LAGUNA（汽水域研究）13，13～28 頁（2006 年 6 月）
LAGUNA 13，p.13－28（2006）

Recent Ostracoda from Urauchi Bay, Kamikoshiki-jima Island, Kagoshima Prefecture, southwestern Japan

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Abstract: At least one hundred and forty−six ostracode species were obtained from 29 surface sediment samples collected from Urauchi Bay, Kamikoshiki-jima, Kagoshima Prefecture, southwestern Japan. Four biofacies (IM, I, M, and O) were identified on the basis of Q-mode cluster analysis. Biofacies IM is distributed in the innermost part of the eastern inlet of the bay and contains many *Xestoleberis hanaii*. Biofacies I is distributed in the inner part of the bay and contains many *Loxoconcha uranouchiensis*. Biofacies M is found in the middle part of the bay and contains *Loxoconcha tosaensis*, *Pistocythereis bradyi*, *Nipponocythere bicarinata*, and *Ambtonia obai*, which are typical middle muddy bay species. Biofacies O is in the outer part of the bay and contains *Loxoconcha japonica*, *Loxoconcha optima*, and *Neonesidea oligodentata*, which live in areas under the influence of open water. *Spinileberis quadriaculeata* and *Cytheromorpha acupunctata*, which are typical inner muddy bay species, are restricted to part of the bay, whereas *Bicornucythere* species, which are typical enclosed inner-middle muddy bay species, are absent from the bay. These distributions suggest that there is little input of fine inorganic sediments or organic matter from the hinterland of Urauchi Bay because the bay is situated in small islands off the main islands of Japan, surrounded by hard sedimentary rocks, and no large rivers flow into the bay. Even when these sediments and organic matter enter the bay, they are transported to the deeper bay bottom or open seas due to the steep geomorphology along the coasts of the bay.

Key words: Recent, Ostracoda, Urauchi Bay, Kamikoshiki-jima Island, southwestern Japan

1. Introduction

Many studies of Recent Ostracoda (Crustacea) in the enclosed bays of the four large islands of Japan (Hokkaido, Honshu, Shikoku, and Kyushu Islands) have been conducted (e.g., Ishizaki, 1968, 1969, 1971; Ikeya and Hanai, 1982; Bodergat and Ikeya, 1988; Ikeya *et al.,* 1992; Yamane, 1998; Yasuhara and Irizuki, 2001; Irizuki *et al.,* 2003). Ikeya and Shiozaki (1993) identified the ostracode species common in Recent enclosed bays in Japan and discussed their ecological aspects. Several small islands are distributed from southern Kyushu to Ryukyu Islands, in southwestern Japan (Fig. 1), which are separated from each other by deep straits. The Tokara Strait is one of those straits and is the geographical barrier to many organisms that have low mobility, such as terrestrial animals. It is possible that the presence of the Tokara Strait has influenced the migration and speciation of the Ostracoda. Only one report of Recent Ostracoda from southern Kyushu Island has been published (Kagoshima Bay, southernmost Kyushu Island; Bodergat *et al.,* 2002). However, this bay is very large and open marine waters flow directly into the bay. No Recent Ostracoda have been reported from enclosed bays of the very small islands separated from the large main islands of Japan, except those in the Ryukyu

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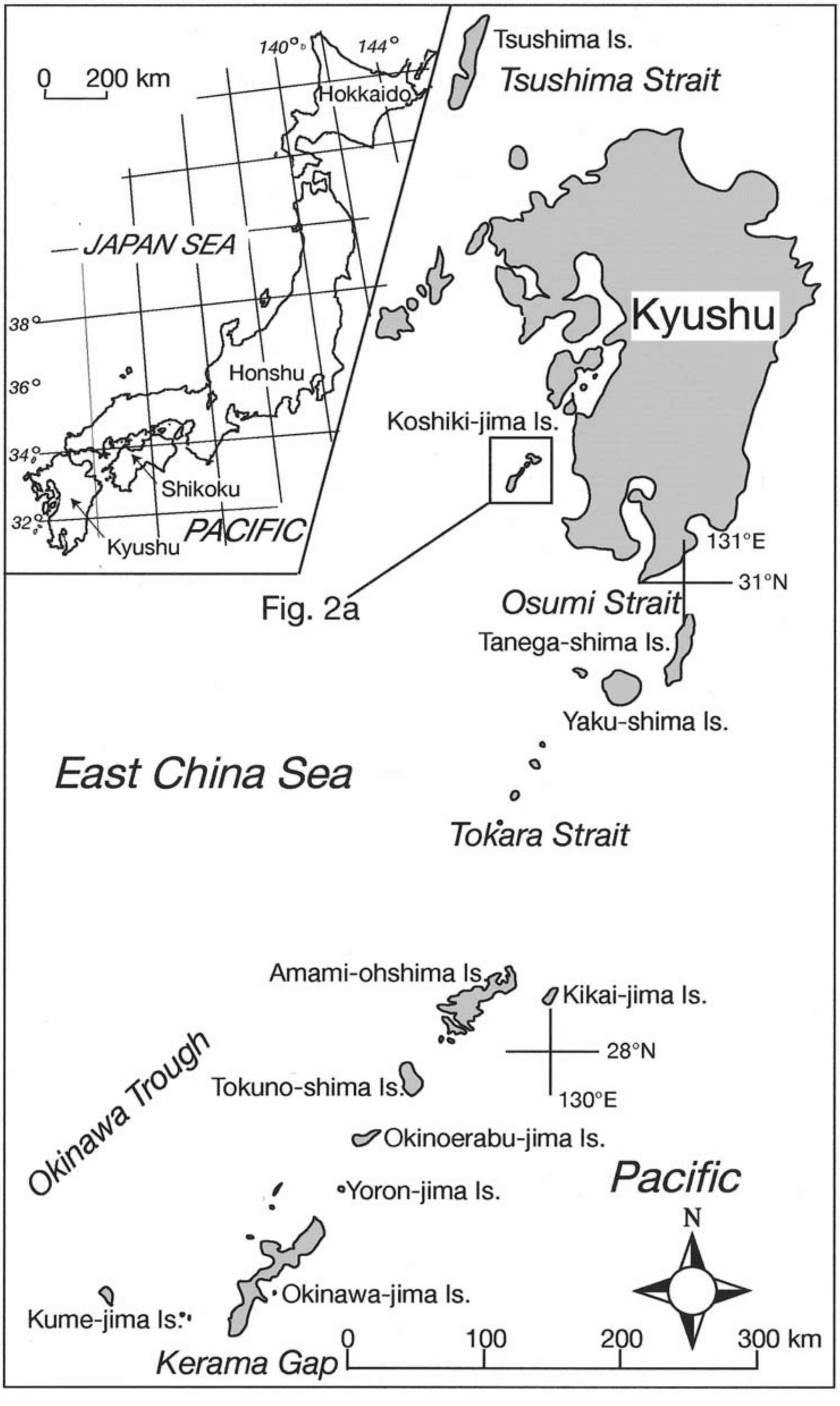

Fig. 1. Index maps of the Japanese Islands and the detailed locations of selected small islands in southwestern Japan.

