Zoodiversity, **57**(1):51–64, 2023
DOI 10.15407/zoo2023.01.051

Morphology

UDC 595.33: 591.4

ADDED MORPHOLOGICAL CHARACTERISTICS OF MUSCLE SCARS, MAXILLULA AND MANDIBLE OF TWO OSTRACOD GENERA *LOXOCONCHA* (LOXOCONCHIDAE) AND *XESTOLEBERIS* (XESTOLEBERIDIDAE)

D. D. Le

Ho Chi Minh City University of Food Industry (HUFI),
140 Le Trong Tan, Tan Phu District,
Ho Chi Minh City, Vietnam
E-mail: dungld@hufi.edu.vn

https://orcid.org/0000-0002-9519-8878

urn:lsid:zoobank.org:pub:E1C1AEF2-6C98-45E9-B8EF-1532CB162FAA

Added Morphological Characteristics of Muscle Scars, Maxillula and Mandible of Two Ostracod Genera *Loxoconcha* (Loxoconchidae) and *Xestoleberis* (Xestoleberididae). Le, D. D. — Total 23 species of the genus *Loxoconcha* Sars, 1866 and 21 species of the genus *Xestoleberis* Sars, 1866 were presented in this study. The results show that most species of the genus *Loxoconcha* consist of four adductor scars to arrange in a curved sub-vertical row and concave anteriorly, except *L. pulchra* carrying five, in which the top one is divided into two. The frontal scars with C-shape, opening anteriorly are presented in most of *Loxoconcha* species, however, the frontal scar with bean-shape or oval-shape is discovered in five species of *L. japonica* group. Most of *L. kosugii* bear the frontal scar with C-shape, but the frontal scar with Y-shape is found in several individuals. This phenemenon shows the close phylogeny between the genus *Loxoconcha* and *Palmoconcha*. About the genus *Xestoleberis*, chaetotaxy of setae on most appendages is a typical character of this genus, except for setae of exopodite on the maxillula. The published fossil records and the tendencies of change in the number of setae on the maxillula and mandible among three phylogenetic groups suggest that Group A or B is an ancestor of the genus *Xestoleberis*, and Group C is a derived group.
Key words**:** *Loxoconcha*, mandible, maxillula, muscle scar, *Xestoleberis.*

Introduction

Ostracods are small bivalve crustaceans living in various aquatic habitats. Their biodiversity is very high, including many different genera and families (Tran et al., 2021; Schön & Martens, 2016). *Loxoconcha* Sars, 1866 (Loxoconchidae) and *Xestoleberis* Sars, 1866 (Xestoleberididae) are the most diverse ostracod genera. A total of 575 *Loxoconcha* species and 344 *Xestoleberis* species have been recorded around the world (Brandão et al., 2015). The members of these two genera are distributed in low to middle latitude areas in marine and brackish waters (Kempf, 1986 a, b).

The body structure of Ostracoda consists of carapaces outside and soft parts inside. Carapaces of ostracods are closed by scars running through the central part of the body and attached to the inner surface of the calcified outer lamellae (fig. 1). The adductor scar pattern is an important taxonomic character. As well as a pattern of adductor scars, there may be frontal scars and a pair of "mandibular scars" which are not muscle scars but the points of attachment of chitinous rods which, together with the mandible, form a tripod with its apex butted against a fulcra point on the inside of the valve (fig. 1) (Horne et al., 2002). The soft parts of ostracoda are enveloped inside the carapace, so functions such as locomotion and feeding require that the appendages be extended outside the carapace (Tanaka & Tsukagoshi, 2013). The mandibles are the third pair of appendages and in most ostracods each has a strong, heavily sclerotized coxa, provided ventrally with a number of teeth. The main functions of mandibles are feeding, crawling or digging (fig. 2) (Athersuch et al., 1989). The maxillula (referred as maxilla or the first maxilla by some authors) is the fourth head appendage of ostracods. It lies immediately behind the mandible and has two main functions, i. e., feeding and, in some groups, respiration (fig. 2) (Athersuch et al., 1989; Horne et al., 2002).

