wind speed.

**Fig. 8.** Time series of the first to third principal components (PC1–PC3) for the period 1981–2000 estimated based on the environmental variables (sea surface temperature, sea surface salinity, solar radiation, precipitation, and wind speed).

**Fig. 9.** Time series of (a) PC1 and abundance (log cells mL$^{-1}$) of *Skeletonema costatum* s.l., and (b) PC2 and abundance (log cells mL$^{-1}$) of *Eucampia zodiacus*. All time series are 5-year running mean.
ters in Japan (Takada & Nishida 1984, Tsuruta et al. 1987, Nakamura et al. 1989, Yoshida et al. 2000, Yamada & Kazuwar 2004) and in other countries (Revelante & Gilmartin 1980, Karentz & Smya 1984, Zhao et al. 2005). This species usually dominates phytoplankton communities in terms of cell density, but seldom in terms of carbon biomass because of its small cell size (Kim et al. 2004). However, we observed the dominance of *S. costatum* s.l. both numerically and quantitatively.

Matsumura et al. (2001) reported that the mean of dissolved inorganic nitrogen (DIN) gradually decreased from around 35 µM in 1989 to around 30 µM in 1998. However, the present result revealed the dominance of *S. costatum* s.l. during the study period, suggesting that the DIN value in the late 1990s was not a level sufficient to alter diatom community structure.

Although *S. costatum* s.l. dominated the diatom community, its numerical abundance and biomass varied. When its occurrence was moderate, especially from the late 1980s to the mid 1990s, several community groups with distinctive species composition replaced the *S. costatum* s.l. group (Group I in Fig. 6). Species diversity increased when those community groups appeared, except for the one dominated by *Rhizosolenia setigera*, and the frequency and interval of the appearance of these groups varied. The decline in *S. costatum* s.l. due to unfavorable environmental conditions likely provided other diatom species with ecological niches. A similar succession pattern was observed in Osaka Bay (Yoshida et al. 2000), where diverse species occurred when the abundance of *S. costatum* s.l. declined.

We found a significant positive correlation between temporal variation in *S. costatum* s.l. abundance and PC1. Pearson’s correlation between interannual variation of PC1 and environmental variables indicated that PC1 was significantly positively correlated with solar radiation and sea surface salinity, and negatively with precipitation, sea surface temperature and wind speed. These correlations suggest that *S. costatum* s.l. was abundant in years with sunny, less rainy, cool, and saline conditions, whereas it was less abundant in years with rainy, cloudy, warm, and low salinity conditions. Han et al. (1989) indicated that occurrence of less saline (<20) water due to inflow of river waters leads *S. costatum* s.l. blooms (>10⁵ cells mL⁻¹) during the spring and the summer in Tokyo Bay. This is contrary to our result of the positive relationship between *S. costatum* s.l. abundance and salinity, suggesting that other environmental variables may more affect on *S. costatum* s.l. abundance during the winter. Among the variables studied here, solar radiation, which was suggested to be positively correlated with *S. costatum* s.l., is possibly considered because light condition during the winter may be more critical for phytoplankton than in the summer.

The present study revealed a negative correlation between the time-series abundance of *Eucampia zodiacus* and PC2, indicating that *E. zodiacus* became more abundant in years with strong winds. This suggests that the abundance of *S. costatum* s.l. and *E. zodiacus* in Tokyo Bay varied with different climatic forcings at different temporal scales. Their interannual variation may be accounted for by some large-scale climatic forcings, perhaps by the rainy (cloudy), warm, and windy conditions. We examined the correlations between the PCs and several climatic indices of the Pacific Ocean with various frequencies; i.e. the Pacific Decadal Oscillation index (Joint Institute for the Study of the Atmosphere and Ocean 2007), North Pacific Index (The National Center for Atmospheric Research 2007a), and wintertime Southern Oscillation Index (The National Center for Atmospheric Research 2007b), which influence wintertime hydrographic conditions and the lower levels of the food web in waters adjacent to Japan (Chiba & Saino 2003, Chiba et al. 2006). However, no significant correlations were detected between the PCs and the climate indices. In contrast to the offshore environment, local weather in the inner bay might be determined by a combination of multiple climatic and geographic conditions.

*Skeletonema costatum* s.l. became the dominant species in Tokyo Bay as eutrophication proceeded, and the dominance of the species continued during study period due to the nutrient unlimited growth of phytoplankton. Recently, Kanda et al. (2008) reported depletion of nutrients, especially phosphate, in Tokyo Bay. Owing to efforts towards reducing the nutrient load to the bay by local governments along the coast, nutrient depletion in the winter season may occur in the near future and phytoplankton community composition may change as a consequence. It is our intention to continue monthly monitoring of phytoplankton at the same station and it is expected that statistical analysis including nutrients as environmental factors should reveal the effect of nutrient load reduction on phytoplankton community composition.

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