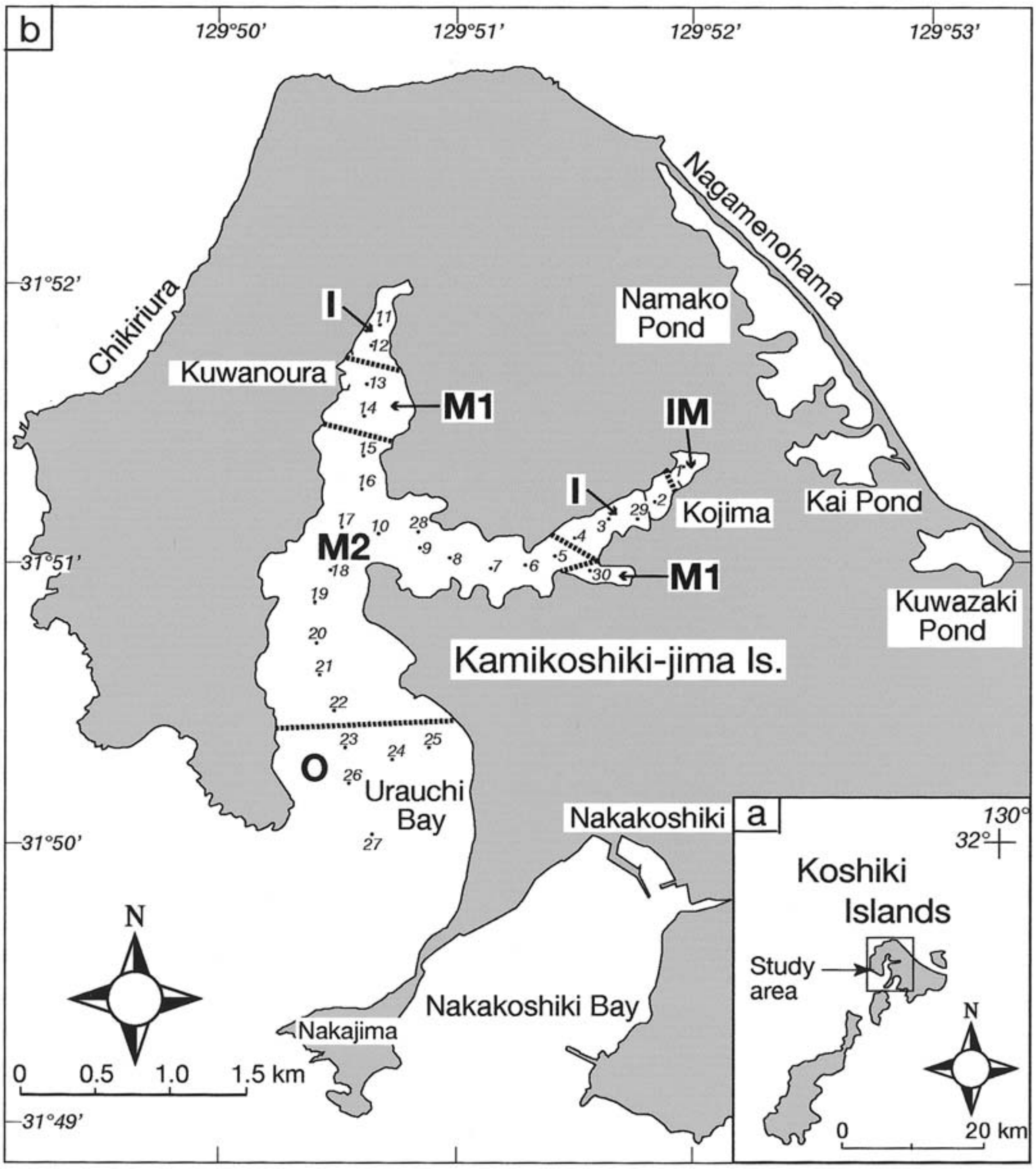

Fig. 2. Maps showing the location of Urauchi Bay (a) and sampling localities (b). IM, I, M 1, M 2, and O mean ostracode biofacies or subbiofacies.

Islands (Okinawa-jima Island etc.; Fig. 1). Therefore, we investigated the Recent Ostracoda from Urauchi Bay on Kamikoshiki-jima Island, off Kyushu Island, which is situated to the north of the Tokara Strait.

2. Localities and Methods

Koshiki-jima Island is situated 30–50 km off Kushikino Port, Kagoshima Prefecture, southwestern Japan (Figs. 1, 2) and consists of three small islands (Kamikoshiki, Nakakoshiki, and Shimokoshiki-jima Islands). The water depth between Kyushu Island and Koshiki-jima Island is less than 100 m, suggesting that both islands were connected during the last glacial period. Urauchi Bay is located in the northwestern part of Kamikoshiki-jima Island (Fig. 2). It is a Y-shaped, narrow and elongated bay with a longer axis of about 4.5 km. The width at its mouth is about 1.2 km. The water depth is about 25 m in the middle to outer parts of the bay and 45 m at the bay mouth. There is little inflow of fresh water. Only small streams are distributed in the bay head areas. The Paleogene Kamikoshiki-jima Group (the Nakakoshiki, Oshima, and Segami Formations, in ascending order) is predominantly distributed around Urauchi Bay. It is mainly composed of non-marine to marine alternating beds of sandstone and mudstone (Inoue *et al.,* 1979). Along part of the western coast of the bay, non-marine to marine sandstone and mudstone

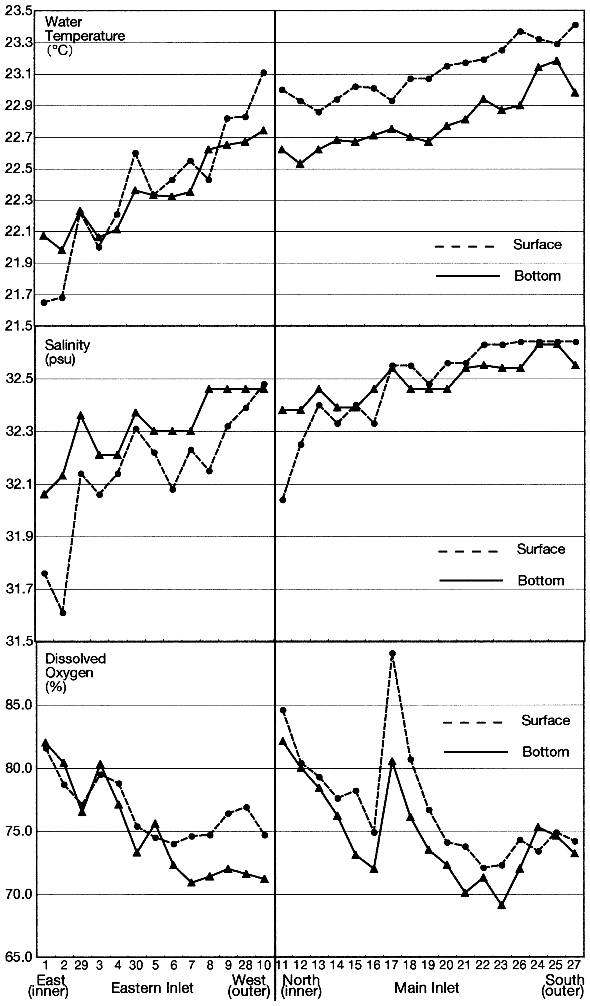

Fig. 3. Spatial variations of water temperature (℃), salinity (psu) and dissolved oxygen (%) in surface and bottom waters.

of the Cretaceous Himenoura Group are exposed (Inoue *et al.,* 1982). These hard rocks form the steep geomorphology along many parts of the bay coast.

A total of 30 surface sediment samples (UU-1 to UU-30; Fig. 2) were collected, using an Ekman–Birge grab sampler from a small ship on November 6–7, 2004. The intervals between sample sites were about 250 m. We determined the thickness of the oxygenated layer, and the color and smell of the sediments. We then collected samples for ostracode, foraminiferal, and total organic carbon, total nitrogen, and total sulfur contents (CNS) analyses from the uppermost 1 cm of the surface sediments using a small spoon, and soaked them in 10% neutral formalin. Residual samples were washed on a 2 mm mesh sieve on the ship and the macrobenthic animals were described. Only ostracodes are reported in this study. Takata *et al.* (2006) have reported the benthic foraminifers and total organic carbon, total nitrogen, and total sulfur contents of the same samples.

We investigated the depth variations in water temperature, salinity, and dissolved oxygen of the surface and bottom waters using the Hydrolab Quanta package.

3. Laboratory Procedures

Wet surface-sediment samples were washed through a 0.063 mm sieve on a 3 L beaker, into which the finer sediments (i.e., mud particles) were eluted with the washing water. After washing, one part per hundred volumes of the stirred water containing the finer sediments was collected from the beaker using a pipette, and the sediments were dried and weighed. The coarser sediments on the sieve screen were soaked in 0.5% Rose Bengal solution, for easy identification of living ostracode and foraminiferal specimens. These samples were washed thoroughly, dried, and weighed. The total weight of a sample was calculated as the weight of the dried coarse sediments plus 100 times the weight of the dried fine sediments.

All ostracodes were picked from the separated sediment samples, which included about 200 individuals, on a 0.125 mm sieve. The number of specimens refers to both valves and carapaces.

4. Results and Discussion

4.1. Environments on the study dates

(1) Water temperature: Surface and bottom water temperatures ranged from 21.7℃ to 23.4℃ and 22.0℃ to 23.2℃, respectively (Table 1; Fig. 3). The bottom water temperature was lower than the surface temperature at all sites except UU-1 to 3, UU-8 and UU-29. Although water temperature depends mainly on climate in measurement time of the investigation days, it seemed to be lower in the inner part of the eastern inlet and higher in the outer part of the main inlet. Differences between the surface and bottom water temperatures were small in all areas (Table 1).

(2) Salinity: The salinity of the surface and bottom waters ranged from 31.6 to 32.6 psu and 32.1 to 32.6 psu, respectively (Table 1; Fig. 3). Salinity increased toward the outer bay. Surface salinity in the innermost part of both the eastern and main inlets was slightly lower due to the inflow of small amounts of fresh water. The bottom salinity was slightly higher than that of the surface at UU-1 to UU-9, UU-28 to UU-30 in the eastern inlet and at UU-11 to UU-14 and UU-16 in the main inlet. In contrast, the bottom salinity was slightly lower than that of the surface waters in the middle to outer bay. Thus, no salinity layer was present on the days of the study (Table 1).

(3) Dissolved oxygen: Dissolved oxygen in both the surface and bottom waters ranged from 70 to 90% (Table

Table 1. Details of sample localities. WD: water depth, DO: dissolved oxygen.