The muscle scars of carapace, maxillula and mandible of the soft parts play very important roles in classifying living ostracods because of their significant taxonomic characters (Tsukagoshi, 1988; Tsukagoshi et al., 2006). Therefore, the aims of this paper are to document in comprehensive way morphological characteristics of the muscle scars of the genus *Loxoconcha*, and of maxillula and mandible of the genus *Xestoleberis*. These results are useful for taxonomic utility of the two genera.

Material and methods

Sampling and preservation. Samplings were mainly carried out on reef slopes using SCUBA diving, on reef flats, tidal beaches and river mouths during low tide at some localities in the Okinawa Island, Okinawa Prefecture, southern Japan (fig. 3 and Appendix 1) and in Vietnam (fig. 4 and Appendix 1). Specifically, two investigations were conducted in the Okinawa Island, one during May 9–13, 2013 and the other in the period from May 28 to June 2, 2014. Two surveys were done in Vietnam, the first at the coast of Ha Long Bay, Quang Ninh Province, northern Vietnam in December 2013 and the second at Nha Trang Bay Marine Protected Area, Nha Trang city, central Vietnam and Phu Quoc Marine Protected Area, Kien Giang Province, southern Vietnam in November 2014. Additionally, some specimens collected on tidal beaches at some locations around Japan such as Miura, Kanagawa Prefecture; Kisarazu, Chiba Prefecture; Uranouchi Bay, Kochi Prefecture and Miyazaki, Miyazaki Prefecture, Japan by us from 2012 to 2015 or by other members of the laboratory of Shizuoka University, Japan were used in the present study (fig. 3 and Appendix 1).

In each site (figs 3, 4), sediments (sand, rubble dead coral, silt, etc.) and sea weeds, sponges etc. were collected and put into a plastic bottle using a scoop. Superficial sediments were collected from the uppermost 5 mm of the active layer. Then, all of the collected specimens were fixed in 5–10 % formaldehyde neutralized with hexamethylenetetramine, before being washed through 16-mesh (# 1 mm) and 250-mesh (# 0.063 mm) sieves. Part of the washed material containing ostracods and small sediment was fixed with 70–80 % alcohol for later observations of the appendages, and the remaining material was dried.

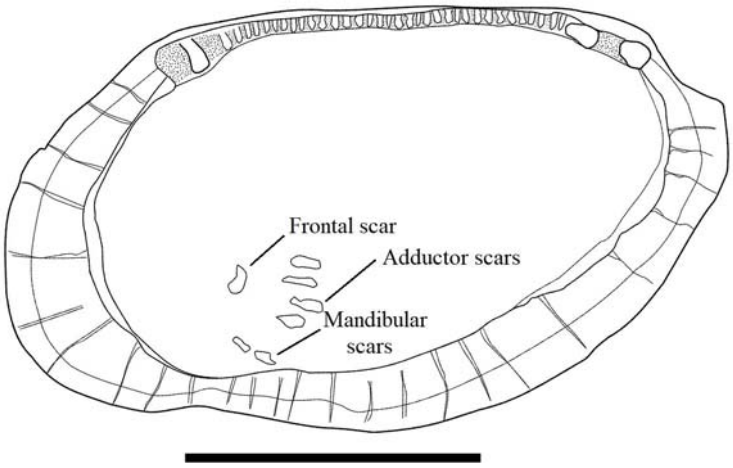

Fig. 1. Sketching of male right valve in internal lateral view of carapace of *Loxoconcha damensis* (adult ♂) indicating the adductor scars, mandibular scars and frontal scar. Scale 200 μm.

Specimen treatments. All the specimens were dissected under a stereoscopic microscope in the laboratory. Appendages were used to calculate the number of setae on the maxillula, mandible and sketched using a differential interference contrast microscope with a camera lucida (BX-50, OLYMPUS). Dried valves were coated with gold using a quick auto-coater (JFC-1500, Ion Sputtering Device) and were then observed with a scanning electron microscope (SEM) (JSM-5600LV, JEOL). SEM photos were used to measure the type of pore on the carapace, species group, the number of adductor scars, the shape of frontal scar.

