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Dynamic of Particulate Organic Matter and Phytoplankton in Akkeshi-ko Estuary

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Abstrak

Penelitian ini dilakukan untuk mendapatkan gambaran yang jelas mengenai dinamika dari bahan organik terlarut dan komposisi jenis dari fitoplankton pada perairan estuari Hokkaido. C/N ratio diukur dengan menggunakan C/N analyzer dan identifikasi fitoplankton dilakukan di bawah mikroskop elektron. Fluktuasi musiman dari konsentasi PON dan POC dalam perairan relatif sama di seluruh stasiun pengamatan. Konsentrasi POC dan PON relatif lebih tinggi pada bagian dalam Akkeshi estuary selama musim semi dan musim panas dan konsentasi tersebut terlihat lebih tinggi di luar lokasi estuari selama musim gugur. Dari total 128 jenis yang diidentifikasi di lokasi penelitian, 103 spesies fitoplankton ditemukan pada permukaan sedimen dan 102 diantaranya ditemukan mengapung di perairan. Pada permukaan sedimen ditemukan 12 spesies dari diatom bentik dan 2 spesies dari diatom pelagik dan mendominasi lokasi penelitian. Pada kolom air ditemukan 12 spesies dari diatom bentik dan 3 spesies dari diatom pelajik ditemukan dominan dan mendominasi lokasi penelitian. Hal ini disebabkan oleh terjadinya peningkatan bahan organik terlarut dan fitoplankton selama musim semi dan musim panas yang disebabkan oleh peningkatan kandungan nutrien yang berasal dari luar perairan estuari.

Kata kunci: *Bahan organic terlarut, fitoplankton, bentik diatom, pelagik diatom*

Abstract

This research was to clarify the dynamic of particulate organic matter (POM) and species composition of phytoplankton in an estuarine. C/N ratio was measured in a C-N Analyzer and phytoplankton was identifying under electron microscope. The seasonal fluctuation of POC and PON concentration was generally similar in all stations. POC and PON concentration were generally higher in inert part of estuary during spring and summer and its concentrations seem high at outside part during autumn. From total 128 species of diatoms identified in the Akkeshi-ko estuary, 103 and 102 species of phytoplankton occurred on the upper layer of sediments and in water column, respectively. On the upper layer sediments, there were 12 species of benthic diatoms and 2 species of pelagic diatoms were most common and dominantly occurred in all stations. In water column, 12 species of benthic diatoms and 3 species of pelagic diatoms were most common and predominantly occurred in all stations. The main reason of this condition is the concentration of POM and phytoplankton was increase during spring and summer cause of high input nutrient from outside of estuarine.

Key words : *particulate organic matter, phytoplankton, benthic diatom, pelagic diatom.*

Introduction

In most of estuarine ecosystems, POM plays an important role as a key component of biogeochemical cycles and providing nutrition for the basal food web (Minor *et al.,* 2001). POM and POC served as important organic matter to support estuarine microbial food weebs (Prahl *et al*.,1997; Kasim, 2006). Particulate organic matter (POM) in estuaries or coastal seas composed of marine origin, i.e. the ultimate source of the POM is marine phytoplankton, and a terrestrial origin, as rivers and winds transport POM from the continents to the sea. The rivers alone transport annually more particulate organic carbon to the oceans than the total amount of organic carbon buried in all marine sediments (Megens, 2000).. In a tidal shallow estuary, rivers were the major source of nutrient and organic matters (Prahl *et al*.,1997; Kasim, 2006). This area has also been influenced by the tidal current as the major factor for the input and output of organic matters. The correspondence between river and ocean flow system enhance the turbulent systems and affects the increasing of the organic and inorganic materials cycling in these sites (Ogawa & Ogura,1997) and as a preferential places for accumulation of organic matter from marine and river (Goni *et al*., 2003). Generally, these areas have high inorganic nutrients and particulate organic matter (POM) available for a major cycling pattern of essential elements such as C, N and P (Minor *et al.,* 2001).

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POM is supplied to estuaries from a variety of sources. In the fact, amounts of organic matter were come from the coastal sea, local runoff and sediments. POM in water column of estuaries is composed of living organisms (mainly phytoplankton, as well as bacterioplankton and microzooplankton) and non-living particles (fraction of detritus or organic debris that generally from non-living planktonic materials and small piece of macrophyte, which represent potential energy sources for consumer species) (Volkman & Tanoue, 2002; Goni *et al*., 2003).