Sample	Date	Time	Latitude	Longitude	Sediment	WD(m)	Temp.(℃)		Salinity(psu)		DO(%)	
			(WGS84)	(WGS84)			surface	bottom	surface	bottom	surface	bottom
UU-01	2004.11.6	10:05	31° 51.538'	129° 51.830'	slightly muddy granuler v.c.s-c.s.	1.8	21.7	22.1	31.8	32.1	81.6	82.0
UU-02	2004.11.6	10:16	31° 51.424'	129° 51.712'	granuler m.s.	3.7	21.7	22.0	31.6	32.1	78.7	80.4
UU-03	2004.11.6	10:32	31° 51.363'	129° 51.515'	muddy f.s.	11.0	22.0	22.1	32.1	32.2	79.5	80.3
UU-04	2004.11.6	10:58	31° 51.297'	129° 51.358'	muddy m.s.	14.1	22.2	22.1	32.1	32.2	78.8	77.1
UU-05	2004.11.6	11:31	31° 51.225'	129° 51.273'	f.sandy mud	22.0	22.3	22.3	32.2	32.3	74.5	75.6
UU-06	2004.11.6	12:01	31° 51.194'	129° 51.153'	silt	23.7	22.4	22.3	32.1	32.3	74.0	72.3
UU-07	2004.11.6	16:49	31° 51.190'	129° 51.004'	silt	26.5	22.6	22.4	32.2	32.3	74.6	70.9
UU-08	2004.11.6	16:33	31° 51.216'	129° 50.858'	silt	27.3	22.4	22.6	32.2	32.5	74.7	71.4
UU-09	2004.11.6	16:13	31° 51.249'	129° 50.709'	silt	27.7	22.8	22.7	32.3	32.5	76.4	72.0
UU-10	2004.11.6	15:51	31° 51.301'	129° 50.539'	sandy silt	28.1	23.1	22.7	32.5	32.5	74.7	71.2
UU-11	2004.11.6	13:35	31° 52.054'	129° 50.544'	ill-sorted m.s.	3.9	23.0	22.6	32.0	32.4	84.6	82.1
UU-12	2004.11.6	13:49	31° 51.985'	129° 50.512'	muddy m.s.	11.4	22.9	22.5	32.3	32.4	80.4	80.0
UU-13	2004.11.6	14:08	31° 51.846'	129° 50.490'	muddy f.s.	18.7	22.9	22.6	32.4	32.5	79.3	78.4
UU-14	2004.11.6	14:27	31° 51.728'	129° 50.474'	muddy f.s.	22.8	22.9	22.7	32.3	32.4	77.6	76.2
UU-15	2004.11.6	15:00	31° 51.588'	129° 50.466'	silt	28.8	23.0	22.7	32.4	32.4	78.2	73.1
UU-16	2004.11.6	15:30	31° 51.473'	129° 50.470'	sandy silt	28.3	23.0	22.7	32.3	32.5	74.9	72.0
UU-17	2004.11.7	9:46	31° 51.325'	129° 50.370'	sandy silt	30.6	22.9	22.8	32.6	32.5	89.1	80.5
UU-18	2004.11.7	10:10	31° 51.170'	129° 50.325'	slightly muddy f.s.including m.s.	28.2	23.1	22.7	32.6	32.5	80.7	76.1
UU-19	2004.11.7	10:35	31° 51.059'	129° 50.268'	slightly muddy f.s.including m.s.	29.0	23.1	22.7	32.5	32.5	76.7	73.5
UU-20	2004.11.7	10:58	31° 50.907'	129° 50.271'	slightly muddy f.s.including m.s.	27.9	23.2	22.8	32.6	32.5	74.1	72.3
UU-21	2004.11.7	11:16	31° 50.799'	129° 50.283'	slightly muddy f.s.including m.s.	28.0	23.2	22.8	32.6	32.5	73.8	70.1
UU-22	2004.11.7	11:40	31° 50.662'	129° 50.340'	slightly muddy f.s.including m.s.	28.5	23.2	22.9	32.6	32.6	72.1	71.3
UU-23	2004.11.7	11:58	31° 50.547'	129° 50.384'	slightly muddy m.s.	29.0	23.3	22.9	32.6	32.5	72.3	69.1
UU-24	2004.11.7	14:23	31° 50.495'	129° 50.601'	sorted m.s.	15.2	23.3	23.1	32.6	32.6	73.4	75.3
UU-25	2004.11.7	14:38	31° 50.548'	129° 50.751'	well-sorted m.s.	8.5	23.3	23.2	32.6	32.6	74.9	74.6
UU-26	2004.11.7	14:57	31° 50.412'	129° 50.417'	slightly muddy m.s.	29.6	23.4	22.9	32.6	32.5	74.3	72.0
UU-27	2004.11.7	15:17	31° 50.228'	129° 50.517'	well-sorted c.s.	28.9	23.4	23.0	32.6	32.6	74.2	73.2
UU-28	2004.11.7	15:56	31° 51.306'	129° 50.711'	sandy silt	27.0	22.8	22.7	32.4	32.5	76.9	71.6
UU-29	2004.11.7	13:15	31° 51.367'	129° 51.648'	slightly muddy m.s.	10.0	22.2	22.2	32.1	32.4	77.1	76.5
UU-30	2004.11.7	13:50	31° 51.175'	129° 51.435'	muddy f.s.	10.0	22.6	22.4	32.3	32.4	75.4	73.3

f.s: fine sand, m.s.: medium sand, c.s.: coarse sand, v.c.s.: very coarse sand

1; Fig. 3). Thus, Urauchi Bay in the study season is in an oxic condition. The dissolved oxygen in the bottom waters was slightly lower than that of the surface waters at all but four sites (UU-1 to UU-3 and UU-5) in the inner part of the eastern inlet. It tended to decrease toward the outer bay areas. However, the differences in dissolved oxygen between the surface and bottom waters were small.

(4) Sediments: Samples from the innermost part of the eastern inlet (UU-1 and 2) consisted of granular medium to very coarse sand (Table 1), with mud contents of less than 10% (Table 1; Fig. 4). The mud content increased toward the middle part of the bay and substrates changed from sand to muddy sand. Samples UU-6 to UU-10 in the middle part of the eastern inlet of the bay were composed of silt, with a very thick (4–5 cm) oxidized layer of a yellowish brown color. Sample UU-11, which was taken from the innermost part of the main inlet, consisted of poorly sorted medium sand with a mud content of less than 10%. Samples UU-15 to 17 consisted of mud, with a thick yellowish-brown-colored oxidized layer. The mud content decreased toward the outer part of the bay and samples UU-24 to 26 consisted of well-sorted medium sand. Sample UU-27, which was collected in the outermost part of the bay, was composed of coarse sand. Thus, no oxygen-poor bottom sediments were observed in Urauchi Bay on the study dates.

4.2. Ostracode biofacies

At least 146 species were obtained from 29 samples (Table 2). Most of them are composed of dead valves or carapaces and living specimens were few (Table 3). Fifty -seven species, of which total number of specimens was more than 10, are shown in Figs. 5 to 9. The Shannon-Wiener function was used for the index of species diversity. Equitability (E) was calculated using the function of Buzas and Gibson (1969). Q-mode cluster analysis was conducted on the basis of 28 samples, each containing more than 100 specimens, and 65 species that were represented by more than three specimens in any sample. Horn's overlap index (Horn, 1966) was used as the similarity index and clustering was performed with an unweighted pair group arithmetic method of averages (UPGMA). The computer program used for the analysis was PAST (Paleontological Statistics), which is a free, easy-to-use data analysis package designed for paleontological data (Hammer *et al.,* 2001). The results indicate four ostracode biofacies (IM, I, M, and O), described below (Figs. 2–4).

(1) Biofacies IM: This biofacies is composed of only one sample (UU-1), which was collected in the innermost part of the eastern inlet. *Xestoleberis hanaii* is the dominant species in this biofacies. This species lives on and around seaweeds, mainly in intertidal rocky shores and *Zostera* beds (Okubo, 1984; Kamiya, 1988). The

Table 2. Faunal list of Recent Ostracoda from Urauchi Bay. The number of specimens refers to both dead (valves and carapaces) and living specimens.