Division of species groups. The pore groups of species of the genus *Loxoconcha* were identified using the distributional pattern of pore systems below eye tubercle (Ishii et al., 2005), whereas species groups of the genus *Xestoleberis* were divided based on the pore types of Puri (1974) and combination of pore types of Sato & Kamiya (2007).

All the illustrated specimens are deposited in the collections of the Shizuoka University Museum (Japan) and are identified by numbers with the prefix SUM-CO.

Results

Muscle scars of the genus *Loxoconcha*. Muscle scars of a total of 23 species of the genus *Loxoconcha* were observed in this study (table 1 and fig. 7). Most of these species have four adductor muscle scars arranging in a weakly curved sub-vertical row or a curved sub-vertical row and concave anteriorly. However, some individuals of species *L. pulchra* have five adductor muscle scars, in which the top one was divided into two (fig. 7, M). The four adductor muscle scars are normally unequal in dimensions with each other; the second scar from the top is much longer than the other in some species, e. g., *Loxoconcha* sp. 1, *L.* sp. 9, *L.* sp. 30, *L. mutsuensis*, *L. modesta*, *L. harimensis*, *L.* sp. 8 and *L. damensis* (fig. 7, B, D, F–H, J–L).

The frontal scar with C-shape, opening anteriorly was recorded in most species of the genus *Loxoconcha* (table 1 and fig. 7). However, the frontal scar with bean shape or oval

T a b l e 1. Characters of muscle scars of 23 species of the genus *Loxoconcha*

No.	Species name	Group	Number of adductor scars	Shapes of frontal scar	*N*
1	*Loxoconcha shanhaiensis*	A	4	Bean or oval shape	3
2	*L. japonica*	A	4	Bean or oval shape	3
3	*Loxoconcha* sp. 9	A	4	Bean or oval shape	4
4	*Loxoconcha* sp. 10	A	4	Bean or oval shape	3
5	*Loxoconcha* sp. 8	A	4	Bean or oval shape	5
6	*Loxoconcha* sp. 1	A	4	C-shape	3
7	*Loxoconcha* sp. 30	A	4	C-shape	3
8	*L. mutsuensis*	A	4	C-shape	4
9	*Loxoconcha* sp. 13	A	4	C-shape	4
10	*L. tosaensis*	A	4	C-shape	3
11	*L. harimensis*	A	4	C-shape	4
12	*L. damensis*	A	4	C-shape	5
13	*L. pulchra*	B	4–5	C-shape	6
14	*L. uranouchiensis*	B	4	C-shape	3
15	*L. noharai*	B	4	C-shape	5
16	*L. santosi*	B	4	C-shape	5
17	*Loxoconcha* sp. 5	B	4	C-shape	3
18	*Loxoconcha* sp. 4	B	4	C-shape	3
19	*Loxoconcha* sp. 26	B	4	C-shape	2
20	*L. kosugii*	B	4	C-shape and Y-shape	3
21	*L. sesokoensis*	C	4	C-shape	5
22	*L. yoshidai*	C	4	C-shape	5
23	*Loxoconcha* sp. 3	C	4	C-shape	3

