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Species composition of Ostracoda in the Okinawa islands, and geographical distribution of the two genera *Loxoconcha* and *Xestoleberis* (Arthropoda: Crustacea) around Japan

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ABSTRACT

This study was conducted in the period of 2012 to 2015 in some locations of Japan. At each location, samplings were carried out on reef slopes using SCUBA diving, on reef flats, tidal beaches and river mouths during low tide. The specimens then were treated using a differential interference contrast microscope with a camera lucida (BX-50, OLYMPUS), a quick auto-coater (JFC-1500, Ion Sputtering Device), a scanning electron microscope (SEM) in the laboratory of Shizuoka University,… The result shows that total 139 species of recent ostracoda belonging to 28 families, 70 genera recorded in the Okinawa Islands, southern Japan are found. Most diversified families include Loxoconchidae (26 species - 18.7%), Xestoleberididae (17 species - 12.2%), Bairdiidae (13 species - 9.4%), Hemicytheridae (13 species - 9.4%), Leptocytheridae (8 species - 5.8%). Based on the distributional pattern of pore systems located below the eye tubercle of Loxoconcha and the types of pores on carapaces of Xestoleberis, the species groups of the two genera were divided into three groups, i.e., Groups A, B and C. Geographical distribution of three species groups was shown for each location in the present report. The geographical distribution of three species phylogenetic groups (i.e. Groups A, B and C) of the two genera Loxoconcha and Xestoleberis suggests that the fauna of two genera in the Okinawa islands are more similar to southern faunas (e.g., Vietnam, Philippines, Australia,…) than Japanese Island Arc fauna. Hence, the origin of two genera Loxoconcha and Xestoleberis in the Okinawa islands, southern Japan may be from the South.

Keywords: *Loxoconcha*, *Xestoleberis*, evolution, migration, origin.

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INTRODUCTION

The Okinawa islands are an island group in southern Japan, the West Pacific. The island is located at 26°30'N, 127°56'E and has an area of about 1,200 km^2. Also, the island is mainly surrounded by highly diversified coral reefs. Thus, there have been various studies on Recent ostracods from the Okinawa islands, but most were conducted within some limited areas [1–6]. A comprehensive study has yet to be done on the Recent ostracod fauna in the Okinawa islands.

Loxoconcha (Loxoconchidae) and *Xestoleberis* (Xestoleberididae) are the most diverse Recent ostracod genera. Five hundred seventy-five species and 344 species of the *Loxoconcha* and *Xestoleberis* have been identified worldwide [7]. The species of the two genera are distributed in low to middle-latitude areas in marine and brackish waters. In Japan, the species of the two genera widely inhabit from the South to the North, and they also are found very commonly in the water areas around the Okinawa islands [8–12].

The present study summarizes the species composition of recent Ostracoda from the Okinawa islands, southern Japan. Significantly, the species composition and species groups of the two genera *Loxoconcha* and *Xestoleberis* in the Okinawa islands as well as in the other areas of the Pacific Ocean are inferred in order to elucidate their geographical distribution, migratory route, speciation, and evolutionary process. Finally, understanding the origin of the ostracod fauna in the Okinawa islands must become an important tool for subsequent studies on paleogeography, paleoceanography, and paleo marine currents.

MATERIALS AND METHODS

Sampling and specimen treatment

Locations and date of sampling

Investigations were conducted in the Okinawa islands, Okinawa Prefecture; Miura city, Kanagawa Prefecture; Kisarazu city, Chiba Prefecture; Uranouchi bay, Kochi Prefecture and Miyazaki, Miyazaki Prefecture (Japan) from 2012 to 2015 (Fig. 1). Detailed information of sampling sites is shown in Table 1.