Phytoplankton which is the most important in the total particulate organic matter in the estuary is a pivotal role in carbon cycling of estuarine food web (Muylaert *et al*., 2000). It is providing particulate organic carbon as nutritive for higher trophic level (Revilla, 2000).

In this study, dynamic of POM and phytoplankton were investigated in the Akkeshi-ko estuary. The aim of this research is to clarify dynamic and fluctuation of POM as carbon and nitrogen (C/N) content in water column and the phytoplankton community as a part of organic POM in Akkeshi-ko estuarine. The structure composition and abundance, of 'phytoplankton' in the water column was also examined to compare between species composition of the phytoplankton assemblages in sediment and in water column.

Materials and Methods

Study sites and field methods

The field study was conducted at the Akkeshi-ko estuary, which located at eastern part of Hokkaido (43° 00' N 144° 51' E), Northern Japan (Figure. 1). The Akkeshi-ko estuary is almost enclosed but connected to Akkeshi Bay with a narrow channel. Most of the estuary is covered with extensive eelgrass, *Zostera marina* and *Z. japonica* beds (Kasim & Mukai, 2009).

Phytoplankton samples from were collected monthly from surface water at 20 stations in the Akkeshi-ko estuary for 10 months (March–December 2005). About 1000 ml water samples were collected monthly at each station. Positions of stations were determined using shipboard Global Positioning System. In winter, almost all surface of the estuary was covered with ice, thus it was impossible for water sampling. Sediment samples were also collected by an Ekman–Birdge grab from the surface bottom at 20 stations. Benthic diatoms were subsampled from the sediment samples by a mini core (diameter: 3 cm). The sediment sample was picked up by cellophane plastic at the one cm upper layer due to vertical change of diatom assemblages has been known (Rathburn *et al*., 2001).

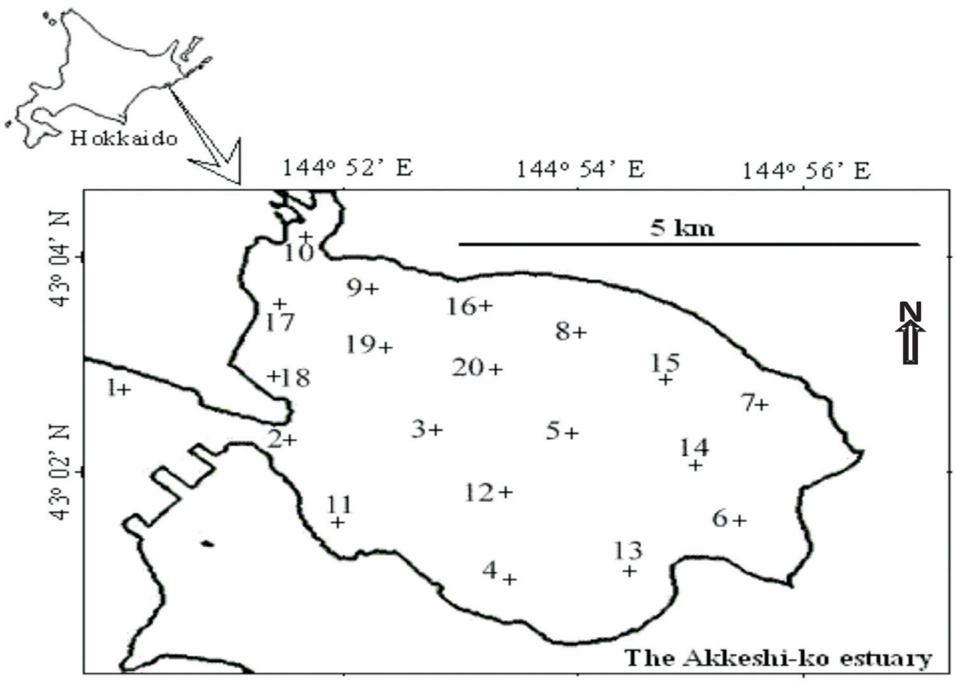

Figure 1. Sampling stations (Sts. 1 – 20) in the Akkeshi-ko.