UU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29	30	total
Aglaiocypris ? nipponica Okubo, 1980	2				1											1					1									5
Ambtonia obai (Ishizaki, 1971)					6	13	12	13	22	26				2	24	57	30	3	9	7	10	4	1				3			242
Argilloecia lunata Frydl, 1982					1																									1
Argilloecia sp.	1					2																								3
Aurila cymba (Brady, 1869)	29	10	6	2							8	11		2				2			3		2	2	2	4		8	2	93
Aurila hataii Ishizaki, 1968																			1						1	1				3
Aurila spinifera Schornikov & Tsareva, 1995					6	7	3	1	3	3			5		1	1	3		3	1		1					3	2	2	45
Aurila cf. *uranouchiensis* Ishizaki, 1968			2	3	11	5			2				2	2	1				2	3	3			1		2	10	2	2	53
Aurila sp.																			1											1
Australimoosella tomokoae (Ishizaki, 1968)																		1	1											2
Bythoceratina angulata Yajima, 1987						1	1										1									1	1			5
Bythoceratina hanaii Ishizaki, 1968					2	1									1			1				1	1	2			1			10
Bythoceratina cf. *hanaii* Ishizaki, 1968				1	1	1	1																							4
Bythoceratina sp. 1						2																								2
Bythoceratina sp. 2								1																						1
Bythocythere cf. *maisakensis* Ikeya & Hanai, 1982																						1		2	2					5
Bythocythere sp.																					1									1
Callistocythere alata Hanai, 1957			1	1	1	1						1				1			3					1		1		7	1	19
Callistocythere asiatica Zhao, 1984		2				2				1								1		1			4	3						14
Callistocythere japonica Hanai, 1957				4	2		1		1							1									1					10
Callistocythere numaensis Frydl, 1982				1																										1
Callistocythere pumila Hanai, 1957					1						1																		1	3
Callistocythere tateyamaensis Frydl, 1982					1	1							1																	3
Callistocythere tosaensis (Ishizaki, 1968)	3	1																1												5
Callistocythere undulatifacialis Hanai, 1957	2	1	6	9	12	9	8	2	5		1	4	7	3	5	8	6		7	4	3	4				4	10	9	4	133
Callistocythere sp.					1											2	1			1	2	1								8
Cletocythereis bradyi Holden, 1967							1																				1			2
Cobanocythere sp.																			1											1
Copytus posterosulcus Wang, 1985						4	1	1	6	1					1	5														19
Coquimba ishizakii Yajima, 1978		2				1										1					1	1	2	2			1	3		14
Coquimba cf. *subgibba* Hu, 1982										1						1	3		1					2						8
Coquimba sp.																			1											1
Cornucoquimba shimajiriensis Nohara, 1987																							2							2
Cornucoquimba tosaensis (Ishizaki, 1968)				1		2	1																				1			5
Cornucoquimba sp.					1																									1
Cythere sp.						1									1	2		1												5
Cytherelloidea hanaii Nohara, 1976			2	3	14	12	10	9	13	11			1	3	12	30	10	2	12	12	9	6	5			3	3			182
Cytherois cf. *nakanoumiensis* Ishizaki, 1969		2		2																									4	8
Cytherois cf. *uranouchiensis* Ishizaki, 1968		1	1								1											2						1	12	18
Cytherois sp. 1					2	3			2			1	1					1			2						1			13
Cytherois sp. 2	1	2		4	3	1	4		1		1		2	3		2	1	1	1	1	4	1					2		3	38
Cytheromorpha acupunctata (Brady, 1880)				1	25	55	12	8	19	17	3	4	22	18	28	49	17	1	7	1	1						1	3	64	356
Cytheroptern donghaiense (Zhao, 1988)					1	2	1	2	5	3					3	5	1		3		1									27
Cytheropteron sp.																		1												1
Eucythere sp.															1															1
Hanaiborchella sp.										1							1													2
Hemicytherura cuneata Hanai, 1957		1				1		1		2	1				3	1	1		2			2	2	1	1	2				21
Hemicytherura kajiyamai Hanai, 1957																			1	1				3		1				6
Hemicytherura tricarinata Hanai, 1957			1								3	1			1								1							7
Hemicytherura sp.																							1							1
Isocythereis roochuensis Nohara, 1987																	1													1
Loxoconcha hattorii Ishizaki, 1971		5	2									1																1		9
Loxoconcha harimensis Okubo, 1980		1			3		2										2		1					2	2	1		2		16
Loxoconcha japonica Ishizaki, 1968		3	1	1	14	10	7	4	10	6	1	8	2		7	11	10	16	16	13	17	15	23	29	4	21	7	5	2	263
Loxoconcha kattoi Ishizaki, 1968		1		1	5	7	3	1		2			1	1				2			2	2	2	2		1			2	35
Loxoconcha kitanipponica Ishizaki, 1971		2	1	1	6	4		2								2					1						3	1	2	25
Loxoconcha optima Ishizaki, 1968							1			4				1		1	2	3	2	5	1	3	5	9	8	2				47
Loxoconcha pulchra Ishizaki, 1968											2	2																		4
Loxoconcha uranouchiensis Ishizaki, 1968	104	54	41	34	32	31	20	4	3	5	29	111	24	7	6	12	8	7	13	10	4	10	4	4		7	17	72	14	687
Loxoconcha tosaensis Ishizaki, 1968		13	24	19	63	61	31	17	20	32	2	51	55	27	31	107	35	18	52	40	37	20	16	3		11	36	18	28	867
Loxoconcha zamia Ishizaki, 1968					3	1	1																							5
Loxoconcha sp.						1																								1
Loxocorniculum mutsuense Ishizaki, 1971					1	1	1		1	2					1					3	3	1		3		2				19
Macrocypris sp.					2	3			1					1					2			1							1	11
Morkhoveina inconspicua (Brady, 1880)					1		1																						1	3
Munseyella japonica (Hanai, 1957)					1	2		1	1					1		2			1											9
Neohornibrookella lactea (Brady, 1866)																	6		1	1			1	1		1				11
Neonesidea oligodentata (Kajiyama, 1913)		5		1	9	4		1	1	1		1		1		1	1	1	3	6	6	9	9	7	3	8		3		81
Neonesidea sp.																1				1	2									4
Neonesidea ? sp.							1									1														2
Neopellucistoma inflatum Ikeya & Hanai, 1982				3	27	19	4	3	5	6			1	5	4	15	2		7	6	2	2	1				1			113
Nipponocythere bicarinata (Brady, 1880)					39	51	26	27	34	35			7	10	35	78	30	10	25	11	15	13	1				24			471
Pacambocythere japonica (Ishizaki, 1971)				1																										1
Paracathaycythere costaereticulata Whatley & Zhao, 1991	1	1	2		1			1	1		2	1																	1	11

Table 2. (continued)

UU	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29	30	total
Paracytheridea dialata Gou & Huang, 1983				1												1														2
Paracytheridea neolongicaudata Ishizaki, 1966																								1						1
Paradoxostoma aculeoliferum Schornikov, 1975							2	1	1	2				1		2		2	3		1	2	2	1		4				24
Paradoxostoma brunneum Schornikov, 1975						1							1				1	2	1	2		1	1			1				11
Paradoxostoma coniforme Kajiyama, 1913					1												1												1	3
Paradoxostoma convexum Okubo, 1977					1	3		1									1													6
Paradoxostoma cf. *denticulatum* Okubo, 1977																						2								2
Paradoxostoma japonicum Schornikov, 1975																							1							1
Paradoxostoma cf. *lunatum* Okubo, 1977																					1									1
Paradoxostoma setoense Schornikov, 1975																		1	2							1				4
Paradoxostoma cf. *setosum* Okubo, 1977						1			1									1												3
Paradoxostoma yatsui Kajiyama, 1913					2							2				3			1		1	3		2						14
Paradoxostoma sp. 1		1	1		4			1									1		1									2		11
Paradoxostoma sp. 2					1		1	1		1						1		3	2		2			1		1				14
Paradoxostoma sp. 3					2	1	1												1	1	1			1		1				9
Paradoxostoma sp. 4																					1	1				1				3
Paradoxostoma sp. 5					3	1																					1		1	6
Paradoxostoma sp. 6																	1			1	2									4
Paradoxostoma spp.			1			1	2		2			1		1				2	2	1		1								14
Parakrithe sp.						2		1	2	2						2	1													10
Parakrithella pseudadonta (Hanai, 1959)	5	2	1	1	7	6	1			3	1	1	2		1	7	2	4	2	5	3	3	4	1		2	2	3		69
Perrisocytheridea inabai Okubo, 1983		5	3		1	1					10	1				1	1	2	1	1	1	1	1	6	1		1	10	2	50
Phlyctocythere sp.																			1											1
Pistocythereis bradyformis (Ishizaki, 1968)			1	5	64	62	20	15	12	19		1	16	22	46	37	19	3	4	4	4	3					6	5	43	411
Pistocythereis bradyi (Ishizaki, 1968)			2	3	37	81	33	18	42	50			13	14	59	109	97	14	43	37	57	36	8			2	17	2	6	780
Pontocythere japonica (Hanai, 1959)																				1		2				1				4
Pontocythere kashiwarensis (Hanai, 1959)		4	5	2	1			1	2	2	3	1			1	1	1	2	4	2	3	1	2	3		3		8	1	53
Pontocythere miurensis (Hanai, 1959)						1															1		2							4
Pontocythere sekiguchii Ikeya & Hanai, 1982																										2				2
Pontocythere sp. 1	4	5	9	1	6		1				28	8	1	1			6	1	3	5	5	4	5	2	2	2		7	1	107
Pontocythere sp. 2								1																						1
Pontocythere sp. 3									1									1												2
Propontocypris attenuata (Brady, 1868)					1	2	1	1		2		1								1	1							1		11
Propontocypris clara Zhao, 1988																						1								1
Propontocypris pirifera (G.W.Müller, 1894)	2																													2
Propontocypris sp. 1	14	1	3	2	2	2					1			1			1		1			1		1		1			1	32
Propontocypris sp. 2	4	1	2	1								4	2				1	1	1	1	3	4							1	26
Propontocypris sp. 3																					1									1
Pseudoaurila japonica (Ishizaki, 1968)				2	11	1	1			1						1			1									1		19
Pseudocythere frydli Yajima, 1982						1																	1			2				4
Pseudocythere sp.						1													1											2
Pseudopsammocythere tokyoensis Yajima, 1978				1		1								1																3
Robustaurila ishizakii (Okubo, 1980)																				3		1				1				5
Robustaurila salebrosa (Brady, 1869)																								3						3
Schizocythere kishinouyei (Kajiyama, 1913)										1			1				1	1					1	1	1	1	1			9
Sclerochilus mukaishimensis Okubo, 1977					1								1				1			1							1	1		6
Sclerochilus sp.																1		1												2
Sclerochilus ? sp.																						1								1
Semicytherura kazahana Yamada *et al* ., 2005																		2	2				1	1		2				8
Semicytherura mukaishimensis Okubo, 1980	1	1			1					1						1	1		2	3	2							2		15
Semicytherura okinawaensis Nohara, 1987									2																					2
Semicytherura polygonoreticulata Ishizaki & Kato, 1976					1												2													3
Semicytherura sasameyuki Yamada *et al* ., 2005		1		1												1	1													4
Semicytherura wakamurasaki Yajima, 1982																											1			1
Semicytherura sp. 1					3	3	1	1											1	1		1	2				3	1		17
Semicytherura sp. 2	1		2	1	1	1			1			1						1	4	1	2	2	3					3		24
Semicytherura sp. 3																											1			1
Spinileberis quadriaculeata (Brady, 1880)	1	2	6	11	16	10	3		3	1	3	6	10	20	9	14			1	2							1	9	64	192
Thalassocypria inujimensis Okubo, 1980			1		1	1			1								1		1										2	8
Trachyleberis ishizakii Yasuhara *et al.* , 2002				12	5	2	2	1		1		11	8	3		1	6	3	4	3	5	3	1			3	3	3	1	81
Trachyleberis scabrocuneata (Brady, 1880)	3	25	8	2	1	6					15	7	1		2	1	2		4		3	2		7		2	1	25	4	121
Trachyleberis straba Frydl, 1982					2	3																								5
Trachyleberis sp.																													1	1
Triebelina sp.																				1				1						2
Xestoleberis hanaii Ishizaki, 1968	175	12	6	1	10	21	6	1	1	3	1		3		2	8	6	6	10	5	18	12	9	7	1	9	7	11	6	357
Xestoleberis ishizakii Schornikov, 1975				2	9	7			2			1					2	1	4	3	3	6	5	2	1	5	9			62
Xestoleberis setouchiensis Okubo, 1979							1		1							1										3				6
Xestoleberis sp. 1					2																1	1	1							5
Xestoleberis sp. 2																			2			1		1						4
Xiphichilus sp.							4	7	3	6					2	2			1								1			26
Gen et sp. indet. 1			1				1	1	1	1									2		1					1				9
Gen et sp. indet. 2																										1				1
No. of specimens	353	167	142	142	496	545	235	151	234	255	117	243	190	151	288	593	329	127	292	213	254	196	133	121	30	125	182	231	281	
No. of species	18	30	29	37	63	62	42	34	38	35	21	27	26	25	27	47	46	40	60	43	49	47	37	37	14	42	35	32	33	

