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Original Paper

VERTICAL CHANGES OF RECENT OSTRACODE ASSEMBLAGES AND ENVIRONMENT IN THE INNER PART OF JAKARTA BAY, INDONESIA

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ABSTRACT

A short sediment core from the inner part of Jakarta Bay, Indonesia, was quantitatively analysed for ostracods (minute Crustacea), total organic carbon (TOC) and total nitrogen (TN) contents, and the vertical distributions were recorded. A total of 53 ostracod species were obtained from 80 continuous core samples. The dominant species were Keijella carriei and Loxoconcha wrighti, which are common in areas with high TOC and TN contents. Based on an analysis of ostracod assemblages and carbon/nitrogen ratio, the study site began to be influenced by organic contamination from around 1950. Although the population of Jakarta City has increased rapidly since then, TOC and TN contents which were low, have gradually increased (0.7%–0.9% and 0.10%–0.12%, respectively), probably due to addition of nutrients from river sedimentation. The increased sedimentation rate after 1950 resulted in an increasing TOC ratio. The observed correlation between TOC and dominant species shows that Phlyctenophora orientalis may be a good indicator for monitoring increases in the narrow TOC content range of 0.7%–1.1%.

Key word: Ostracoda, TOC, CNS analysis, Jakarta Bay

Correpsondence :

INTRODUCTION

Although the northern coastline of West Java is extensive (approximately 365,000 km), knowledge of the Recent Ostracoda from this region is sparse. Recent Ostracoda from Indonesian regions have been the subject of several studies (Brady, 1880; Kingma, 1948; Keij, 1953, 1964; Carbonel and Moyes, 1987; Dewi, 1997); however, few studies have been conducted on the northern coast of West Java; Jakarta Bay: Brady (1867–1872) and Fauzielly *et al.*, (in press); Thousand Islands: Keij (1974, 1975) and Whatley and Watson (1988).

Ostracoda is a meiobenthic class belonging to the subphylum Crustacea, containing organisms with an average size of 1 mm living in a wide range of aquatic habitats from Ordovician to Recent (Horne et al., 2002). Ostracods possess two calcified valve-like shells, which can be preserved for a long time and which are abundant in sediment cores. Several recent studies using sediment cores have revealed that ostracod species could potentially be used to reconstruct the history of bottom environments and as a proxy for organic contamination.

Many studies of ostracods in short sediment cores have been conducted in East Asia, especially in Japan (Yasuhara et al., 2003, 2007; Yasuhara and Yamazaki, 2005; Irizuki et al., 2011). However, no similar studies have been conducted in southeastern Asia. In inner bays adjacent to a metropolis, such as Jakarta Bay, where humans have greatly accelerated the rate of deposition of terrestrial particles in the ocean and increased water fertility, no studies have yet been conducted that record the distribution of ostracods in relation to environmental change. Core sediments from muddy inner bays are best suited for this line of inquiry, because they provide high resolution.

The aim of this study was to reconstruct the paleoenvironments in the inner part of Jakarta Bay over the past several hundred years, based on ostracod assemblages and total organic carbon (TOC) and total nitrogen (TN) contents. This is the first study to demonstrate temporal shifts in recent ostracod assemblages in Indonesian bays in relation to organic pollution, using short sediment cores.

MATERIALS AND METHODS

Study area

Jakarta Bay is a semi-enclosed bay located on the western side of the northern part of Java Island, Indonesia. It is a shallow bay, with an average depth of approximately 15 m, an area of 514 km2 and a shoreline of approximately 72 km long (**Fig. 1**). The bay is very fertile as a result of the abundant supply of nutrients from rivers that cross the city.

Human activity in and around the bay began thousands of years ago. Initially, the bay was used only for fishing, although it is probable that some shipping took place along the coast. The current harbours of Tanjung Priok and Sunda Kelapa were first used more than 300 years ago. In recent decades, many of the people living around the bay have been involved in fish and shrimp farming. The sand beaches have been dredged for landfill and thousands of hectares surrounding the bay have been transformed into fish ponds, luxury residences and industrial zones (UNESCO, 2000).