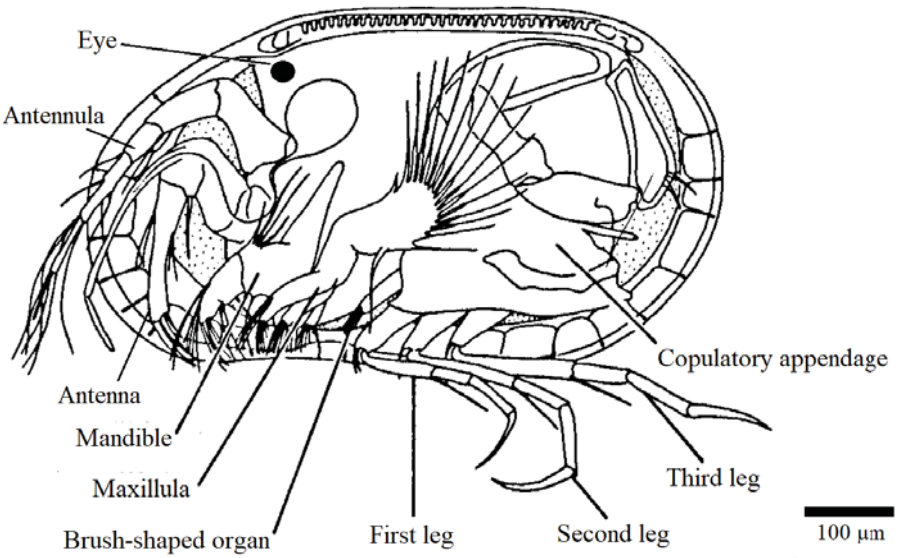

Fig. 2. *Loxoconcha elliptica* (adult ♂), seen from the left side with left valve removed, to show the general arrangement of the appendages (only one of each pair of appendages shown for clarity) (Athersuch et al., 1989).

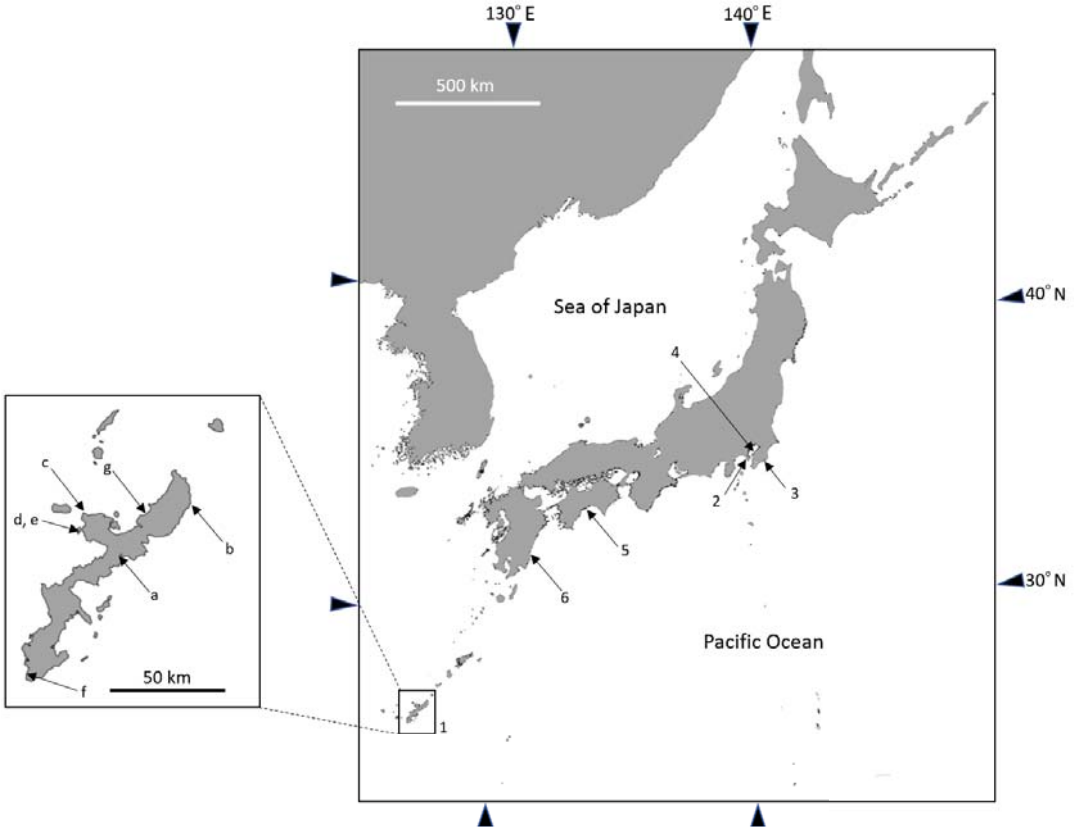

Fig. 3. Study sites in Japan. Details of occurrence are shown in Appendix 1. Star shapes (Sampling and using ready specimens), solid circles (Only using ready specimens).