C : N analyses

For estimating the C/N ratio of POM, 100 ml sample waters in every station were filtered onto Whatman GF/C filter and dried at 60 ^{o}C. The filters were packed air-tied in aluminum foil and measured in a C-N Analyzer (EA Flash 1112 series).

Phytoplankton enumeration

Immediately after sampling, 100 ml water samples were preserved with 0.2 % formaldehyde solution. Phytoplankton in the water samples were condensed from 100 ml subsamples to become 10 ml by a hand centrifugation (the methods see Kasim, 2006; Kasim & Mukai, 2006; Kasim & Mukai, 2009).

The 'phytoplankton' in a water sample was identified and counted to the lowest taxonomic level as well as possible. The taxonomic identification of phytoplankton was carried out according to Yamaji (1977), Kawamura and Hirano (1989), Mizuno & Saito (1990), Kato *et al*. (1977), Sawai & Nagumo (2003), and online publication by Departemen of Marine Botani, Japan Science and Technology Corporation, and Department of Biological Sciences.

Results and Discussion

Seasonal variation of POC and PON

POC and PON in the Akkeshi-ko estuary were fluctuating in every month. In April, July and October, the averages of POC and PON concentrations of all stations were ≥ 1.2 mg/L and > 0.15 mg/L, respectively (Figure. 2). From this figure, the POC concentration seems to have high concentration in April and July.

The pattern of seasonal variation of POC in Akkeshi was different among stations. High POC concentration at Sts. 1 (2.9 mg/L) and 10 (2.0 mg/L) occurred in autumn. The stations were located near Akkeshi Bay (St. 1) and the front of the Bekanbeusi River-mouth (St.10). In St. 5 and 16 (inner part of estuary), the concentration of POC was high 1.7 and 2.3 mg/L, respectively in spring. Particularly in St. 14, the POC further increased and reached high concentration (3.6 mg/L) in summer (Figure. 3). In tidal Yorkshire Ouse River and Humber Estuary, averaged concentration of organic carbon and nitrogen percentages during the year February 1995-March 1996 were 2.6 +/- 0.6% and 0.21 +/- 0.04%, respectively. Higher POC levels were observed near the Humber's mouth and and in the upper estuarine reaches during winter and springtime freshwater inflows. At these times of high runoff, the POC content of SPM increased progressively up-estuary from the coastal zone to the tidal River Ouse (Uncles *et al*, 2000)

PON concentrations fluctuated also and reached the high concentration at St. 4 (0.20 mg/L), 5 (0.23 mg/L) and 16 (0.28 mg/L) during spring, and at station 14 (0.46 mg/L) during summer. At St. 1 and 10, the concentration of PON was high 0.43 and 0.41 mg/L, respectively in autumn (Figure. 3).

The seasonal fluctuation of POC and PON concentration was generally similar in all stations

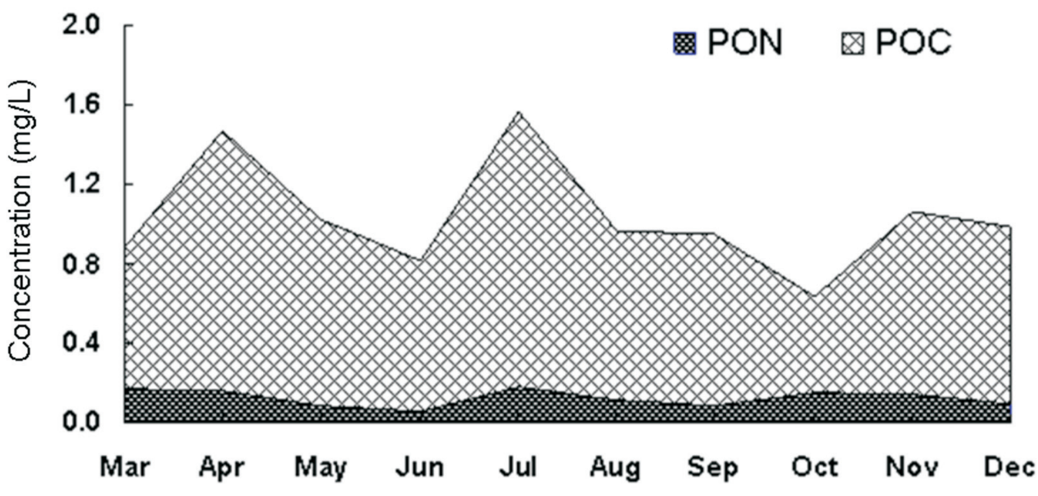

Figure 2. The seasonal fluctuation of POC and PON during March-December 2005 in the Akkeshi-ko estuary.