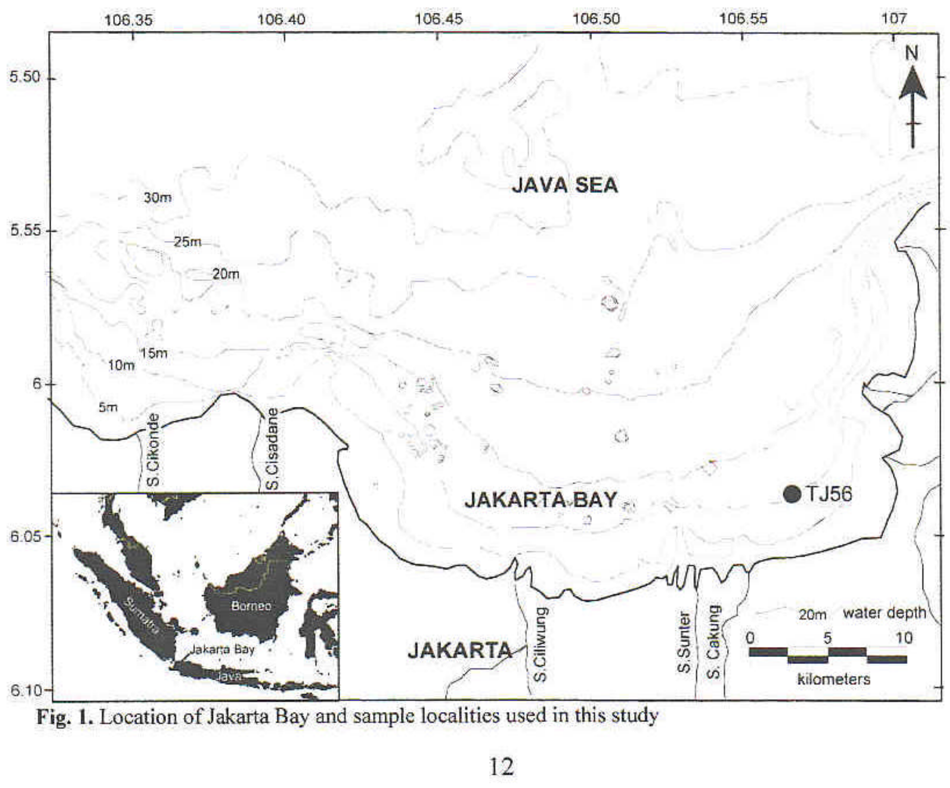

Fig. 1. Location of Jakarta Bay and sample localities used in this study

The population in Greater Jakarta (Jabotabek) increased rapidly from 138,600 in 1905 to 8,259,300 in 1990, an increase of almost 60-fold (pemprov DKI, 2011).
Another problem facing Jakarta is flooding. The uncontrolled growth of housing along the riverside, heavy sedimentation and the dysfunctional drainage system in Jakarta, especially in the riverside areas, make it susceptible to flooding. Jakarta has experienced extensive flooding in 1918, 1976, 1996, 2002 and 2007 (Tanuwidjaja, 2010).

The high population growth rate together with the expansion of Jakarta City during the second half of the 20th century have led to serious pollution and over-exploitation of coastal resources, threatening the sustainability of the marine environment. Jakarta Bay has undergone some of the most drastic changes over the last few decades.

Sediment collection

The 80-cm long sediment core used in this study was collected in 1994 by the Indonesian Marine Institute using a gravity corer. The water depth at the study site is 11 m. Sediments are composed of homogeneous massive dark greyish brown (2.5Y 4/2) clay from a core depth of 1–40 cm, containing small fragments ($\phi < 1$ mm) and olive grey (5Y 4/2) clay from a core depth of 40–80 cm, containing large fragments of molluscs. The colour and size of the shell fragments gradually changed from a depth of 45 cm (**Fig. 2**).

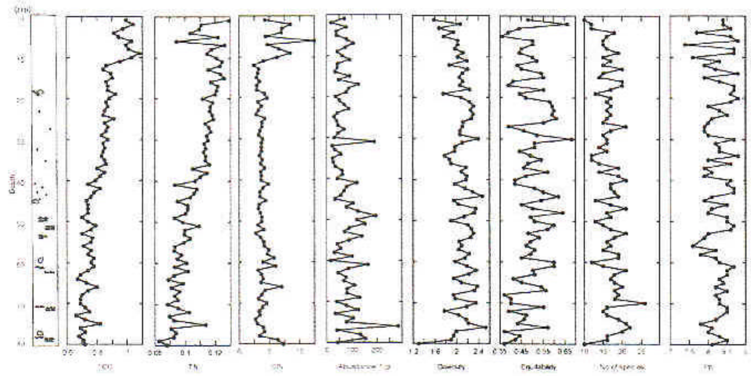

Fig. 2. Temporal changes of composition of ostracode assemblages (abundance, number of species, diversity,equitability) and total organic carbon (TOC)content (wt%),total Nitrogen (TN) content (wt/%) and the ratio of TOC/TN contents. Abundance means the number of specimens per 1 gr dry sediment.

All symbols in column shows shell fragments.

The core was continuously sliced in 1-cm thick samples, creating a total of 80 samples. For ostracod analysis, samples were weighed and washed through a 63-µm sieve, and subsequently, oven dried and dry sieved to separate the >125 µm fraction. The dried sediments were weighed and mud contents were calculated based on water content and the residual weight of the washed samples.

Ostracod analysis

Samples from the >125 µm fraction containing abundant ostracod specimens were divided using a sample splitter into separate samples, each containing approximately 200 specimens. The number of specimens refers to the sum of the left and right valves. One carapace was counted as two valves. Most specimens were composed of separate valves, and carapaces were rare.

Grain size analysis

Grain size analysis was conducted using a laser diffraction particle size analyser (SALD-3000S) after decomposition of organic matter and pyrite with 30% H2O2 for several days.

TOC analysis

TOC and TN contents were measured using the combustion method at 1000 °C in a FISONS analyzer EA 1108, after treatment to remove the carbonate fraction. This treatment was performed by adding 1 M HCl to the weighed sediment in Ag cups.

Results

Grain size

The median grain size of samples in the study area ranged from approximately 7.4 to 8.8 ϕ (Table 1) but most samples were less than 8 ϕ, suggesting that cores are mainly composed of clay. The mud content of all samples was greater than 60%, except TJ56-56 (Table 1), which contained relatively coarser particles (Md ϕ = 7.6 ϕ). The profile of grain size was relatively constant, but some fluctuations were apparent, particularly in the uppermost portion of the core (core depth: 1–10 cm; **Fig. 2**).