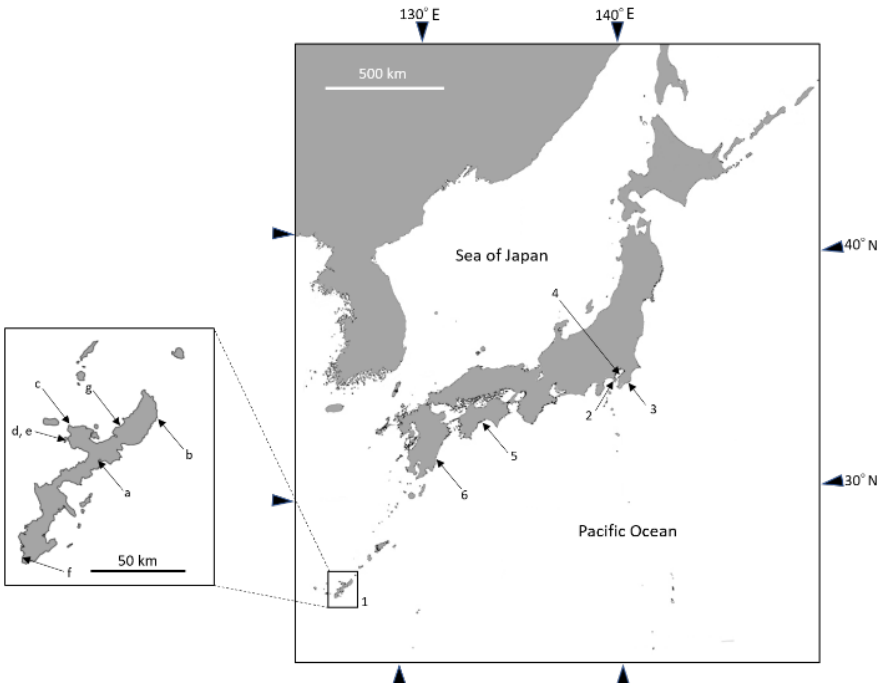

Figure 1. Study sites in Japan: Detailed information of each site was shown in Table 1

Table 1. Information of sampling sites

Loc. No.	Locality Name	Longitude (E)	Latitude (N)	Collected Date	Number of samples
1a	Ohura R. estuary, Okinawa	128°02’30”	26°33’00”	11/5/2013	3
1b	Ada R. estuary, Okinawa	128°18’50”	26°44’30”	30/5/2014	4
1c	Bise, Motobu city, Okinawa	127°52’44”	26°42’00”	10/5/2013, 31/5/2014	2
1d	Sesoko Beach, Sesoko island, Okinawa	127°51’28”	26°39’15”	10/5/2013, 1/6/2014	6
1e	Sesoko Beach, Sesoko island, Okinawa	127°51’72”	26°37’06”	10/5/2013, 1/6/2014	5
1f	Nashiro Beach, Itoman city, Okinawa	127°39’01”	26°05’05”	12/5/2013	2
1g	Ogimi village, Okinawa	128°08’04”	26°42’06”	12/5/2013	2
2	Aburatsubo Bay Misakimachi Miura city, Kanagawa Pref.	139°36’38”	35°09’16”	11/8/2014	3
3	Amatsu-Kominato, Chiba Pref.	140°11’09”	35°07’20”	18/11/2012	2
4	Obitsu R. estuary, Chiba Pref.	139°53’48”	35°24’06”	18/11/2012	3
5	Uranouchi bay, Kochi Pref.	134°22’09”	33°25’43”	21/2/2014	2
6	Miyazaki city, Miyazaki Pref.	113°26’58”	31°53’78”	22/2/2014	2

Method of sampling and specimen treatment

Samplings were conducted on reef slopes using SCUBA diving, on reef flats, tidal beaches, and river mouths during low tide. At each sampling point, the upper layer of 5–10 mm of sediment, sea grass, and sea algae was scooped into a plastic bottle using a spoon (a flat spoon with dimensions of 12×15 cm or a rectangular spoon of 4×7 cm, depending on the degree of surface irregularity). Then, all the collected specimens were fixed in 5–10% formaldehyde that had been neutralized with hexamethylenetetramine before being washed through 16-mesh (# 1 mm) and 250-mesh (# 0.063 mm) sieves. Part of the washed material was fixed with 70–80% alcohol to observe the appendages, and the remaining material was dried.

Morphological observations and taxonomy

The specimens were dissected under a binocular microscope in the laboratory. Their appendages and carapaces were then observed and sketched using a differential interference contrast microscope with a camera lucida (BX-50, OLYMPUS) to obtain illustration photos. Also, soft parts were mounted on a sliding glass in the “Neo Sigaral” agent for the dissected specimens, and carapaces were on a cardboard slide with a single hole.

Dried carapaces and individuals were coated with gold using a quick auto-coater (JFC-1500, Ion Sputtering Device) and observed with a scanning electron microscope (JSM-5600LV, JEOL). Using computer software such as ImageJ and Adobe Photoshop, the scanning electron microscope photos were subsequently used to identify carapace size, pore groups, muscle scars, and hinge elements.

Species of the two genera were classified based on the morphology of carapaces, the chaetotaxy of appendages, muscle scars, and hinge elements following Sars (1866) [13], Yassini & Jones (1995) [14].

Most of the illustrated specimens were deposited in the collection of the Shizuoka University Museum, identified by numbers with the prefix SUM-CO.