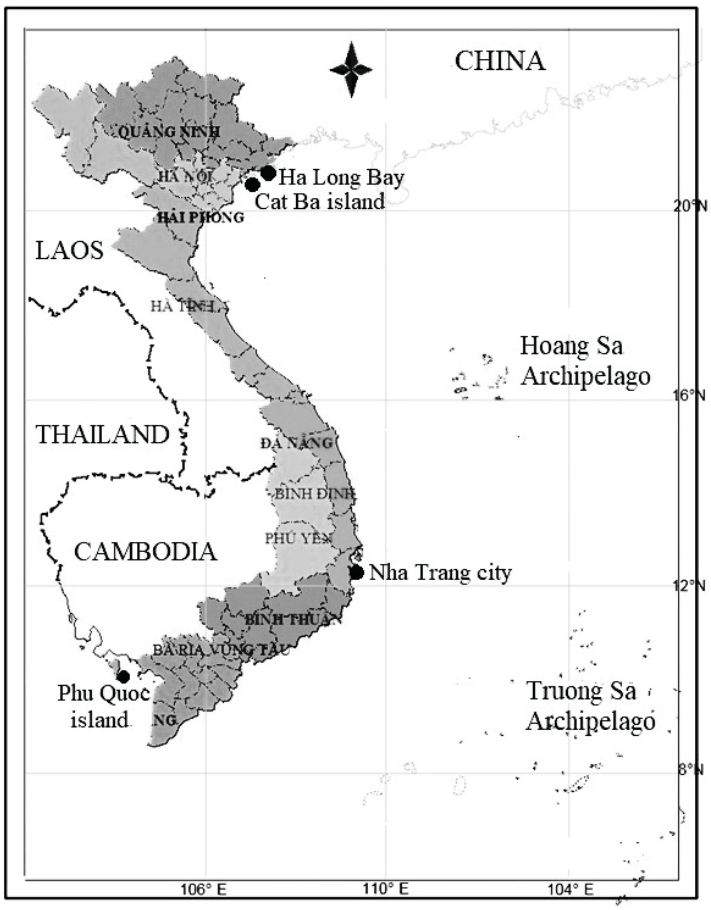

Fig. 4. Map of Vietnam showing four surveyed areas with solid circles, Phu Quoc Island, Nha Trang Bay, Ha Long Bay and Cat Ba Island.

shape was discovered in the species of *L. japonica* group, i. e., *L. shanhaiensis*, *L. japonica*, *L.* sp. 9, *L.* sp. 10 and *L.* sp. 8 (table 1 and fig. 7, A, C–E, K). Most individuals of *L. kosugii* bear the frontal scar with C-shape (fig. 8, A–C), but the frontal scar with Y-shape was found in several individuals of this species (fig. 8, D).

Maxillula and mandible of the genus *Xestoleberis*. The maxillula and the mandible of a total of 21 *Xestoleberis* species were observed in the present study, including 18 species inhabited in Japan coast (including the Okinawa Islands) and 3 species (*X.* sp. 7, *X. vietnamensis* and *X. munensis*) in Vietnam (table 2; figs 9, 10; Appendix 1). Also, data on the chaetotaxy of the maxillula and the mandible of 3 species are referred completely from the previous studies, of 5 species are both referred and newed, and of 13 species are showed herein for the first time (table 2). The checked results of several soft appendages indicated that the number of setae of the outer first podomere of the endopodite on the maxillula ranges from 2 to 5, of three endites on the maxillula from 11 to 14, of exopodite on the maxillula from 13 to 17 and of the third podomere of mandibular endopodite from 2 to 6 (table 2).

As ranking of species groups, the number of setae of the first podomere of maxillulan endopodite is low in the Group C (average of 2 setae) and high in the Group B (average of 4 setae) and the Group A (average of 4 setae). The number of setae of the third podomere of the endopodite on the mandible is constant among species of each group, and this number