Table 3. Species list of living ostracode specimens.

UU	1	2	6	9	11	12	15	19	25	26	29	30	total
Ambtonia obai (Ishizaki, 1971)			1	1									2
Aurila cymba (Brady, 1869)		1											1
Callistocythere alata Hanai, 1957											1		1
Callistocythere tosaensis (Ishizaki, 1968)	2												2
Callistocythere undulatifacialis Hanai, 1957										1	1		2
Cytherelloidea hanaii Nohara, 1976								1					1
Cytherois cf. *uranouchiensis* Ishizaki, 1968											1		1
Loxoconcha optima Ishizaki, 1968									2				2
Loxoconcha tosaensis Ishizaki, 1968										1		1	2
Loxoconcha uranouchiensis Ishizaki, 1968	4				2	1					2		9
Nipponocythere bicarinata (Brady, 1880)								1					1
Parakrithella pseudadonta (Hanai, 1959)	1												1
Pistocythereis bradyi (Ishizaki, 1968)							1						1
Pontocythere sp. 1					3								3
Propontocypris sp. 2		1											1
Trachyleberis scabrocuneata (Brady, 1880)		7											7
Xestoleberis hanaii Ishizaki, 1968	1										1		2
Number of living specimens	8	9	1	1	5	1	1	2	2	2	6	1	39

species diversity and equitability are both lowest among the biofacies ($H(S) = 1.47$, $E = 0.24$).

(2) Biofacies I: This biofacies is composed of six samples (UU-2 to 4, 11, 12, and 29), which were collected from the inner part of the bay. It is characterized by an abundance of *Loxoconcha uranouchiensis*. This species lives abundantly on sandy sediments around *Zostera* beds (Kamiya, 1988). *Loxoconcha tosaensis*, which is a muddy-bay species (e. g., Ishizaki, 1968), is a subordinate species. Species diversity and equitability are low to moderate in this biofacies ($H(S) = 1.98–2.89$, $E = 0.27–0.49$).

(3) Biofacies M: This biofacies is composed of 18 samples, which were collected in the middle part of the bay and is divided into two subbiofacies (M 1 and M 2). Subbiofacies M 1 is composed of three samples (UU-13, 14, and 30). *Loxoconcha tosaensis*, *Cytheromorpha acupunctata*, and *Spinileberis quadriaculeata* are the main species of this subbiofacies. The latter two species are characteristic of enclosed inner bays in Japan (Ikeya and Shiozaki, 1993). Species diversity and equitability are moderate ($H(S) = 2.41–2.58$, $E = 0.34–0.53$). Subbiofacies M 2 is composed of 15 samples (UU-5–10, 15–22, and 28). *Pistocythereis bradyi*, *L. tosaensis*, *Nipponocythere bicarinata*, and *Ambtonia obai* are dominant in this subbiofacies, most of which live abundantly in muddy middle bays of more than 10–15 m in depth (e.g., Yasuhara *et al.,* 2005). Such phytal species as *Loxoconcha japonica* and *Paradoxostoma* spp. are also present. *Cytherelloidea hanaii*, which is a subtropical species (Nohara, 1981), is common in this subbiofacies. Species diversity is moderate to high and equitability is low to moderate ($H(S) = 2.48–3.27$, $E = 0.30–0.58$).

(4) Biofacies O: This biofacies is composed of three samples (UU-23, 24, and 26), which were collected from the outer part of the bay. *Loxoconcha japonica*, *Neonesidea oligodentata*, and *Loxoconcha optima* are dominant in this biofacies. The former two species live on seaweeds around rocky tidal shores or *Zostera* beds and all three species live in areas under the influence of open water (e.g., Okubo, 1975; Kamiya, 1988). Species diversity and equitability are moderate to high ($H(S) = 3.08–3.28$, $E = 0.52–0.63$).

4.3. Relationships between dominant species, biofacies, and environmental factors

Loxoconcha uranouchiensis, which is the dominant species of biofacies I, is abundant in the inner shallowest part of the bay, where substrates are composed of sand to muddy sand. Its relative abundance rapidly decreases at a water depth of more than about 15 m in the middle of the bay. *Loxoconcha tosaensis*, which is the subordinate species in biofacies I and the dominant species in biofacies M, occurs at a water depth of about 5 m and is the dominant species in muddy sand to muddy bottoms at water depths of around 15 m. *Ambtonia obai*, *N. bicarinata*, and *P. bradyi*, which are major members of biofacies M, have similar depth distributions. They occur mainly in muddy bottoms at a water depth of more than about 15 m. *Pistocythereis bradyi* is the dominant species at water depths of 25–30 m. These species are rare on sandy bottoms in the outer part of the bay (biofacies O). *Loxoconcha japonica*, *L. optima*, and *N. oligodentata*, which are major members of biofacies O, are rare in the inner to middle parts of the bay, but are abundant in the sandy bottoms of the outer parts of the bay, which are under the influence of open water. Species diversity increases gradually toward the outer bay. Thus, the species distributions and biofacies are controlled by water depth, substrates, and the degree of influence of open water.