Division of species groups

The pore groups of species of the genus *Loxoconcha* were identified using the distributional pattern of pore systems below the eye tubercle [15]. In contrast, species groups of the genus *Xestoleberis* were divided based on

the pore types of Puri (1974) [16] and the combination of pore types of Sato & Kamiya (2007) [10].

RESULTS

Species composition of recent ostracoda in the Okinawa islands

Results from the published reports and this study show that 139 species of recent Ostracoda belonging to 28 families and 70 genera were classified in the Okinawa islands, Southern Japan (Table 2, Appendix 1). Among them, families with a high number of species include Loxoconchidae (26 species - 18.7%), Xestoleberididae (17 species - 12.2%), Bairdiidae (13 species - 9.4%), Hemicytheridae (13 species - 9.4%), Leptocytheridae (8 species - 5.8%), etc. As genus ranking, genera with many species consist of *Loxoconcha* (22 species), *Xestoleberis* (13 species), *Bairdia* (11 species), and *Paradoxostoma* (11 species). The external view of carapace of Loxoconcha and Xestoleberis species found in this study was shown in Fig. 2.

Table 2. Number of species, genus following each family in the Oknawa islands

No.	Family	Number of genus	Number of species	% number of species
1	Bairdiidae	3	13	9.4
2	Bythocyprididae	1	1	0.7
3	Bythocytheridae	1	2	1.4
4	Candonidae	1	1	0.7
5	Cobanocytheridae	2	2	1.4
6	Cushmanideidae	1	1	0.7
7	Cytherellidae	1	4	2.9
8	Cytheridae	3	3	2.2
9	Cytherideidae	1	1	0.7
10	Cytheroidea	1	1	0.7
11	Cytheromatidae	2	2	1.4
12	Cytheruridae	5	6	4.3
13	Eucytheridae	1	1	0.7
14	Hemicytheridae	11	13	9.4
15	Krithidae	1	1	0.7
16	Leptocytheridae	6	8	5.8
17	Limnocytheridae	1	1	0.7
18	Loxoconchidae	2	26	18.7
19	Macrocyprididae	1	1	0.7
20	Paracytherideidae	1	1	0.7
21	Paradoxostomatidae	3	13	9.4
22	Pectocytheridae	5	5	3.6
23	Polycopidae	3	4	2.9
24	Pontocyprididae	3	4	2.9
25	Pussellidae	1	1	0.7
26	Schizocytheridae	1	1	0.7
27	Trachyleberididae	5	5	3.6
28	Xestoleberididae	3	17	12.2
	Total	70	139	100