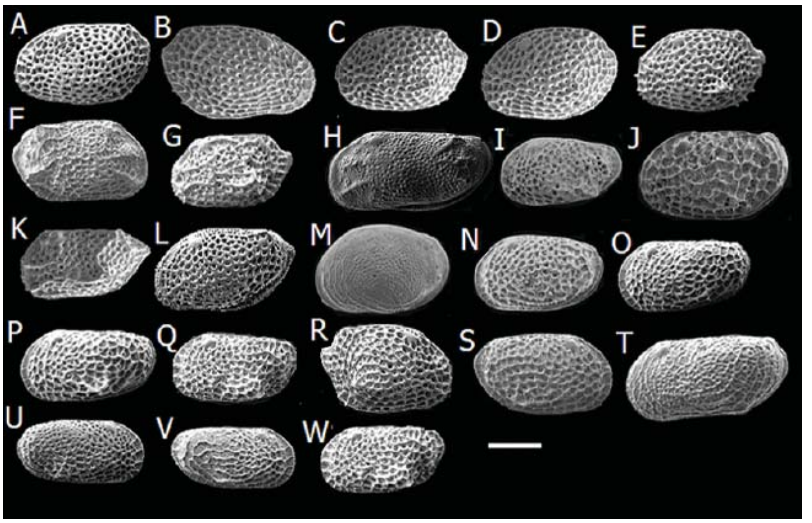

Fig. 5. External view of 23 species examined of *Loxoconcha*: A — *L. shanhaiensis* (♂, LV); B — *Loxoconcha japonica* (♂, RV); C — *Loxoconcha* sp. 9 (LV); D — *Loxoconcha* sp. 10 (LV); E — *Loxoconcha* sp. 8 (LV); F — *Loxoconcha* sp. 1 (♀, RV); G — *Loxoconcha* sp. 30 (LV); H — *L. mutsuensis* (♂, LV); I — *Loxoconcha* sp. 13 (LV); J — *L. tosaensis* (LV); K — *L. harimensis* (LV); L — *L. damensis* (♂, LV); M — *L. pulchra* (LV); N — *L. uranouchiensis* (♂, LV); O — *L. noharai* (♂, LV); P — *L. santosi* (♂, LV); Q — *Loxoconcha* sp. 5 (LV); R — *Loxoconcha* sp. 4 (RV); S — *Loxoconcha* sp. 26 (♀, RV); T — *L. kosugii* (♂, LV); U — *L. sesokoensis* (♂, RV); V — *L. yoshidai* (♂, RV); W — *Loxoconcha* sp. 3 (♂, LV). Scale 200 μm. Abbreviations: LV, left valve; RV, right valve.

is low in the Group C (2 setae), median in the Group A (4 setae) and high in the Group B (6 setae). On the other hand, the total number of setae of three endites and of exopodite on the maxillula varies among species within each group, and there are no differences in the two characters among three groups (table 2).

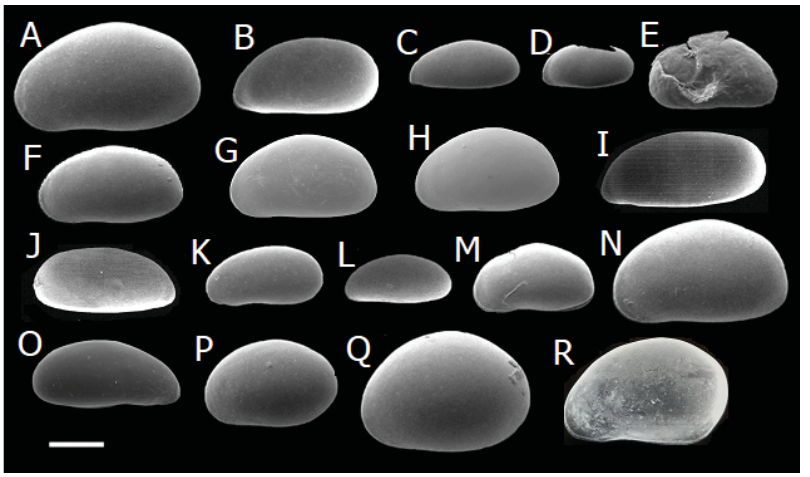

Fig. 6. External view of 18 species examined of *Xestoleberis*: A — *Xestoleberis hanaii* (♂, LV); B — *Xestoleberi* sp. 1 (♂, LV); C — *Xestoleberi* sp. 2 (♀, LV); D — *Xestoleberi* sp. 5 (♀, LV); E — *Xestoleberi* sp. 6 (♂, RV); F — *Xestoleberis* sp. 7 (♂, LV); G — *X. vietnamensis* (♂, LV); H — *X. munensis* (♂, LV); I — *X. magutiensis* (♀, LV); J — *X. kamiya* (♂, RV); K — *X. ikeya* (LV); L — *X. planuventer* (♀, LV); M — *X. ryukyuensis* (♀, LV); N — *X. sesokoensis* (♂, LV); O — *X. setouchiensis* (♀, RV); P — *X. kuroshio* (♂, LV); Q — *X. magnoculus* (♀, LV); R — *X. notoensis* (♀, LV). Scale 200 μm. Abbreviations: LV, left valve; RV, right valve.