TOC and TN contents

The profile of TOC content showed three trends. First, TOC content was relatively constant (approximately 0.75 wt%) from the lowest portion of the core (core depth of 80 cm) to a depth of approximately 45 cm. Thereafter, TOC content gradually increased and reached approximately 0.85 wt% at a core depth of 12 cm. TOC content then increased rapidly, reaching more than 1.0 wt% in the upper part of the core. The TN profile displayed trends similar to TOC content. The C/N ratio ranged from 6.9 to 11.0. The C/N ratio was stable from the lowest portion of the core to a depth of 12 cm (approximately 7.5). It increased rapidly from that horizon and reached approximately 9.0 (**Table 1, Fig. 2**).

Ostracoda

A list of the ostracod species is shown in **Table 2.** Fifty-three ostracod species were identified, and 48 of them comprised less than 5% of the total specimens in the samples. **Fig 3** shows scanning electron microscopy photographs of the dominant species from the core.
Two species, *Keijella carriei* and *Loxoconcha wrighti*, were abundant throughout the core; 36% and 14%, respectively. These species were first reported from the Java Sea, west of Bawean Island, Indonesia (Dewi, 1997) and were abundantly distributed in the inner to middle parts of Jakarta Bay, Indonesia (Fauzielly et al., in press). In Jakarta Bay, *K. carriei* is abundant at a water depth of less than 20 m, in a sediment with a fine grain

Table 1. List of sample data

sample	grainsize (ϕ)	mud content (%)	TN (wt%)	TOC(wt%)	C/N ratio	Diversity (H)	Evenness (H)
TJ56-1	8.4	75.7	0.13	0.99	7.70	1.6	0.5
TJ56-2	8.4	91.7	0.11	1.04	9.39	2.1	0.7
TJ56-3	8.6	94	0.11	0.97	8.84	1.7	0.4
TJ56-4	7.7	96.7	0.10	0.91	8.78	1.9	0.4
TJ56-5	8.6	99.8	0.12	0.94	7.75	1.8	0.4
TJ56-6	8.8	96.2	0.09	1.03	10.96	2.0	0.5
TJ56-7	7.4	96.1	0.13	0.99	7.84	2.0	0.5
TJ56-8	8.7	90	0.12	1.01	8.64	2.0	0.4
TJ56-9	8.7	97.3	0.11	1.08	9.39	2.1	0.4

TJ56-10	7.6	96.5	0.12	1.03	8.50	2.0	0.5
TJ56-11	8.3	97	0.12	0.95	7.92	2.2	0.5
TJ56-12	7.9	94.3	0.12	0.86	7.17	1.9	0.4
TJ56-13	8.2	98.3	0.12	0.84	7.00	2.2	0.5
TJ56-14	8.8	94.3	0.12	0.89	7.42	2.1	0.5
TJ56-15	7.9	98.3	0.13	0.9	6.92	2.0	0.6
TJ56-16	8.3	98.5	0.12	0.86	7.17	2.1	0.4
TJ56-17	8.7	97	0.12	0.87	7.25	2.1	0.4
TJ56-18	8.7	94.4	0.12	0.87	7.25	2.2	0.6
TJ56-19	8.6	97.3	0.12	0.92	7.67	1.7	0.4
TJ56-20	8.8	92	0.11	0.88	8.00	2.1	0.5
TJ56-21	8.6	96.5	0.12	0.86	7.17	2.2	0.6
TJ56-22	8	95.5	0.12	0.87	7.25	2.3	0.6
TJ56-23	8.3	94.8	0.12	0.85	7.08	2.3	0.6
TJ56-24	8.5	96.6	0.12	0.84	7.00	2.3	0.6
TJ56-25	8.1	96.6	0.12	0.91	7.58	2.3	0.6
TJ56-26	8	95.9	0.11	0.85	7.73	2.1	0.6
TJ56-27	7.9	93.9	0.12	0.87	7.25	2.1	0.4
TJ56-28	7.9	95	0.12	0.86	7.17	2.1	0.5
TJ56-29	8	95.2	0.11	0.83	7.55	2.1	0.5
TJ56-30	8.7	95.8	0.12	0.87	7.25	2.4	0.7
TJ56-31	8.2	94.3	0.11	0.84	7.64	2.1	0.5
TJ56-32	8.3	97.1	0.11	0.85	7.73	2.0	0.5
TJ56-33	8.3	96.8	0.11	0.84	7.64	2.0	0.4
TJ56-34	8.8	98.3	0.11	0.83	7.55	1.8	0.5
TJ56-35	8	97.1	0.11	0.85	7.73	1.9	0.5
TJ56-36	8.6	95.3	0.12	0.86	7.17	1.9	0.5
TJ56-37	7.9	97.1	0.1	0.8	8.00	2.2	0.5
TJ56-38	8.1	95.2	0.11	0.85	7.73	2.1	0.6