(except in station 10). While the concentration POC was high in most stations, PON also increased. POC and PON concentration were generally higher in inert part of estuary during spring and summer and its concentrations seem high at outside part (St. 1) during autumn, except for St. 10, the PON concentration was high during autumn. POC also related to the input of terrestrial organic matter from Bekanbeusi River during autumn. In several estuarine ecosystems, The POC concentration strongly related to the phytoplankton concentration or fragment of macrophyte abundance (Takamura *et al*., 2003) and also input of nutrient from river during spring and summer season (Hedges *et al*., 1997). River discharge has been shown to be an important factor in regulating POC dynamic in most estuarine area during spring and summer (Moon & Dustan, 1990). In San Francisco Bay, during summer season, the high concentration of phytoplankton were associated with the increasing of POC concentration near the surface water and its concentration seemed to decrease during autumn season when the phytoplankton biomass was low (Wienke & Cloern, 1987).

Variation of POC and PON in estuarine system particularly in the Akkeshi-ko estuary have been addressed to many factors, including variation in contribution of different source of POC, PON from the Bekanbeusi River, nutrient input from terrestrial area. Effect of tidal disturbance and variation in phytoplankton species composition inside the estuary.

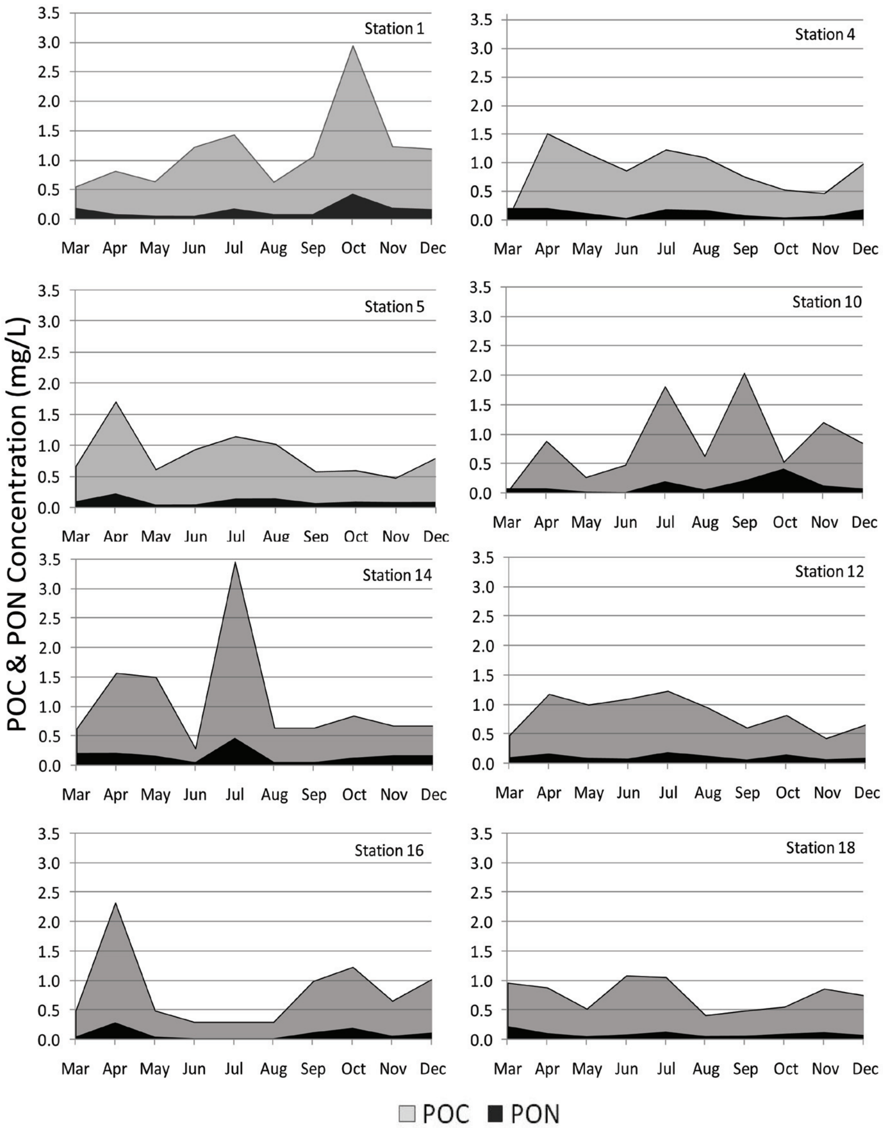

Figure 3. Seasonal fluctuation of POC and PON concentration (mg/L) in selected station of representation area at the Akkeshi-ko estuary.

Tabel 1. Taxonomic list of phytoplankton recorded on the surface sediment and in the water column of the Akkeshi-ko estuary. Very rare is the abundance of diatoms < 1 % to total diatoms abundance in every month, rare is the abundance of diatoms between 1 – 3 % to total diatom abundance and common is > 3 % to total diatoms abundance

Phytoplankton Species		
Very Rare	Rare	Common
Amphiprora alata,	*Achnanthes brevipes*	*A. hauckiana* var. *hauckiana*
Amphora spp.	*Actinoptychus* sp.	*Amphora* sp.
Bacteriastrum sp.	*Amphora helenensis*	*A. ventricosa*