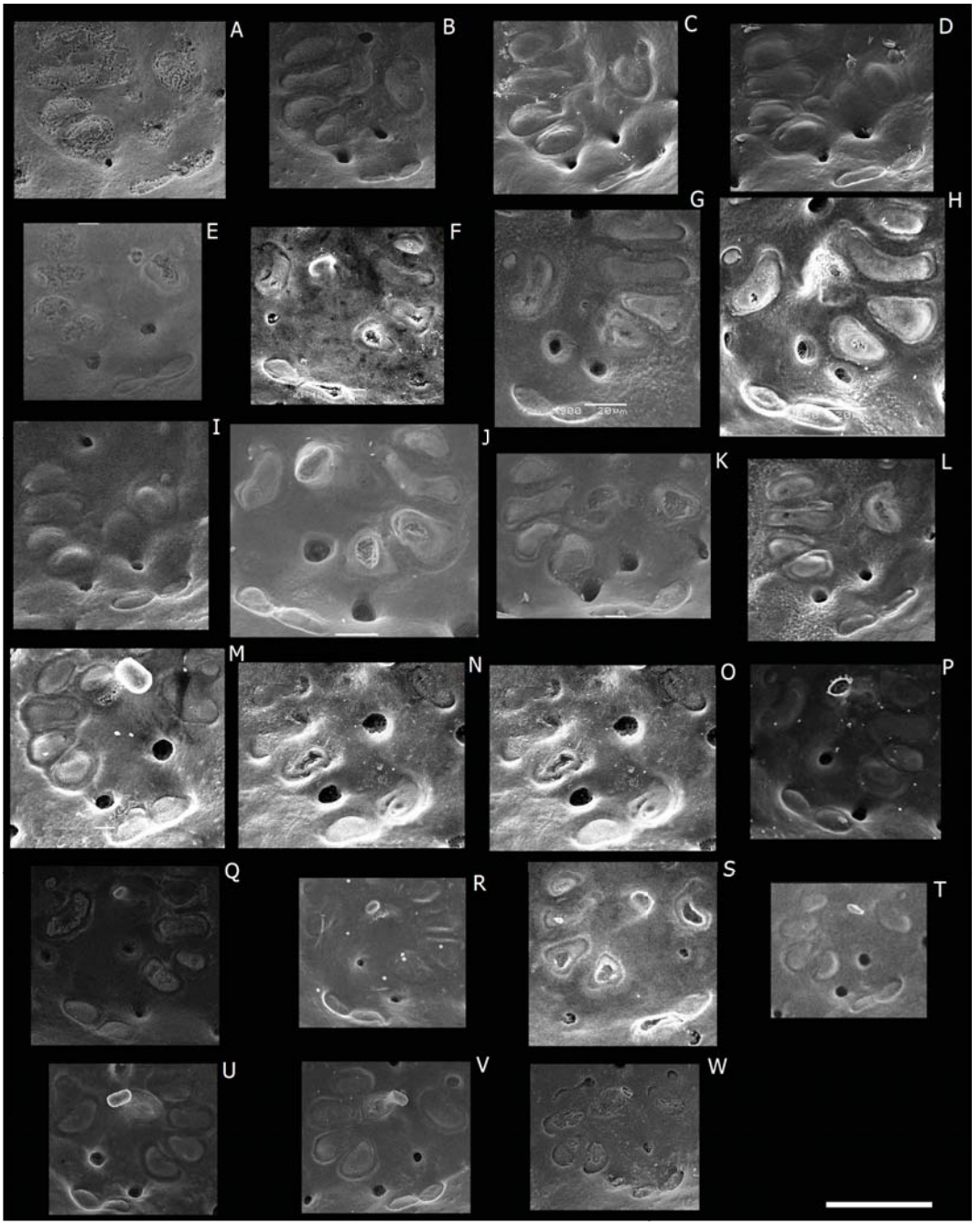

Fig. 7. Muscle scars of 23 species of the genus *Loxoconcha*: A — *L. shanhaiensis* (♂, LV); B — *Loxoconcha* sp. 1 (♀, LV); C — *L. japonica* (♂, LV); D — *Loxoconcha* sp. 9 (LV); E — *Loxoconcha* sp. 10 (LV); F — *Loxoconcha* sp. 30 (RV); G — *L. mutsuensis* (♂, RV); H — *L. modesta* (♂, RV); I — *L. tosaensis* (♂, RV); J — *L. harimensis* (♀, LV); K — *Loxoconcha* sp. 8 (♀, LV); L — *L. damensis* (♂, LV); M — *L. pulchra* (♂, LV); N — *L. kosugii* (♂, LV); O — *L. uranouchiensis* (♂, LV); P — *L. noharai* (♂, RV); Q — *L. santosi* (♀, RV); R — *Loxoconcha* sp. 5 (♀, RV); S — *Loxoconcha* sp. 