TJ56-39	7.9	95.7	0.11	0.82	7.45	2.2	0.5
TJ56-40	8.6	95.1	0.11	0.79	7.18	2.2	0.4
TJ56-41	8.5	84.6	0.09	0.74	8.22	2.0	0.4
TJ56-42	8.7	92.7	0.11	0.82	7.45	2.2	0.5
TJ56-43	8.7	86.6	0.11	0.78	7.09	2.3	0.5
TJ56-44	8.1	86.5	0.1	0.76	7.60	2.5	0.6
TJ56-45	7.9	93.1	0.09	0.73	8.11	2.0	0.5
TJ56-46	8.5	94.4	0.1	0.74	7.40	2.0	0.4
TJ56-47	8.1	94.3	0.1	0.74	7.40	2.3	0.5
TJ56-48	8	84.7	0.1	0.74	7.40	2.3	0.6
TJ56-49	8.5	79	0.09	0.7	7.78	2.1	0.5
TJ56-50	8.5	89.7	0.1	0.74	7.40	1.9	0.5
TJ56-51	8.7	93.6	0.11	0.79	7.18	2.2	0.6
TJ56-52	8.6	88.9	0.1	0.76	7.60	2.3	0.6
TJ56-53	8	93.6	0.1	0.7	7.00	2.3	0.5
TJ56-54	7.9	94.9	0.1	0.77	7.70	2.3	0.5
TJ56-55	7.8	81.1	0.1	0.76	7.60	2.1	0.5
TJ56-56	7.6	47	0.09	0.71	7.89	2.1	0.5
TJ56-57	8.2	90.2	0.09	0.76	8.44	2.0	0.5
TJ56-58	7.8	92.1	0.09	0.74	8.22	2.2	0.5
TJ56-59	8.2	90.9	0.09	0.78	8.67	2.2	0.5
TJ56-60	8.3	97.1	0.1	0.76	7.60	2.0	0.6
TJ56-61	8.7	79	0.09	0.78	8.67	2.2	0.6
TJ56-62	8.5	94.9	0.1	0.74	7.40	2.4	0.5
TJ56-63	8.5	93.3	0.09	0.69	7.67	2.2	0.5
TJ56-64	8.3	61.4	0.09	0.67	7.44	1.9	0.4
TJ56-65	8.4	82.9	0.1	0.73	7.30	2.1	0.5
TJ56-66	8.2	87.4	0.09	0.8	8.89	2.4	0.5
TJ56-67	8.5	94.7	0.1	0.74	7.40	2.3	0.6

TJ56-68	8.2	94.3	0.09	0.7	7.78	1.9	0.4
TJ56-69	8.3	87.7	0.09	0.69	7.67	2.0	0.4
TJ56-70	8.3	87.5	0.09	0.69	7.67	2.3	0.4
TJ56-71	8.5	83.4	0.1	0.72	7.20	2.2	0.6
TJ56-72	8.5	85.9	0.1	0.75	7.50	1.8	0.4
TJ56-73	8.3	87	0.09	0.66	7.33	2.0	0.5
TJ56-74	8.2	82.3	0.09	0.72	8.00	2.2	0.5
TJ56-75	7.8	88.3	0.11	0.82	7.45	2.2	0.4
TJ56-76	8.1	80.6	0.09	0.69	7.67	2.5	0.6
TJ56-77	8	84.8	0.09	0.72	8.00	2.0	0.4
TJ56-78	8.3	68.4	0.09	0.68	7.56	1.9	0.4
TJ56-79	8.5	65.8	0.08	0.71	8.88	1.9	0.4
TJ56-80	8.1	67.7	0.09	0.72	8.00	1.3	0.4

size (silt–clay), with a TOC content of 0.5–1.5 wt% (Fauzielly et al., in press), whereas to the west of the Bawean Island, this species has been found in gravelly mud at a water depth of 25 m (Dewi, 1997). *L. wrighti* is abundant at water depths of 10–30 m in Jakarta Bay (Fauzielly et al., in press) whereas in the Java Sea, it is found in gravelly mud bottoms at a water depth of 63 m (Dewi, 1997). *K. carriei and L. wrighti* are common in areas with high TOC and TN contents, even when they are anoxic (Fauzielly et al., in press).

The species *Pistocythereis* cf. *bradyformis*, *Neomonoceratina delicata*, *Phlyctenophora orientalis*, *Neomonoceratina iniqua*, Loxoconchidae gen. sp. indet., *Hemicytheridea reticulata* and *Propontocypris* sp. 1, were common throughout the core (3%–10%). Loxoconchidae gen. sp. indet. is the same species as Dewi's (1997) new genus and new species (*Baweanconcha indonesiana*), but it was never formally described. Most of the species reported are commonly found living in tropical shallow seas in southeastern Asia at water depths of 20–50 m (Whatley and Zhao, 1987, 1988; Zhao and Whatley, 1989; Mostafawi, 1992; Dewi, 1997, Fauzielly et al., in press). *P. orientalis* was rarely found in the lower half of the core, whereas *H. reticulata* and Loxoconchidae gen. et sp. indet. were common in the lower half of the core (Figure 4).