Campyloneis grevillei	*A. lineolata*	*Aulacoseira ambigua*
C. placentula	*A. salina*	*Bacillaria paradoxa* var *paxilifer,*
Coscinodiscus excentricus	*Biddulphia obtuse*	*Cocconeis costata*
C. lecustris	*Biddulphia* sp.	*C. scutellum*
Eunotia serra,	*Caloneis* sp.	*Cymbella minuta*
Leptocylindrus sp.	*Chaetoceros* sp.	*Diploneis smithii*
Navicula marina	*Climacosphenia* sp.	*Donkinia* sp.
Pleurosigma elongatum	*Cocconeis pediculus*	*Frustulia rhomboids*
Rhizosolenia alata	*Corethron pelagicum*	*Grammatophora* sp.
Rhizosolenia sp.	*C. marginatus*	*Melosira nummuloides*
Tryblionella debilis	*C. oculus iridis*	*Navicula rhynchocephala*
	Coscinodiscus sp.	*Navicula* sp.
	Cosmioneis sp.	*Nitzschia serriata,*
	Cymbella microcephala	*N. sigma,*
	Diatoma hyaline	*Paralia sulcata*
	Diploneis fusca	*Rhabdonema arcuatum*
	Entomoneis sp.	*Rhoicosphenia curvata*
	Epithemia adnata	*Rhopalodia musculus*
	Fragilaria sp.	*Synedra ulna*
	Gomphonema acuminatum	*Thalassiosira* sp.
	G. parvulum	*Tryblionella granulate.*
	Gyrosigma sp.	
	Licmophora sp.	
	Mastoglia sp.	
	Melosira borreri	
	M. juergensi	
	Melosira sp.	
	Meridion sp.	
	Navicula cryptotenella	
	N. gregaria	
	N. peregrine	
	N. salinarum	
	N. slevicensis	
	N. punctata	
	N. scalpeliformis	
	Nitzschia sp.	
	Odontella aurita	
	Pinnularia viridis	
	Pleurosigma affine	
	Pleurosigma fasciola	
	P. intermedium	
	P. rigidum,	
	Rhopalodia gibberula	
	Rhopalodia sp.	
	Skeletonema costatum,	
	Stauroneis phoenicenteron	
	Stephanopyxis spp.	
	Stigmophora sp.	
	Surrirela sp.	
	Synedra sp.	
	Thalassionema nitzschioides	
	Thalassiosira gravid	
	T. hyaline	
	T. nordenskioldi,	
	Tryblionella compressa	
	T. lanceola	
	T. levidensis	
	T. coarctata	

From total 20 station of sampling site, it's found similar trend of POC and PON concentration in several part of estuary. The sampling site was categories into outside part of estuary (St. 1), front part of estuary (Sts. 2, 11, and 18), inner part of estuary (Sts. 3,4,5,8,12,13,16 and 20), upper site of estuary (Sts. 6,7, 14 and 15), and near the mouth Bekambeusy river (Sts. 9, 10, 17 and 19). In Figure 3, representation of each part of estuary was described to clarify the seasonal pattern of POC and PON concentration of Akkeshi estuary.