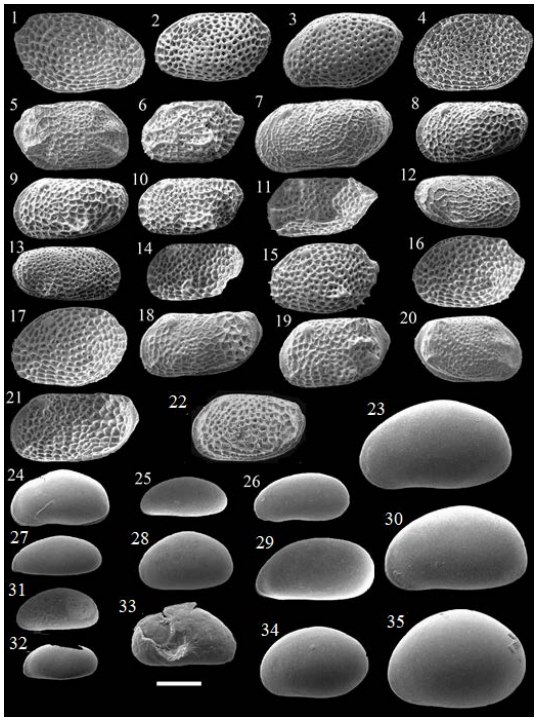

Figure 2. External view of examined ostracod carapaces from the Okinawa islands, Southern Japan. 1) *Loxoconcha japonica* (male, RV); 2) *L. shanhaiensis* (male, LV); 3) *L. lilljeborgii* (male, LV); 4) *L. tumulosa* (male, LV); 5) *Loxoconcha* sp. 1 (female, RV); 6) *Loxoconcha* sp. 7 (LV); 7) *L. kosugii* (male, LV); 8) *L. noharai* (male, LV); 9) *L. santosi* (male, LV); 10) *Loxoconcha* sp. 3 (male, LV); 11) *Loxoconcha* sp. 13 (LV); 12) *L. yoshidai* (male, RV); 13) *L. sesokoensis* (male, RV); 14) *Loxoconcha* sp. 6 (LV); 15) *Loxoconcha* sp. 8 (LV); 16) *Loxoconcha* sp. 9 (LV); 17) *Loxoconcha* sp. 10 (LV); 18) *Loxoconcha* sp. 14 (LV); 19) *Loxoconcha* sp. 15 (LV); 20) *Loxoconcha* sp. 16 (RV); 21) *Loxoconcha* sp. 17 (male, LV); 22) *L. uranouchiensis* (male, LV); 23) *Xestoleberis hanaii* (male, LV); 24) *X. ryukyuensis* (male, LV); 25) *X. planuventer* (female, LV); 26) *X. ikeya* (LV); 27) *Xestoleberi* sp. 2 (female, LV); 28) *Xestoleberi* sp. 3 (LV); 29) *Xestoleberi* sp. 1 (female, LV); 30) *X. sesokoensis* (male, LV); 31) *Xestoleberi* sp. 4 (LV); 32) *Xestoleberi* sp. 5 (female, LV); 33) *Xestoleberi* sp. 6 (male, RV); 34) *X. kuroshio* (male, LV); 35) *X. magnoculus* (female, LV). Scale: 200 µm. Abbreviations: LV, left valve; RV, right valve

The similarity in ostracod composition between the Okinawa island fauna and other faunas

Data on the species and genus compositions of two genera, *Loxoconcha* and *Xestoleberis*, in the Okinawa islands were classified by this study from 2012 to 2015. The data on ostracod composition in other areas of the Pacific Ocean and Indian Ocean were collected from published literature.

Results of the comparison of the similarity of ostracod composition between the Okinawa island fauna and other faunas are shown in Table 3. At the genus level, the similarity values between the Okinawa island fauna and Japanese island Arc fauna, between the Okinawa island fauna and southern part faunas (Australia, Vietnam, the Philippines, Malaysia, Indonesia, and China) is relatively high, ranging from 18.8% to 36.9%. At the species level, only species belonging to the genera *Loxoconcha* and *Xestoleberis* were used in the present study. Because many species of these two genera in the Okinawa islands and in other areas have yet to be described, hence the compared results in this study were incomplete. The Sorensen values at the species level are zero in two compared pairs, Okinawa island with New South Wales, Southeast of Australia, Darwin, and Northwestern Australia.

The Sorensen value of the species level of *Loxoconcha* between two close islands, Okinawa and Amami islands (both belonging to Ryukyu islands), is very high (50.1%). In contrast, the Sorensen values are relatively high in the three compared pairs, including between the Okinawa island fauna with Hiuchi-nada bay, Seto Inland Sea of Japan (18.2%); with the shelf seas off China (15.8%), and with the Tsushima warm current in the southwestern area of Japan (12.0%). This fact indicates that the two islands' ostracod faunas are very similar (Table 3).

Geographical distribution of species groups of the genera *Loxoconcha* and *Xestoleberis*

Based on the distributional pattern of pore systems located below the eye tubercle of *Loxoconcha* [15] and the types of pores on

carapaces of *Xestoleberis* [10], the species groups of the two genera were divided into three groups, i.e., Groups A, B and C. Geographical distribution of three species groups was shown for each location (Figs. 3, 4), the first report on division of species groups in Vietnam, Philippines, Australia as well as in Amami island. A list of examined species in this study and the phyletic group to which they belong is shown in Appendix 2.

Table 3. Sorensen index between the Okinawa islands and other areas, and number of species of the genera *Loxoconcha* and *Xestoleberis*

Locations	Sorensen values		Number of species	
	Species level**	Genus's level	*Loxoconcha*	*Xestoleberis*
Otsuchi bay, Pacific Coast of Northeastern, Japan [17]	10.5	35.7	4	4
The Tsushima warm current, Japan [18]	12.0	31.0	11	9
Hamana-ko bay, Pacific Coast of Japan [19]	10.5	31.3	5	4
Hiuchi-nada bay, Seto Inland Sea of Japan [20]	18.2	36.9	13	2
Southwestern Okhotsk Sea off Shiretoko Peninsula, Japan [21]	5.3	28.2	5	3
Northeastern Japan Sea off Okushiri island, Japan [21]	10.0	36.6	5	5
Malacca straits, Malaysia [22, 23]	5.3	28.6	4	4
The shelf seas off China [24]	15.8	18.8	6	2
Coast of Vietnam [25, 26, this study]	5.5	24.7	23	16
Coast of Australia [14, 27, this study]	0	26.8	33	37
Coast of the Philippines	5.9	20.9	22	16
Coast of Indonesia [28, this study]	4.8	33.3	7	5
Amami island, Kagoshima Prefecture, Japan*	50.1	No data	18	No data

Notes: *: only species of *Loxoconcha*, **: species of *Loxoconcha* and *Xestoleberis* were estimated.