To clarify the structure of the ostracod assemblages, the Shannon–Wiener function was used as an index of species diversity [H(S)]. Equitability (E) was calculated using the function of Buzas and Gibson (1969). The diversity index ranged from 1.3 to 2.53

Table 2. Faunal list of ostracode species in core TJ56

Species	TJ56-01	TJ56-2	TJ56-03	TJ56-4	TJ56-05	TJ56-06	TJ56-07	TJ56-08	TJ56-09	TJ56-10	TJ56-11	TJ56-12	TJ56-13	TJ56-14	TJ56-15	TJ56-16	TJ56-17	TJ56-18	TJ56-19	TJ56-20	TJ56-21	TJ56-22	TJ56-23	TJ56-24	TJ56-25	TJ56-26	TJ56-27	TJ56-28	TJ56-29	TJ56-30
Alocopocythere kendengensis																														
Agehella kingmai																														
Argilocea sp	1				3	1	1	4	3	5	9	7	1	5	6	1	9	6	1	3	4	5	2	12	1	5	3	3	5	3
Bowcanconcha indonesiana			2	2	1	11	4	4	1	6	4	2	4	8	7	2	2	4	4	6	5	3	6	3	3	7	3	7		6
Copytus posterosulcus		4	8	9	16	5	11	3	9	11	11	4	10	7	10	7	5	12	8	15	15	21	8	19	2	6	4	6	2	8
Cytherella hemipuncta				3		1	7	2	1	4	4	8	2	6	5	1	1	9			2	5	1	8	1	1	5		4	1
Cytherella incohota										1			2			1	2		1											
Cytherella javaseanse									3							1	1			4										
Cytherella semulalis													2																	
Cytherella koegleri																	1													
Cytherelloidea singulata																									1					
Cytherelloida cf excavata					1																									
Cytherelloida leroi		2		3			1	1																						
Hemicytheridea reticulata				1	1	6		2	2			2	3	1	5		3	6	3	3	3	5	5	1	6	11	5		3	6
Hemicytheridea ornata	2									1						1											1	9		
Hemikrite petersoni																														
Hemikrithe orientalis																														
Keijella carriei	40	23	52	81	91	64	78	65	59	89	70	92	77	75	91	70	69	66	82	82	73	68	57	63	36	82	80	81	41	36
Keijella kloempritensis																														
Keijella reticulata																														
Keijia labyrintica				1																										
Loxoconcha wrighti	16	4	14	19	17	24	33	16	32	23	19	17	26	30	35	21	21	34	12	25	23	19	25	19	17	26	41	22	7	26
Malaycythereis trachodes																														
Neocytheretta adunca						3							2	1								2		3					2	
Neocytheretta sp								1																			1			
Neocytheretta cf angulasa																														
Neocytheretta spongiosa																														
Neocytheretta cf spongiosa											1		1			2		1		1										
Neocytheretta martilineata				1	1			1				3			1		1				7						4	2		3
Neomonoceratina delicata		2	4	3	10		18	7	15	19	8		8	7		6		16		6	13	15	6	11	12	20	12	10	17	9
Neomonoceratina iniqua	5	2	5		3	19			2		8	11	6	5	15	5	8	2	14	2	3	2	6	6	4	6	4	4		7
Neomonoceratina rhomboidea	1	4		1			3		2	1	3	1		1		4				2		1	3	3		3	3	2		3
Neomonoceratina columbiformis																														
Parakrithella sp																	1													
Parakrite placida																														
Paratycerois sp	1			3	2	5	1	1	2	8		1	2		2	5	2		3		5	7	8	5	3	1	1	1	5	
Paracypris nuda		2																												
Phlyctenophora orientalis	12	7	15	10	15	27	15	22	12	13	19	20	14	16	24	10	9	9	7	15	19	10	10	7	5	10	11	15	3	13
Physiocythereis sp	2		3		3				12		6					23	11		5	16					5					
Propontocypris sp 1	3	5	4	5	16	1	5	12	6	5	9	6	8	8	12	13	8	18	33	3	6	13	10	7	6	6		3	5	7
propontocypris sp2				7		9	9		14	9			10	12	11			7		20	18	20	33	34	7	15	12	8	4	7
propontocypris cf subangularis																		1												
Physocythereis cf bradyformis		2	3	29	1		17	17		11	20	15	19	16	9		1	19	1	1	12	14	8	7	3	12	10	20	3	11
Stigmatocythere cf indica												1																		
Stigmatocythere roesmani																														
Stigmatocythere indica				1												1								1			1			
Stigmatocythere sp																														
Tanella gracilis		2	1	2	1	1	1		1		1		2				1	1												
Venericythere sp						1		1																						
Venericythere grima					1				2				1			1	1	1		2							1			
Venericythere papuensis											1					1					1	2	1		1	1	2	1	2	1
Total number speciemen	83	59	111	181	181	178	204	159	178	206	193	191	200	198	233	176	157	212	174	206	209	212	199	209	111	210	204	194	101	147
Total number species	10	12	11	18	17	15	15	16	18	15	16	15	20	15	14	20	20	17	13	17	16	17	16	17	17	16	20	16	14	16
sample weight	2.37	3.17	2.70	4.52	4.68	2.21	3.95	3.98	4.00	3.17	3.87	3.18	4.59	3.18	3.19	3.19	4.54	3.19	4.15	3.20	3.18	2.92	3.19	4.54	3.52	4.76	4.25	3.18	3.18	4.33
split	2	1	2	1	1	1	2	2	1	1	2	1	1	1	1	1	4	2	2	1	1	1	2	1	1	1	1	2	2	1
split sample weight	1.19	3.17	1.35	4.52	4.68	2.21	1.97	1.99	4.00	3.17	1.93	3.18	4.59	3.18	3.19	3.19	1.14	1.60	2.07	3.20	3.18	2.92	1.59	4.54	3.52	4.76	4.25	1.59	1.59	4.33
no of individu	70	19	78	40	39	81	103	80	45	65	100	60	44	62	73	55	138	133	84	64	66	73	125	46	32	44	48	122	63	34