During spring, a season with low temperature and river charged, POC and PON increased in inert part of estuary particularly in Station. 5 and 16. In summer, a period of high temperature and high river charged, POC and PON increased at Station 10 (at mouth the Bekanbeusi River) and also in inert part of the estuary particularly in Station 14. The concentration of POC and PON were high in autumn particularly in Station 1 (near Akkeshi Bay) and 10. This fact appears to relate to input of terrestrial organic matter from Bekanbeusi River during early summer and autumn. While the concentration of POC and PON was high observed during spring particularly in inert part of estuary, it seems similar to high productivity of epiphytic diatoms and growth of seagrasses (Hasegawa unpublished). The concentration of POC was correlated with the growth of phytoplankton and tendency of high concentration in warm season (Ogawa & Ogura 1997). In the Medes Island (northwestern Mediterranean), the high value of POC was strongly addressed to spring season and particularly for dissolved organic carbon (DOC), Its concentration reached the maximum value in spring and summer season (Ribes *et al*., 1999).

Phytoplankton Community

From total 128 species of diatoms identified in the Akkeshi-ko estuary, 103 and 102 species occurred on the surface sediments and in water column, respectively. Most of species was found both on the upper layer of sediment and in the water column. Of these species, 22 species of benthic diatoms and 3 species of pelagic diatom were common on the surface sediments and also in the water column in almost all stations (Table 1).

On the surface sediments of Akkeshi-ko estuary, 12 species of benthic diatoms and 2 species of pelagic diatoms were most common and dominantly occurred in all stations. In water column, 12 species of benthic diatoms and 3 species of pelagic diatoms were most common and predominantly occurred in all stations. In Zuari estuary sustains diverse assemblage of phytoplankton species in the water column. Benthic diatom followed by pelagic diatoms (and dinoflagellates) dominate the phytoplankton community in both surface and bottom waters of this estuary (Devassy & Goes, 1988; Patil, 2003).

In the water column, *Navicula* sp., *C. scutellum*, *Thalassiosira* sp. and *S. ulna* were commonly dominant in all stations. *C. scutellum* was highly abundant in Station 9. *Thalassiosira* sp. reached high concentration in Stasion. 2, 3, and 20. And the most interesting species was *Navicula* sp. and *Thalassiosira* sp. which was most abundant in all other stations (Figure 5). On the surface sediment, *C. scutellum* was most abundant in Stasion. 8, 9, 16 and 20, followed by *Navicula* sp. in Sts. 1, 4, 10 and 18, and also *Rhabdonema arcuatum* in station 19. *P. sulcata* was one of dominant phytoplankton species occurred in all stations. This species did not show the highest abundance, but still commonly occurred in all stations. In station 17 (north side of the Akkeshi-ko estuary), this species was dominant than other species (Figure 4).

Dominant species of phytoplankton assemblage in the Akkeshi-ko estuary occurred adjacent to the seagrass beds. Our observations suggest that several species of the benthic diatom assemblage were always associated with the dense seagrass beds. It is interesting that *C. scutellum*, which was most common at all stations, is a typically phytoplankton species, attaching to the macrophyte. In Ikuraushi (Southeastern part of Akkeshi-ko) - Kanedasaki (Northeastern part of Akkeshi-ko) transect, *C. scutellum* was one of the most abundant living and dead phytoplankton cells in sediment core samples (Sawai, 2001). Tidal movement was able to tear off this phytoplankton from macrophytes, and the phytoplankton sunk onto the sediment, suffered sedimentary processes, re-suspended into the water column, and was grazed by suspension feeders (Orth & Van Montfrans, 1984; Tuji, 2000; Sawai, 2001).