The groups of the genus *Loxoconcha* living around the Okinawa islands include Groups A, B, and C; meanwhile, those around Japanese Island Arc fauna are the Groups A and B. In the case of the genus *Xestoleberis*, the species of the older taxonomic groups (Groups A and B) are abundantly found in the Okinawa Islands. In contrast, most species around Japanese Island Arc belong to the derived taxonomic Group C and few are classified into Group A. Along the coast of Vietnam, the species of the genus *Loxoconcha* belong to Groups A, B, and C; of genus *Xestoleberis* to Groups A and B; of the Philippines, the genus *Loxoconcha* (Groups A and C), the genus *Xestoleberis* (Groups A and B); of Australia, the genus *Loxoconcha* (Groups A and C), the genus *Xestoleberis* (Groups A and B) [26]. Overall, the geographical distribution of the pore groups of the species of two genera, *Loxoconcha* and *Xestoleberis*, in the Okinawa islands is close to southern faunas (Vietnam, the Philippines, and Australia) rather than Japanese Island Arc faunas.

DISCUSSION

Preliminary interpretation of origin of the genera *Loxoconcha* and *Xestoleberis* of the Okinawa islands, southern Japan

The geographical distribution of three species groups of the two genera in Figs. 3, 4 suggests that the *Loxoconcha* and *Xestoleberis* faunas in the Okinawa islands are close instead to Southern fauna than Japanese Island Arc fauna and the origin of the two genera is from the South. This suggestion is strongly supported by Tanaka & Ikeya (2002) [9] when they studied on migration and speciation of the *L. japonica* species group in East Asia. Following them, two species *L. lilljeborgii* and *L. tumulosa*, of this group migrated from the Indian Ocean to the West Pacific Ocean during the early Pliocene. Then, species speciation and evolution processes within this group were done from the South to the North in the West Pacific [9]. Ishii (2004) [29] supported the

above migration tendency when he stated that the origination of the genus *Loxoconcha* s.s. may be in Indo-West Pacific Region and by the late Oligocene (possibly the late Eocene). After Neogene, the Paleogene diversified Loxoconchidae group moved from subtropical-warm temperate shallow marine into harsh environments, such as high latitude colder areas and (or) deep sea, to survive around Japan [29].

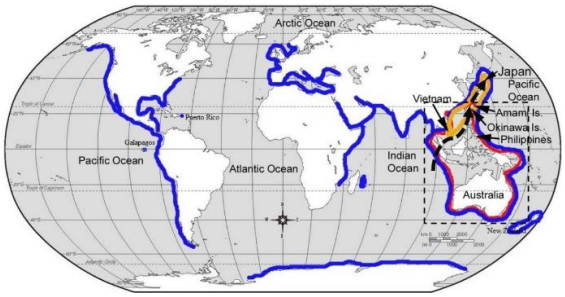

Figure 3. Geographical distribution of three groups and suggested migratory route of the genus *Loxoconcha.* Group A- Blue colour; Group B- Yellow colour; Group C- Red colour; Migratory route- black dot arrows (*Note:* Information of Western Pacific after Le & Tsukagoshi, 2019 [26])

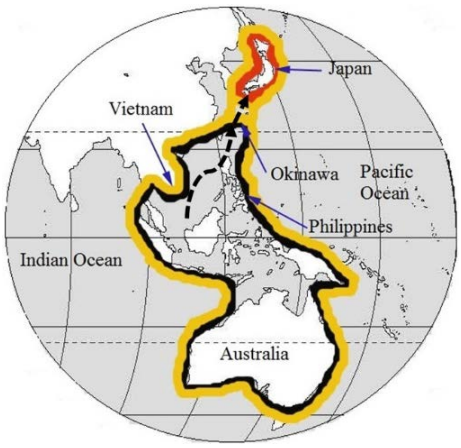

Figure 4. Geographical distribution of three groups and suggested migratory route of the genus *Xestoleberis.* Group A, yellow colour; Group B, red colour; Group C, black colour; migratory route, black dot arrows [26]