Species	TJ56-61	TJ56-62	TJ56-63	TJ56-64	TJ56-65	TJ56-66	TJ56-67	TJ56-68	TJ56-69	TJ56-70	TJ56-71	TJ56-72	TJ56-73	TJ56-74	TJ56-75	TJ56-76	TJ56-77	TJ56-78	TJ56-79	TJ56-80
Alocopocythere kendengensis										1				3	1		1			
Atjehella kmgmai										1										
Argilocea sp		1	3	1			2		1	1				1	2					
Baweanconcha indonesiana	15	15	23	16	12	15	12	9	13	9	20	6	7	3	5	4	4	3	3	
Copytus posterosulcus	2	6	4	1	5	5	8	1			4				3	3	1	5	2	
Cytherella hemipuncta	2			1	1		5	1	1	1		1	1		3	5			1	
Cytherella incohota																				
Cytherella javaseanse		4	1	4	1	7		2						2						
Cytherella semitalis																				
Cytherella koegleri																				1
Cytherelloidea singulata																				
Cytherelloida cf excavata																	1			
Cytherelloida leroi																3				
Hemicytheridea reticulata	12	17	17	5	7	8	14	20	22	24	7	11	1	2	5	10	4	9	6	3
Hemicytheridea ornata	9	8	1	2	3	4	4	1	4	2	2	2	5	5	3	2	2		1	
Hemikrite petersoni																				
Hemikrithe orientalis								1						2		4		1		
Keijella carriei	41	54	52	64	80	68	60	78	82	78	66	73	71	58	65	30	98	66	65	48
Keijella kloempritensis												1					1			
Keijella reticulata					3								5							
Keijia labyrmtica																				
Loxoconcha wrighti	45	43	43	44	28	40	30	28	39	35	38	10	17	16	32	22	22	20	16	10
Malaycythereis trachodes																1				
Neocytheretta adunca										2	1									
Neocytheretta sp																				
Neocytheretta cf angulasa																				
Neocytheretta spongiosa				2					2						2					
Neocytheretta cf spongiosa																		2		
Neocytheretta murilineata		4	2			1	5	1	1	5			2	2	2	1				
Neomonoceratina delicata	14	17	28	23	13	30	10		13	12	14	9	12		19	15	3	1	7	
Neomonoceratina iniqua	8	5		6	3	6	9	15	12	6	8	4	7		4		14	11	5	13
Neomonoceratina rhomboidea	3	3	2	4		3	4	4		8	8		6	16	6	2	1		1	
Neomonoceratina columbiformis										1										
Parakrithella sp		1				1														
Parakrite placida							1													
Paratycerois sp				1		5	1							1	3	1		1	2	1
Paracypris nuda																				
Phlyctenophora orientalis	3	5	3	3	6	10	3	1	5	5	5	8	5	8	2	1	7	6	6	5
Phystocythereis sp			13	7	10	13		11	1			6	16	6			9		3	6
Propontocypris sp 1	2	4	5	1	1		4	4	4	2	12				4	2	4	3		
propontocypris sp2	4	1				8				1										
propontocypris cf subangularis																				
Phystocythereis cf bradyformis	18	1			2	3	17	1	4	17	11	3		3	29	2	5			
Stigmatocythere cf indica		1	1						1	4	3		3	5						
Stigmatocythere roesmani										1						2			2	
Stigmatocythere indica										1		1	3		2	2	4	3	12	
Stigmatocythere sp																		3		2
Tanella gracillis			2		3			1	1	3	1			1	1			1		
Venericythere sp		8		2	4					4						5	9			
Venericythere gonia		4	3			4		1	4	2		1	2	8		4	14	10	2	1
Venericythere papuensis	1	1	6	3	8	10	2	2	2	2	3	2	3	1	1	4			2	
Total number specimen	179	203	209	190	190	241	191	182	212	228	203	138	166	143	194	125	204	145	136	90
Total number species	15	21	18	19	18	19	18	19	19	26	16	15	17	19	21	22	19	16	17	10
sample weight	4.32	4.82	4.58	4.74	5.69	4.51	4.75	4.51	6.65	6.30	5.50	4.78	5.30	5.83	5.48	2.00	2.94	2.00	1.40	5.01
split	4	2	1	2	2	2	2	2	4	1	2	4	1	4	2	4	1	4	4	2
split sample weight	1.08	2.41	4.58	2.37	2.85	2.26	2.38	2.26	1.66	6.30	2.75	1.20	5.30	1.46	2.74	0.50	2.94	0.50	0.35	2.51
no of individu	166	84	46	79	67	107	80	81	128	36	74	116	31	98	71	250	69	290	389	36