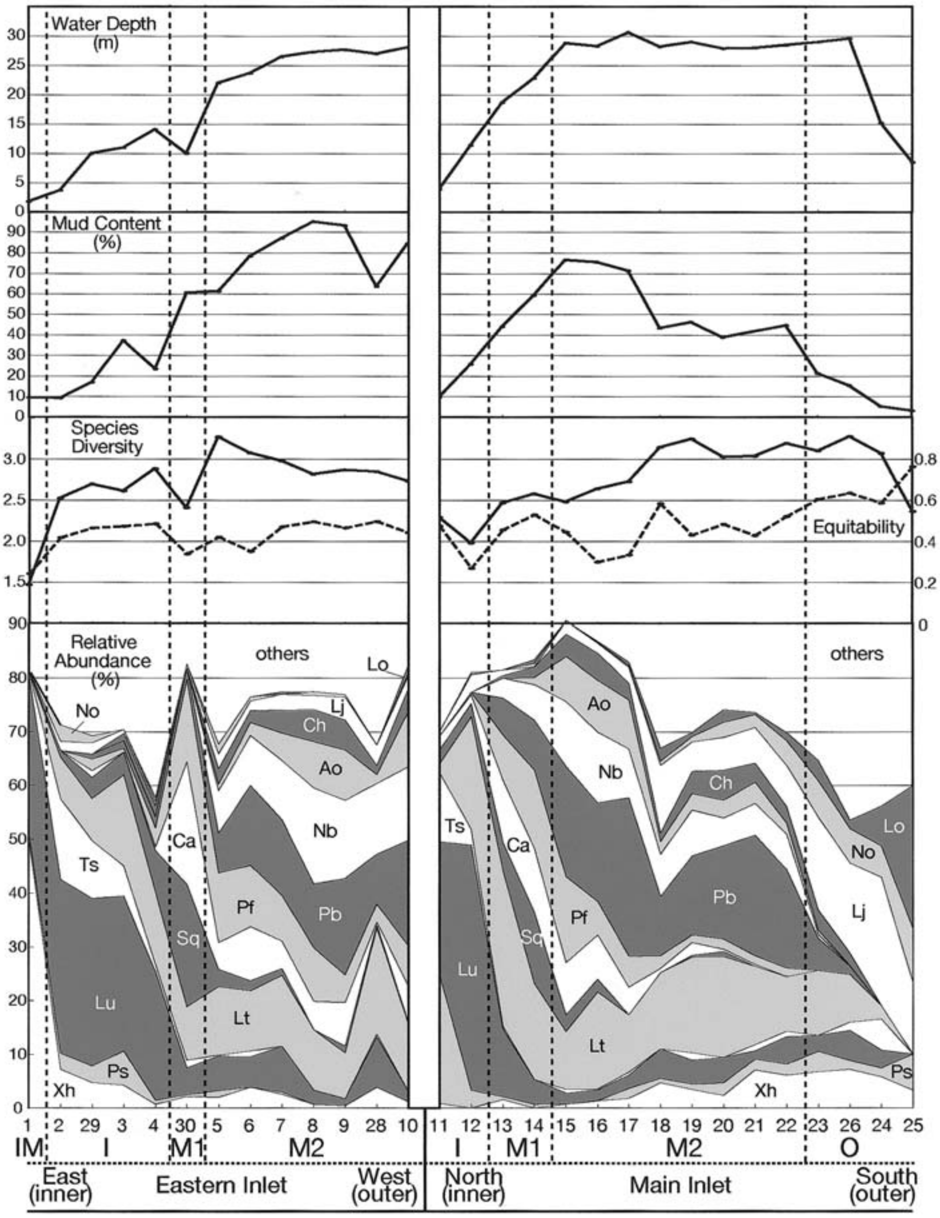

Fig. 4. Spatial variations of water depth (m), mud content (%), species diversity ($H(S)$), equitability, and the relative abundance (%) of selected species in each locality. Xh: *Xestoleberis hanaii*, Ps: *Pontocythere* sp. 1, Lu: *Loxoconcha uranouchiensis*, Ts: *Trachyleberis scabrocuneata*, Lt: *Loxoconcha tosaensis*, Sq: *Spinileberis quadriaculeata*, Ca: *Cytheromorpha acupunctata*, Pf: *Pistocythereis bradyformis*, Pb: *Pistocythereis bradyi*, Nb: *Nipponocythere bicarinata*, Ao: *Ambtonia obai*, Ch: *Cytherelloidea hanaii*, Lj: *Loxoconcha japonica*, No: *Neonesidea oligodentata*, Lo: *Loxoconcha optima*. IM, I, M 1, M 2, and O mean ostracode biofacies or subbiofacies.

4.4. Comparisons with Recent Ostracoda in other enclosed bay areas in Japan

The Recent Ostracoda in enclosed bay areas of the main islands of Japan have been comprehensively studied, as mentioned above. Ikeya and Shiozaki (1993) have compiled several earlier studies and identified *S. quadriaculeata*, *Bicornucythere bisanensis*, and *C. acupunctata* as the dominant species in most inner enclosed bays in Japan. In the enclosed bays of southwestern Japan, such as Osaka and Uranouchi Bays, *Bicornucythere* sp. (= *B. bisanensis* form M of Yasuhara and Irizuki, 2001) occurs abundantly in the inner to middle parts of the bays (Yasuhara and Irizuki, 2001; Irizuki *et al.,* 2005). The genus *Bicornucythere* (*B. bisanensis* and *Bicornucythere* sp.) is not present in Urauchi Bay. *Spinileberis quadriaculeata* and *C. acupunctata* are the most dominant species at only one locality (UU-30). On behalf of these species, *L.*

Fig. 5. Scanning electron micrographs of the selected ostracode species. Scale bars are 0.1 mm. LV: left valve, RV: right valve, LC: left lateral view of carapace.

1. *Cytherelloidea hanaii* Nohara, 1976, adult, LV, sample UU-18, 2. *Neonesidea oligodentata* (Kajiyama, 1913), female, RV, sample UU-25, 3. *Macrocypris* sp., adult, LV, sample UU-6, 4. *Propontocypris attenuata* (Brady, 1868), adult, LC, sample UU-21, 5. *Propontocypris* sp. 1, juvenile, LV, sample UU-1, 6. *Propontocypris* sp. 2, juvenile, LV, sample UU-12, 7. *Perrisocytheridea inabai* Okubo, 1983, adult, RV, sample UU-29, 8. *Pontocythere kashiwarensis* (Hanai, 1959), female, LV, sample UU-29, 9. *Pontocythere* sp. 1, female, LV, sample UU-20, 10. *Copytus posterosulcus* Wang, 1985, juvenile, LV, sample UU-9, 11. *Parakrithe* sp., juvenile, LV, sample UU-10, 12. *Parakrithella pseudadonta* (Hanai, 1959), female, RV, sample UU-3

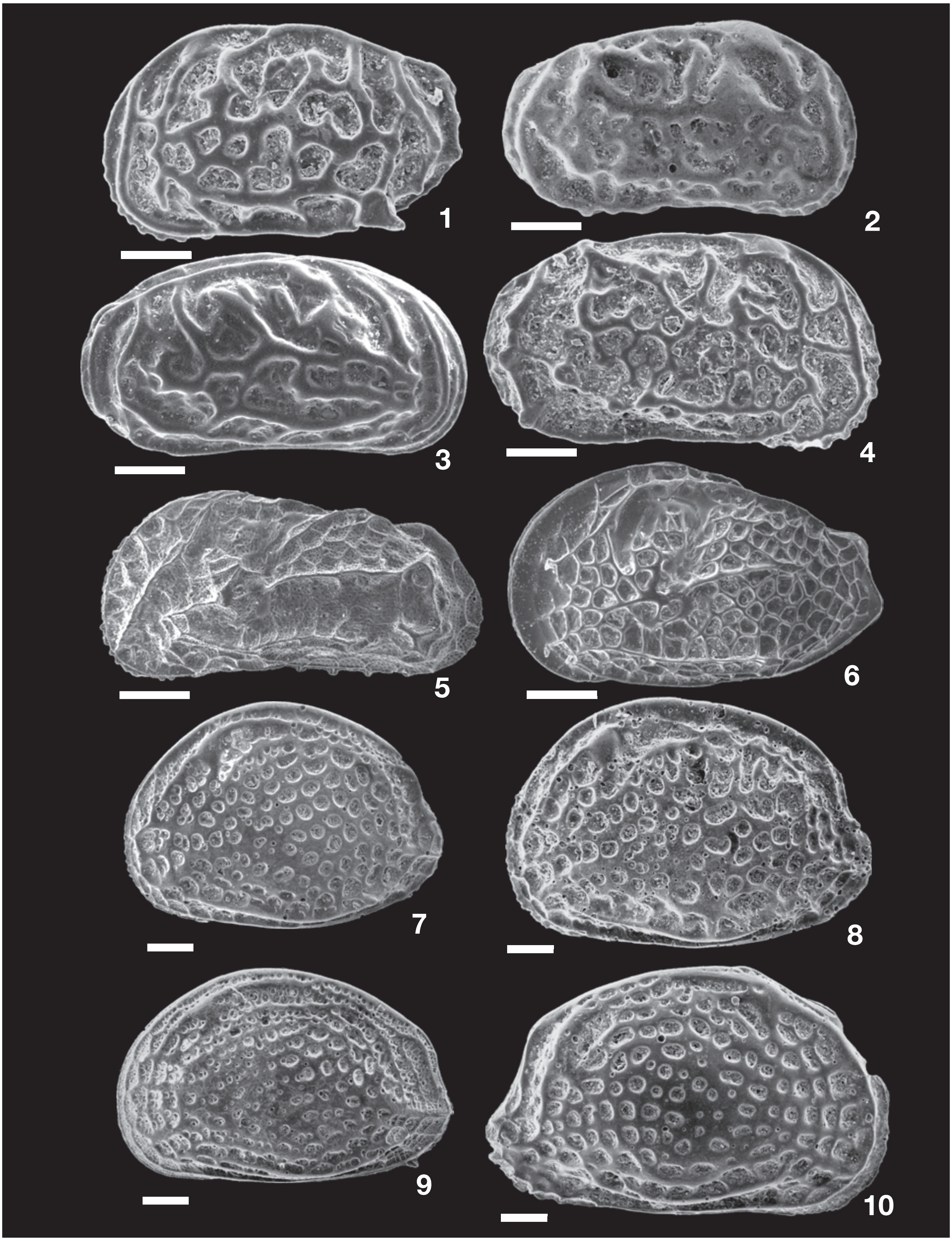

Fig. 6. Scanning electron micrographs of the selected ostracode species. Scale bars are 0.1 mm. LV: left valve, RV: right valve, RC: right lateral view of carapace.