The present study shows the far difference in species composition of the genera *Loxoconcha* and *Xestoleberis* between the Okinawa islands and Japanese Island Arc, except for the species *L. japonica* and *X. hanaii*, the two species distributed in the Okinawa island as well as in Japanese Island Arc [9, 10]. The fauna of *Loxoconcha* in the Okinawa islands is probably older than that in the Japanese Island Arc, for example, the oldest fossil records of *L. kattoi* and *L. uranouchiensis* are known from the Miocene in the Okinawa islands [30], but from the Pliocene in Japanese Island Arc [15]. On the contrary, the climate resemblance explains the similarity of ostracod fauna between the Okinawa islands and Southern parts such as Vietnam, the Philippines, and Australia. Marine ecosystems such as coral reefs, mangrove forests, seagrass beds, and tidal beaches are widespread in the Okinawa islands, Vietnam, the Philippines, and Australia. The area from the Okinawa islands to Northern Australia is presently classified into the tropical zone (http://www.cgrove4-17.org/fry/Science/Climate/climatezones.html) with the warmest average temperature.

Many authors in previous papers also support the migration and speciation tendencies of genera *Loxoconcha* and *Xestoleberis* from the Southern to Northern parts of Japan. Many genera of *Loxoconcha* and *Xestoleberis* species were formerly found in the Southern part of the Okinawa islands. However, they do not appear around this island and live around the Japanese Island Arc [10, 15, 30, 31]. The oldest fossil records of *L. kattoi* and *L. uranouchiensis* also were found in Miocene in southern Okinawa [30] and in Pliocene in Japan Island Arc [15], but instead of living in the Okinawa islands, these species are recently found in Japanese Island Arc [15, 32]. *L. hattorii* and *L. modesta* were shown from the Pleistocene Naha Limestone of the Okinawa islands [33], but the two species are living at Tsukumo bay, Ishikawa Prefecture, Japan [15]. *X. sagamiensis* was abundant in Shinzato Formation, Southern Okinawa, in Pliocene [30], but presently this Recent species is only living from Kyushu northward [10]. The above evidence suggests that the migration and adaptation of many species of *Loxoconcha* and *Xestoleberis* were made from the Okinawa islands to the Japanese Island Arc, and the fauna of these two genera in

the Okinawa islands is older than that in Japanese Island Arc.

CONCLUSION

A total of 139 species of recent Ostracoda belonging to 28 families and 70 genera in the Okinawa islands were reported in this study. Among them, families with a high number of species include Loxoconchidae (26 species - 18.7%), Xestoleberididae (17 species - 12.2%), Bairdiidae (13 species - 9.4%), Hemicytheridae (13 species - 9.4%), Leptocytheridae (8 species - 5.8%).

At the genus level, the Sorensen index between the Okinawa island fauna and Japanese Island Arc fauna, between the Okinawa island fauna and Southern part faunas (Australia, Vietnam, the Philippines, Malaysia, Indonesia, and China) is relatively high, ranging from 18.8% to 36.9%.

The geographical distribution of three phylogenetic groups of the genera *Loxoconcha* and *Xestoleberis* shows that the fauna of the two genera in the Okinawa islands is more similar to southern fauna (e.g., Vietnam, Philippines, Australia) than Japanese Island Arc fauna.

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Appendix

Appendix 1. List of ostracod species from the Okinawa islands, Southern Japan

No.	Scientific name	No.	Scientific name
I	Bairdiidae	67	*L. shanhaiensis*
1	*Bairdia* sp. A	68	*L. tumulosa*
2	*Bairdia* sp. B	69	*Loxocorniculum* sp. A[1]
3	*Bairdia* sp. C	70	*Loxocorniculum* sp. B[1]
4	*Bairdia* sp. D	71	*Loxocorniculum* sp. C[1]
5	*Bairdia* sp. E	72	*Loxoconcha uranouchiensis*[1]
6	*Bairdia* sp. F	73	*Loxoconcha* sp. 1
7	*Bairdia* sp. G	74	*L. kosugii*
8	*Bairdia* sp. H	75	*Loxoconcha* sp. 3
9	*Bairdia* sp. I	76	*Loxoconcha* sp. 13
10	*Bairdia* sp. J	77	*Loxoconcha* sp. 7
11	*Bairdia* sp. K	78	*Loxoconcha* sp. 14
12	*Neonesidea* sp.[1]	79	*Loxoconcha* sp. 15
13	*Triebelina* sp.[1]	80	*Loxoconcha* sp. 16
II	Bythocyprididae	81	*Loxoconcha* sp. 9
14	*Anchistrocheles* sp.	82	*Loxoconcha* sp. 10
II	Bythocytheridae	83	*L. yoshidai*
15	*Bythoceratina* sp.	84	*Loxoconcha* sp. 8
16	*Sclerochilus* sp.	85	*Loxoconcha* sp. 6
IV	Candonidae	86	*Loxoconcha* sp. 17
17	*Paracypris* sp.	87	*Pseudoconcha* sp.
V	Cobanocytheridae	XIX	Macrocyprididae
18	*Cobanocythere* sp.	88	*Macrocyprina* sp.
19	*Paracobanocythere* sp.	XX	Paracytherideidae
VI	Cushmanideidae	89	*Paracytheridea* sp.[3]
20	*Pontocythere* sp.	XXI	Paradoxostomatidae
VII	Cytherellidae	90	*Cytherois* sp.
21	*Cytherelloidea asatoensis*[2]	91	*Paracytherois* sp.[1]
22	*C. hanaii*	92	*Paradoxostoma* sp. H[3]
23	*C. senkakuensis*	93	*P. affine*[1]