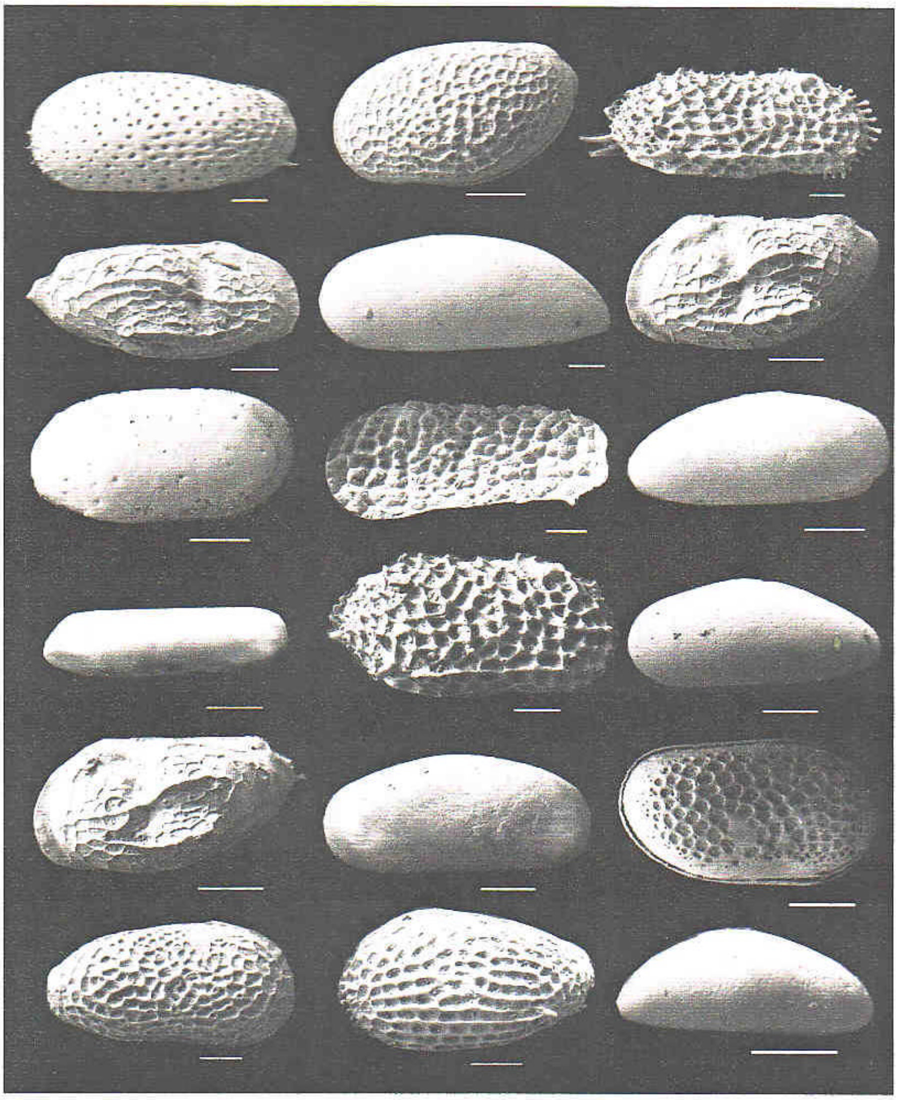

Fig. 3. Scanning electron micrographs of the dominant species. (ALV: adult left valve, ARV: adult right valve, JRV: juvenile right valve) 1, *Keijella carriei* Dewi, ALV, sample TJ 56-8; 2, *Loxoconcha wrighti* Dewi, ALV, sample TJ56-21; 3, *Pistocythereis* cf. *bradyformis* (Ishizaki), ARV, sample TJ56-21; 4 *Neomonoceratina delicata* Ishizaki and Kato, ARV, sample TJ 56-40; 5, *Phlyctenophora orientalis* (Brady),ALV,sample TJ56-25; 6, *Neomonoceratina iniqua* Brady, ALV, sample TJ56-28; 7, Loxoconchidae gen. et sp. Indet, ALV, sample TJ56-6; 8 *Hemicytheridea reticulata* Kingma, ALV, sample TJ56-6; 9, *Propontocypris* sp 2, ARV, sample TJ56- 8; 10, *Copytus posterosulcus* Wang, ARV, sample TJ 56-10; 11, *Phystocythereis* sp, ARV, sample TJ56-74; 12 *Propontocypris* sp 1, ALV, sample TJ56-39. 13, *Neomonoceratina rhomboidea* Hanai, ALV, sample TJ56-37; 14. *Argilocea* sp, ARV, sample TJ56-9; 15. *Cytherella hemipuncta*, Swanson, ARV, sample TJ56-24; 16. *Hemicytheridea ornata* Mostafawi, ALV, sample TJ56-28; 17. *Venericythere papuensis* (Brady),ALV, sample TJ56-14; 18. *Paratycerois* sp, JRV, sample TJ56-4.
Scale bars = 0.1 mm

(low to moderate) (Table 2), and was relatively constant throughout the core but decreased slightly in the uppermost portion. Equitability ranged from 0.36 to 0.68 (moderate to high) (Table 2) and fluctuated throughout the core. Ostracod density (N: the number of specimens per 1 gram dry sediment sample) was approximately 50. However, the average density (N = 93) in the lower half of the core was higher than that in the upper half (N = 58). This trend parallelled the trend for number of species.