In the Akkeshi-ko estuary, abundance of benthic phytoplankton was higher than pelagic phytoplankton during summer, as generally reported in several shallow estuarine water systems (Kasim, 2006, Blackford, 2002; Welker *et al*., 2002). On intertidal flat in the Seto Inland Sea, SW Japan, the biomass of benthic diatoms increased during spring and summer (Montani *et al*., 2003). Phytoplankton assemblages on the surface sediment and water column were generally dominated by benthic phytoplankton. Benthic phytoplankton played a major role throughout the sampling period. From total of 128 species of phytoplankton identified in Akkeshi-ko estuary, 103 and 102 species were occurred on the surface sediment and water column, respectively. Most of the species found in surface sediment were also found in water column of the Akkeshi-ko estuary.

The spatial and temporal fluctuation of phytoplankton generally correlates with light and nutrient availability (Kormas *et al*., 2001; Welker *et*

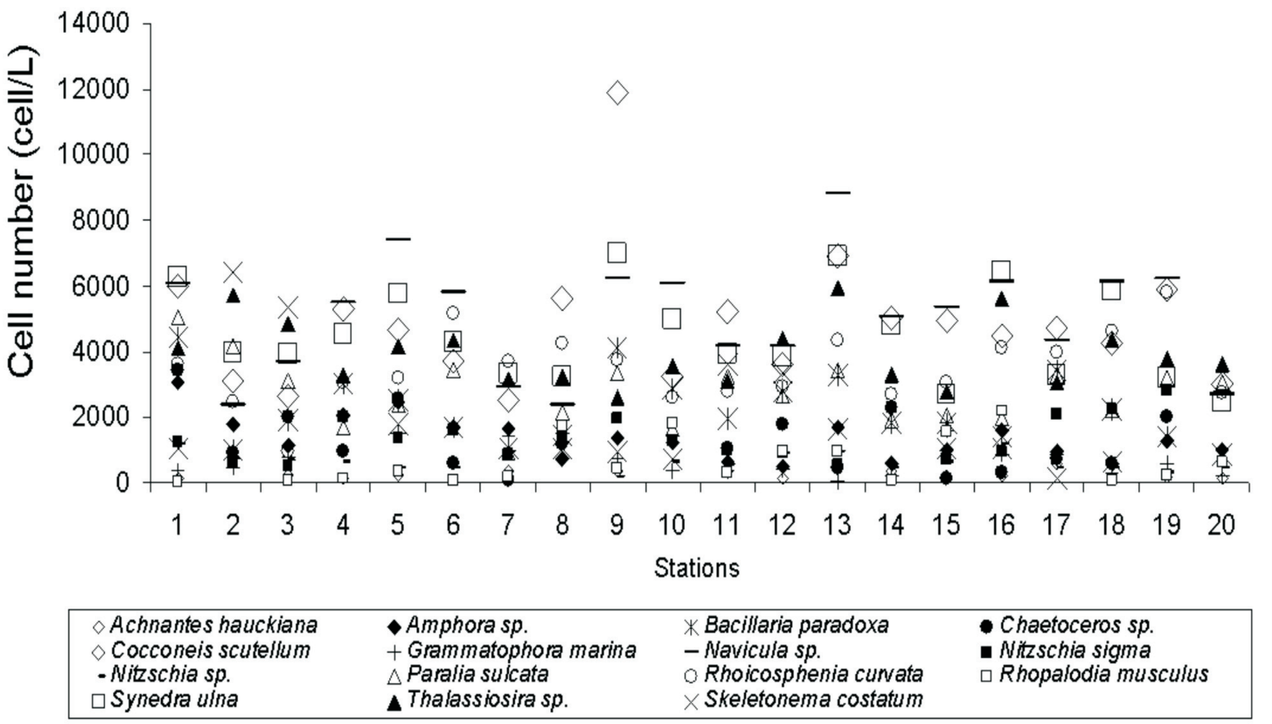

Figure 4. Abundance of selective phytoplankton species (up to 3 % more abundant to the total abundance of all phytoplankton species) in 20 stations of the Akkeshi-ko estuary water column.