1. *Callistocythere alata* Hanai, 1957, female, LV, sample UU-29, 2. *Callistocythere asiatica* Zhao 1984, female, RV, sample UU -2, 3. *Callistocythere japonica* Hanai, 1957, adult, RC, sample UU-25, 4. *Callistocythere undulatifacialis* Hanai, 1957, female, RV, sample UU-5, 5. *Paracathaycythere costaereticulata* Whatley and Zhao, 1991, male, LV, sample UU-3, 6. *Spinileberis quadriaculeata* (Brady, 1880), female, LV, sample UU-30, 7. *Aurila cymba* (Brady, 1869), female, LV, sample UU-29, 8. *Aurila spinifera* Schornikov and Tsareva, 1995, female, LV, sample UU-5, 9. *Aurila* cf. *uranouchiensis* Ishizaki, 1968, adult, LV, sample UU-29, 10. *Pseudoaurila japonica* (Ishizaki, 1968), female, RV, sample UU-5

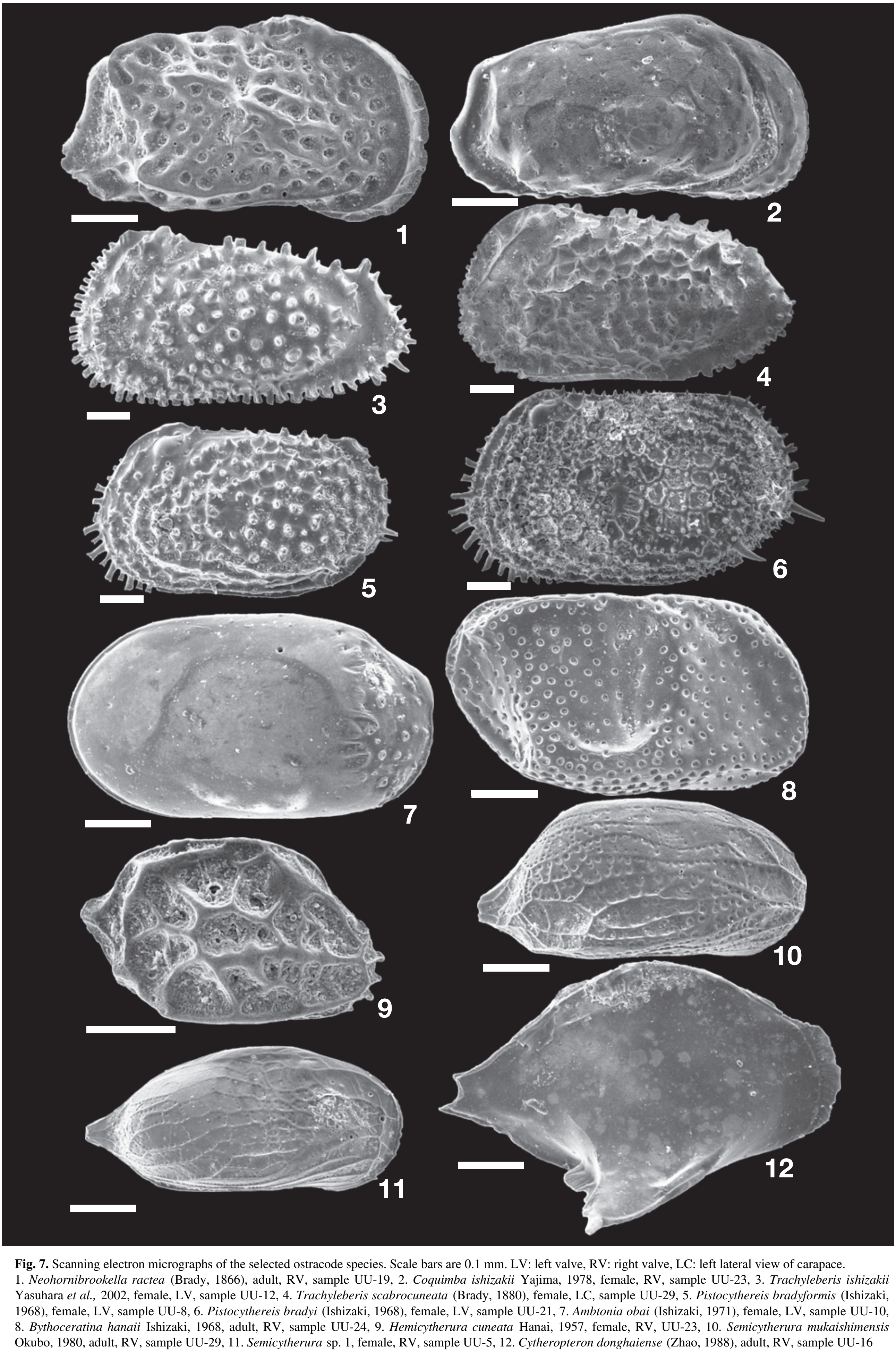

Fig. 7. Scanning electron micrographs of the selected ostracode species. Scale bars are 0.1 mm. LV: left valve, RV: right valve, LC: left lateral view of carapace.
1. *Neohornibrookella ractea* (Brady, 1866), adult, RV, sample UU-19, 2. *Coquimba ishizakii* Yajima, 1978, female, RV, sample UU-23, 3. *Trachyleberis ishizakii* Yasuhara *et al.,* 2002, female, LV, sample UU-12, 4. *Trachyleberis scabrocuneata* (Brady, 1880), female, LC, sample UU-29, 5. *Pistocythereis bradyformis* (Ishizaki, 1968), female, LV, sample UU-8, 6. *Pistocythereis bradyi* (Ishizaki, 1968), female, LV, sample UU-21, 7. *Ambtonia obai* (Ishizaki, 1971), female, LV, sample UU-10, 8. *Bythoceratina hanaii* Ishizaki, 1968, adult, RV, sample UU-24, 9. *Hemicytherura cuneata* Hanai, 1957, female, RV, UU-23, 10. *Semicytherura mukaishimensis* Okubo, 1980, adult, RV, sample UU-29, 11. *Semicytherura* sp. 1, female, RV, sample UU-5, 12. *Cytheropteron donghaiense* (Zhao, 1988), adult, RV, sample UU-16

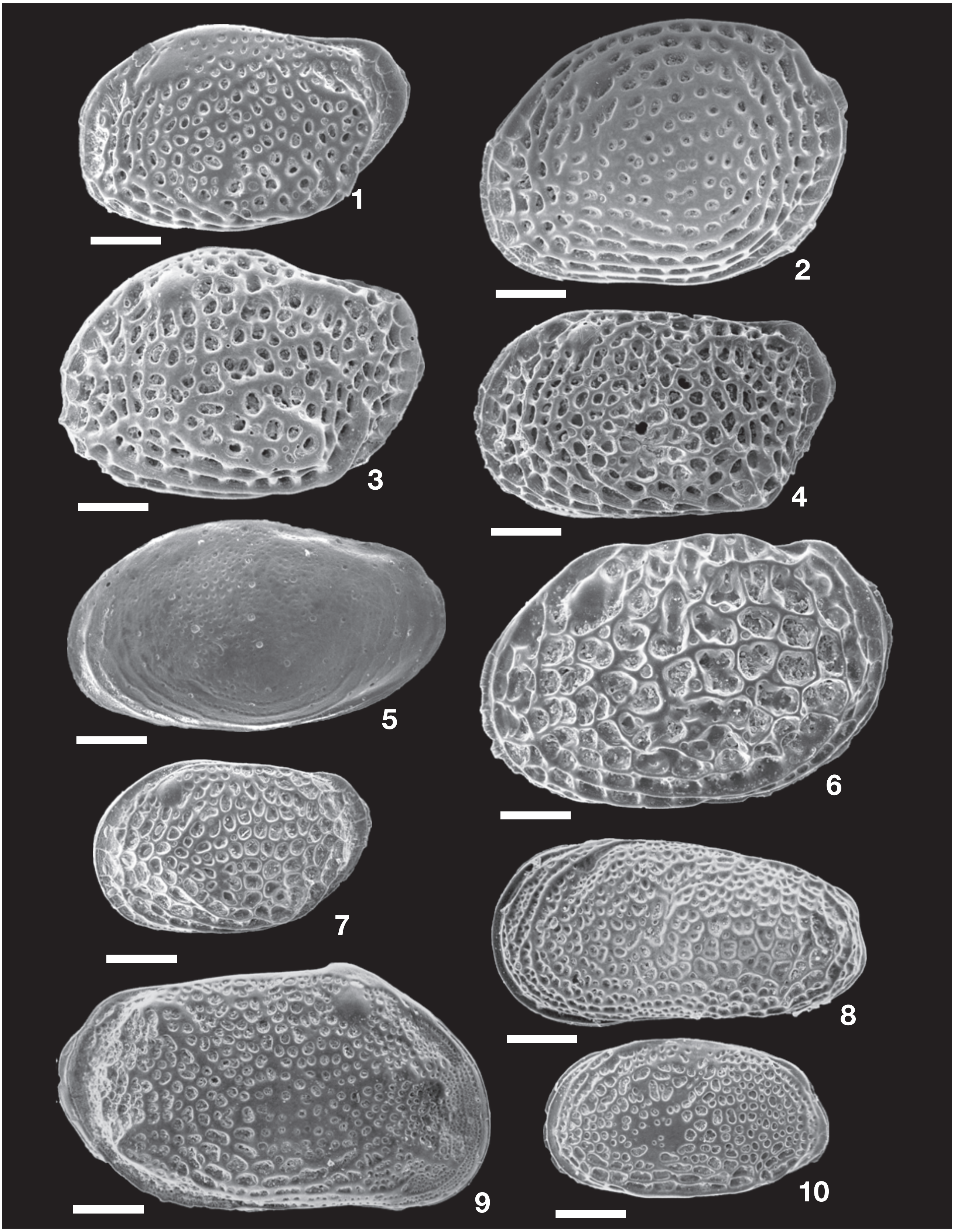

Fig. 8. Scanning electron micrographs of the selected ostracode species. Scale bars are 0.1 mm. LV: left valve, RV: right valve. 1. *Loxoconcha harimensis* Okubo, 1980, female, LV, sample UU-26, 2. *Loxoconcha japonica* Ishizaki, 1968, female, LV, sample UU-18, 3. *Loxoconcha kattoi*, Ishizaki, 1968, female, LV, sample UU-2, 4. *Loxoconcha kitanipponica* Ishizaki, 1971, female, LV, sample UU-29, 5. *Loxoconcha optima* Ishizaki, 1968, juvenile, LV, sample UU-24, 6. *Loxoconcha tosaensis* Ishizaki, 1968, female, LV, sample UU-16, 7. *Loxoconcha uranouchiensis* Ishizaki, 1968, female, LV, sample UU-1, 8. *Cytheromorpha acupunctata* (Brady, 1880), female, LV, sample UU-30, 9. *Loxocorniculum mutsuense* Ishizaki, 1971, adult, RV, sample UU-5, 10. *Nipponocythere bicarinata* (Brady, 1880), female, LV, sample UU-5