No.	Scientific name	No.	Scientific name
24	*Cytherelloidea* sp.[2]	94	*P.* cf. *gibberum*[1]
VIII	Cytheridae	95	*P. lunatum*[1]
25	*Cythere omotenipponica*	96	*Paradoxostoma* sp. A[1]
26	*Schizocythere* sp.	97	*Paradoxostoma* sp. B[1]
27	*Spinileberis* sp.	98	*Paradoxostoma* sp. C[1]
IX	Cytherideidae	99	*Paradoxostoma* sp. D[1]
28	*Perissocytheridea inabai*	100	*Paradoxostoma* sp. E[1]
X	Cytheroidea	101	*Paradoxostoma* sp. F[1]
29	*Cytheroidea* sp.	102	*Paradoxostoma* sp. G[1]
XI	Cytheromatidae	XXII	Pectocytheridae
30	*Microloxoconcha* sp.	103	*Keijia* sp.
31	*Paracytheroma* sp.	104	*Mckenzieartia* sp.
XII	Cytheruridae	105	*Morkhovenia* sp.[1]
32	*Cytheropteron* sp.	106	*Parakeijia* sp.
33	*Cytherura* sp.	107	*Pectocythere* sp.
34	*Eucytherura* sp.[3]	XXIII	Polycopidae
35	*Hemicytherura* sp.	108	*Polycope* sp.
36	*Semicytherura miurensis*[1]	109	*Polycopidae* sp.
37	*Semicytherura* sp.[3]	110	*Parapolycope* sp. 6
XIII	Eucytheridae	111	*Parapolycope* sp. 9
38	*Eucythere* sp.	XXIV	Pontocyprididae
XIV	Hemicytheridae	112	*Pontocypridoidea* sp.
39	*Aurila* sp. A[3]	113	*Pontocypris* sp.
40	*Aurila* sp. B[3]	114	*Propontocypris* sp. 1[1]
41	*Caudites* sp.	115	*Propontocypris* sp. 2
42	*Coquimba* sp.	XXV	Pussellidae
43	*Cornucoquimba* sp.	116	*Pussella* sp.
44	*Finmarchinella* sp.	XXVI	Schizocytheridae
45	*Hermanites* sp.[3]	117	*Neomonoceratina* sp.
46	*Mutilus* sp.	XXVII	Trachyleberididae
47	*Procythereis* sp.	118	*Australimoosella* sp.[4]
48	*Radimella* sp.	119	*Basslerites* sp.
49	*Robustaurila* sp.	120	*Moosella* sp.
50	*Tenedocythere* sp.[1]	121	*Trachyleberis* sp.
51	*T. transoceanica*[1]	122	*Wichmannella* sp.[4]
XV	Krithidae	XXVIII	Xestoleberididae
52	*Parakrithella* sp.	123	*Microxestoleberis* sp.
XVI	Leptocytheridae	124	*Ornatoleberis* sp.
53	*Callistocythere* sp. A[1]	125	*Xestoleberis hanaii*
54	*Callistocythere* sp. B[1]	126	*X. ikeya*
55	*Callistocythere* sp. C	127	*X. kuroshio*
56	*Cluthia* sp.	128	*X. magnoculus*
57	*Ishizakiella* sp.	129	*X. planuventer*
58	*Leptocythere* sp.	130	*X. ryukyuensis*
59	*Neocytheromorpha* sp.	131	*X. sesokoensis*
60	*Tanella* sp.	132	*Xestoleberis* sp. 1
XVII	Limnocytheridae	133	*Xestoleberis* sp. 2
61	*Paracythereis* sp.	134	*Xestoleberis* sp. 3
XVIII	Loxoconchidae	135	*Xestoleberis* sp. 4

No.	Scientific name	No.	Scientific name
62	*Loxoconcha japonica*	136	*Xestoleberis* sp. 5
63	*L. lilljeborgii*	137	*Xestoleberis* sp. 6
64	*L. noharai*	138	*Isocythereis* sp.[4]
65	*L. santosi*	139	*Propontocytheris* sp.[1]
66	*L. sesokoensis*		

Notes: [1]: after Nohara & Tabuki (1990) [34]; [2]: after Nohara (1981a) [2]; [3]: after Tabuki & Nohara (1988) [6]: [4]: after Nohara (1987) [30]; other by this study.