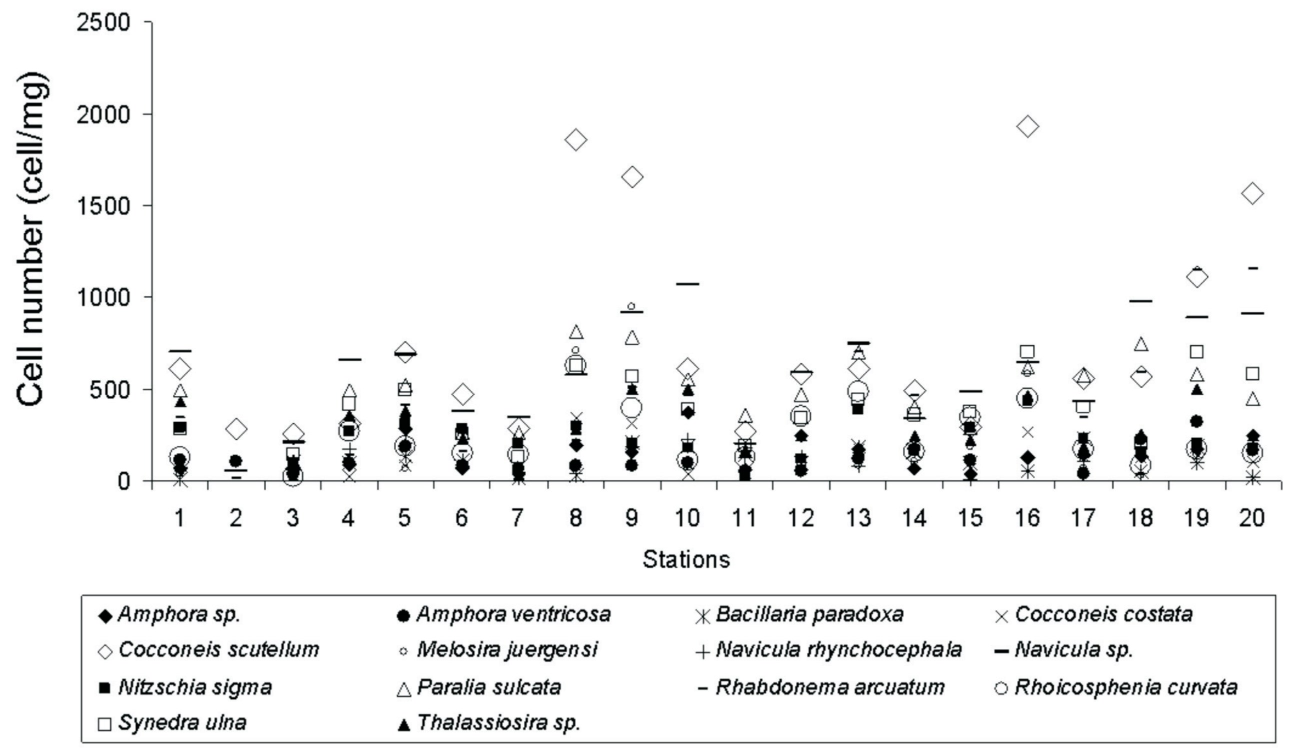

Figure 5. Abundance of selective phytoplankton species (up to 3 % more abundant to the total abundance of all phytoplankton species) on the upper layer of sediment in 20 stations of the Akkeshi-ko estuary.

al., 2002), tidal current (Perrisinotto *et al.*, 2002) and grazing pressure by suspension feeders (Blackford, 2002). In midsummer, the biomass of phytoplankton was higher at several stations in the Adriatic Sea, with nutrient and light availability being key factors limiting the fluctuation of phytoplankton (Blackford, 2002). In the Gulf of Trieste (Northern Adriatic Sea), they have significant correlations between phytoplankton abundance and ammonium, silicate and phosphate concentrations (Welker *et al*., 2002).

Conclusion

The seasonal fluctuation of POM (POC and PON) concentration was generally similar in all stations. The concentration of POM (POC and PON) was increase during spring and summer season. This condition mainly occurs in inert part of estuarine than outside part of estuarine. Amount of phytoplankton was higher in water column than sediment during this season. On the upper layer sediments, there were 12 species of benthic diatoms and 2 species of pelagic diatoms were most common and dominantly occurred in all stations. In water column, 12 species of benthic diatoms and 3 species of pelagic diatoms were most common and predominantly occurred in all stations. The increasing of POM (POC and PON) and phytoplankton in water column and sediment cause by the increasing of nutrient input at the end of spring and summer season.

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