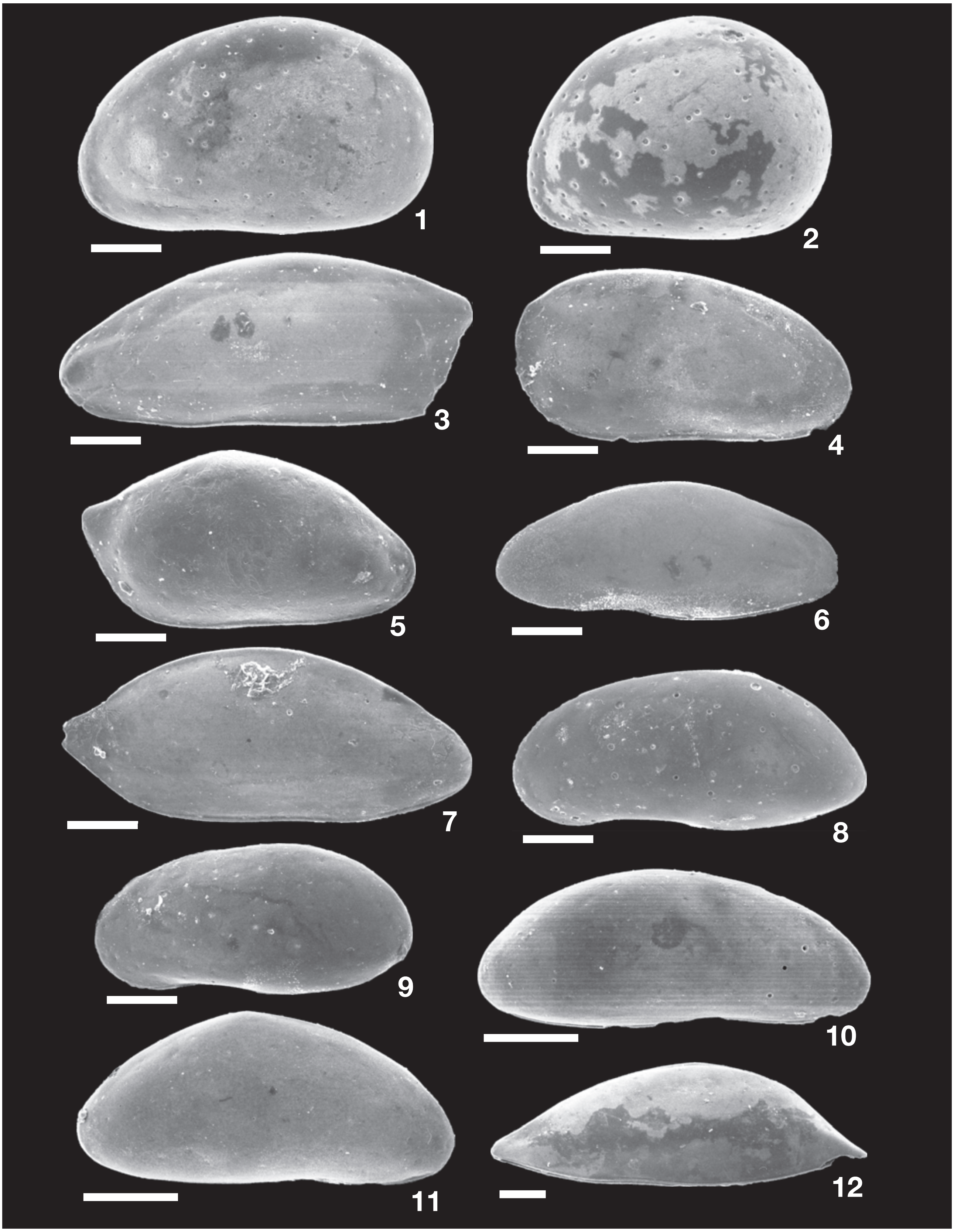

Fig. 9. Scanning electron micrographs of the selected ostracode species. Scale bars are 0.1 mm. LV: left valve, RV: right valve, RC: right lateral view of carapace.

1. *Xestoleberis hanaii* Ishizaki, 1968, female?, LV, sample UU-1, 2. *Xestoleberis ishizakii* Schornikov, 1975, juvenile, LV, sample UU-22, 3. *Paradoxostoma aculeoliferum* Schornikov, 1975, adult, LV, sample UU-16, 4. *Paradoxostoma brunneum*, Schornikov, 1975, adult, RV, sample UU-6, 5. *Paradoxostoma yatsui* Kajiyama, 1913, adult, RV, sample UU-24, 6. *Paradoxostoma* sp. 1, adult, RV, sample UU-5, 7. *Paradoxostoma* sp. 2, adult, RV, sample UU-5, 8. *Neopellucistoma inflatum* Ikeya and Hanai, 1982, adult, LV, sample UU-5, 9. *Cytherois* cf. *uranouchiensis* Ishizaki, 1968, adult, LV, sample UU-30, 10. *Cytherois* sp. 1, adult, RV, sample UU-6, 11. *Cytherois* sp. 2, juvenile, RV, sample UU-2, 12. *Xiphichilus* sp., adult, RC, sample UU-15

uranouchiensis is the dominant species in the inner part of the bay. Thus, there are none, or relatively few, species characteristic of the enclosed inner bays of Japan. According to Ikeya and Shiozaki (1993), *S. quadriaculeata* prefers to live on silty bottoms (Md = 5−8 phi) in brackish waters (salinity = 20−30 psu) at water depths of 2−7 m; *C. acupunctata* is abundant on sandy bottoms (Md = 2−3 phi) in brackish waters (27−30 psu) at water depths of 2−3 m; and *B. bisanensis* (including *Bicornucythere* sp.) is abundant in similar environments to those of *S. quadriaculeata* but prefers to live in deeper waters than the latter (5−10 m in depth). All three species live in flocculent layers and at the top of the oxidized layer. A flocculent layer is composed mainly of inorganic grains of less than 0.1 mm, decomposing organic matter, and fragments of pellets (Ikeya and Shiozaki, 1993). In most of the inner parts of Urauchi Bay, at depths of less than about 10 m, sandy to granular sediments with low mud content cover the bottom surfaces, where flocculent layers are possibly not well developed. Moreover, bottom-water salinity there is slightly higher than that in optimal habitats for those species, suggesting that open marine water flows into even the inner part of the bay. Only locality UU-30 is close to optimal conditions for these species. Thus, there is only a small area where these species prefer to live. This suggests that there is little input of fine inorganic sediments and organic matter from the hinterland of Urauchi Bay because the bay is situated in small islands off the main islands of Japan and is surrounded by hard sedimentary rocks, and no large rivers enter the bay. The results of the CNS analyses also support this interpretation (Takata *et al.,* 2006). Even when sediments do flow into the bay, they are transported to deeper middle-bay bottoms or open seas because of the steep geomorphology of the coasts of the bay. It is possible that enclosed inner-bay species have decreased on or disappeared from these small isolated islands during each interglacial period of the Pleistocene.

Species living in the tropical seas around the Okinawa Islands, such as *Neohornibrookella lactea* and *Cornucoquimba shimajiriensis* (e.g., Nohara, 1987; Tabuki *et al.,* 1987; Tabuki, 2001), are rarely found in Urauchi Bay, and species that live abundantly in the bays of those islands, such as the genera *Neomonoceratina*, *Bishopina*, and *Keijia*, are not found at all in Urauchi Bay.

5. Conclusions

1. At least 146 species were obtained from 29 surface sediment samples from Kamikoshiki-jima Island off Kyushu, southwestern Japan.
2. They were grouped into four biofacies on the basis of Q-mode cluster analysis.
3. The dominant species in the inner part of the bay is *Loxoconcha uranouchiensis*. Species that dominate enclosed inner muddy bays in Japan are not present or are restricted to small areas in Urauchi Bay.

Acknowledgments

We thank S. Yamaguchi of Marushima-so for his helpful supports of surveys. This study was supported by the Grant-in-Aid for Scientific Research (Grant nos. 15540451 and 17540442) of the Scientific Research Fund of the Japan Society for the Promotion of Science.

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