Appendix 2. List of examined species of the genera *Loxoconcha* and *Xestoleberis* and their sampling location, habitat, salinity and the phyletic group to which they belong

Species name	Sampling location	Habitat	Salinity	Group
Loxoconcha japonica	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. shanhaiensis	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. lilljeborgii	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. tumulosa	Okinawa islands, Southern Japan	Phytal	n	A
L. sp. 1	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. sp. 7	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. kosugii	Sesoko island, Okinawa islands, Southern Japan and Kisarazu city, Chiba Pref., Central Japan	Bottom	b-n	B
L. noharai	Ohura estuary, Okinawa islands, Southern Japan	Bottom	b	B
L. santosi	Ada, Okinawa islands, Southern Japan	Bottom	b	B
L. sp. 3	Sesoko island, Okinawa islands, Southern Japan	Bottom	n	C
L. sp. 13	Sesoko island, Okinawa islands, Southern Japan	-	-	C
L. yoshidai	Bise beach, Motobu town, Okinawa islands, Southern Japan	Bottom	n	C
L. sesokoensis	Sesoko island, Okinawa islands, Southern Japan	Bottom	n	C
L. sp. 6	Ikei, Okinawa islands, Southern Japan	-	-	-
L. sp. 8	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
L. sp. 9	Sesoko island, Okinawa islands, Southern Japan	Phytal	-	A
L. sp. 10	Sesoko island, Okinawa islands, Southern Japan	Phytal	-	A
L. sp. 14	Iriomote island, Okinawa islands, Southern Japan	-	-	A
L. sp. 15	Ohura estuary, Okinawa islands, Southern Japan	-	-	A
L. sp. 16	Sosu, Okinawa islands, Southern Japan	-	-	A
L. sp. 17	Ikei, Okinawa islands, Southern Japan	-	-	A
L. mutsuensis	Miyazaki, Miyazaki Pref., Southern Japan	Phytal	n	A
L. harimensis	Miura city, Kanagawa Pref., Central Japan	Bottom	n	A
L. tosaensis	Miura city, Kanagawa Pref., Central Japan	Bottom	n	A
L. modesta	Miura city, Kanagawa Pref., Central Japan	Bottom	n	A
L. pulchra	Kisarazu city, Chiba Pref., Central Japan	Bottom	b	B
L. uranouchiensis	Miura, Kanagawa Pref., Central Japan	Bottom	b-n	B
L. sp. 4	Miura, Kanagawa Pref., Central Japan	Bottom	b-n	B
L. sp. 5	Obitsu river estuary, Chiba Pref., Central Japan	Bottom	b	B
L. sp. 30	Uranouchi Bay, Kochi Pref., Southern Japan	-	-	A
Xestoleberis hanaii	Sesoko island, Okinawa islands, Southern Japan; Aburatsubo bay, Miura, Kanagawa, Central Japan	Phytal	n	A
X. sesokoensis	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
X. ryukyuensis	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
X. planuventer	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
X. ikeya	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	A
X. sp. 1	Midland island, Okinawa islands, Southern Japan	-	n	A

Species name	Sampling location	Habitat	Salinity	Group
X. sp. 2	Sesoko island, Okinawa islands, Southern Japan	-	n	A
X. sp. 3	Midland island, Okinawa islands, Southern Japan	-	n	A
X. sp. 4	Sesoko island, Okinawa islands, Southern Japan	-	n	A
X. sp. 5	Sesoko island, Okinawa islands, Southern Japan	-	n	A
X. sp. 6	Sesoko island, Okinawa islands, Southern Japan	-	n	A
X. kuroshio	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	B
X. magnoculus	Sesoko island, Okinawa islands, Southern Japan	Phytal	n	B
X. setouchiensis	Kisarazu city, Chiba Pref., Central Japan	Phytal	n	A
X. sagamiensis	Aburatsubo bay, Miura, Kanagawa, Central Japan	Phytal	n	C

Notes: Abbreviations: Pref., Prefecture; Pro., Province; MPA, Marine Protected Area; b, brackish water; n, normal marine water.