Discussion

The chronology of the core was based on the ^{210}Pb information from the Centre for Oceanological Research and Development of the Indonesian Institute of Sciences (Rositasari, pers. comm.), from a study site located approximately 6 km southeast of the present core. The sedimentation rate ranged from 0.4 to 2.0 cm/year, and the maximum sedimentation rate was in the 50–60 cm layer. Thus, the age of this core ranges from prior to 1920 AD (depth > 60cm) to 1994 AD.

The stable clay sedimentation throughout the core and its location in a semi-enclosed bay indicate that sediments were accumulated at the study site in a low-energy and stable environment. The history of the depositional environment in this core can be divided into two major intervals (0–45 cm = approximately 1994–1950 AD); 45–80 cm = approximately 1950–before 1918 AD) based on TOC and TN contents. The upper interval is characterized by higher TOC (0.79–0.95 wt%) and TN (0.10–0.13 wt%) contents and dark greyish brown clay containing sporadic shell fragments. The lower interval is characterized by low TOC (0.66–0.82%) and TN (0.09–0.11%) contents and massive olive grey clay containing large fragments of molluscs (**Fig. 4**)

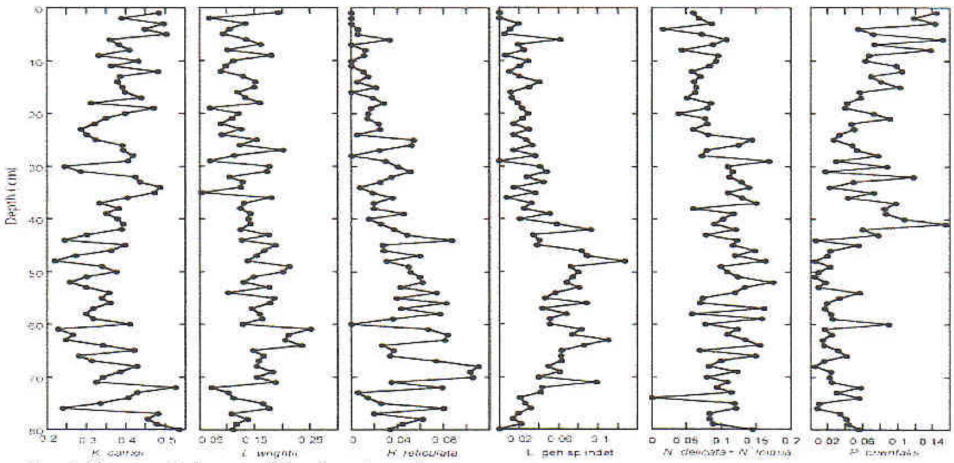

Fig. 4. Temporal change of dominant species

The increase in TOC and TN contents can be explained by the increase in population of Jakarta City. From 1950 to 1990, the population rapidly increased by almost fourfold, from 1,733,600 to 7,515,000. Waste from domestic areas and industries that produce nutrients probably caused the increase in TOC and TN contents. Although the population increased rapidly, TOC content gradually increased, suggesting a high rate of sedimentation and dilution by natural forces.

The gradual increase in TOC content since around 1950 did not greatly impact the structure of ostracod assemblages; the diversity index showed stable values throughout the core, but species number and density decreased slightly in the upper half of the core. Ostracod assemblages were composed of high percentages of K. carriei, L. wrighti, N. delicata and N. iniqua throughout the core at relatively stable frequencies, which were not affected by the small increase in TOC content.

The percentages of *Loxoconchidae gen. et sp. indet*. and *H. reticulata* decreased at a core depth of 45 cm (around 1950), where TOC content began to increase. Fauzielly et al. (in press) reported recent ostracods from core top samples collected in 1994 in Jakarta Bay and analysed the relationships between the density of dominant species in Jakarta Bay and TOC and TN contents. According to this study, *H. reticulata* is dominant in the middle part of Jakarta Bay and decreases abruptly at more than 0.8 and 0.14 wt% in TOC and TN, respectively, and prefers lower TOC and TN contents. Thus, it is considered that the increase in TOC content since around 1950 was a direct cause of the decrease in the relative abundance of *H. reticulata*. On the other hand, the relative abundance of *P. orientalis* increased rapidly between core depths of 45 cm and 40 cm, and from 40 cm upward, it was relatively more common (4%–16%) than in the lower portion of the core (1.7%–10%). *P. orientalis* was common in the inner part of Jakarta Bay in 1994 (Fauzielly et al., in press). TOC content indicates pollution and is a source of food for ostracods. A small increase in TOC content allows *P. orientalis* to thrive, and thus, *P. orientalis* may be used as an indicator of an increase in TOC content within a narrow range.

CONCLUSIONS

1. A total of 53 ostracod species were recognized in a core from the inner part of Jakarta Bay. The dominant species were *Keijella carriei* and *Loxoconcha wrighti*.
2. Abundance of *K. carriei* and *L. wrighti* throughout the core indicates that the benthic portion of Jakarta Bay was an organic-rich environment.
3. The rapid population increase in Jakarta City over the last 80 years caused an increase in the TOC content of muddy sediment. However, the increase in the TOC content is limited to between 0.7% and approximately 1.1 %, probably due to the high mud sedimentation rate.
4. In approximately the 1950s, Loxoconchidae gen. sp. indet. and *L. wrighti* decreased and *Phlyctenophora orientalis* increased due to organic contamination related to the increased population of Jakarta City. Thus, these markers may become useful tools for monitoring of coastal areas displaying the effects of organic pollution.

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