4 (LV); T — *Loxoconcha* sp. 26 (♂, LV); U — *L. sesokoensis* (♂, RV); V — *L. yoshidai* (♂, LV); W — *Loxoconcha* sp. 3 (♂, LV). Scale 100 μm. Abbreviations: LV, left valve; RV, right valve.

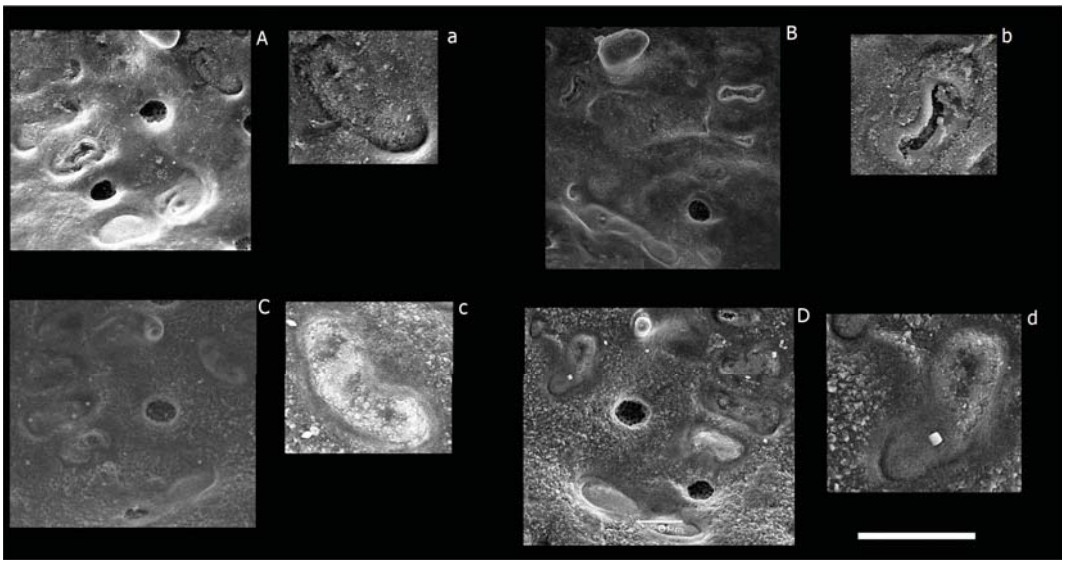

Fig. 8. Muscle scars of *Loxoconcha kosugii*: A — ♂, LV; B — ♂, RV; C. ♀, LV; D — ♀, RV. a–d, frontal muscle scar of A–D, respectively. Scale: 50 μm for A–D; 20 μm for a–d.

T a b l e 2. Number of setae of three endites, the 1st podomere of maxillular endopodite, exopodite of the maxillula and the 3rd podomere of mandibular endopodite of 21 species of the genus *Xestoleberis*

No.	Species	Group	Maxillula			Mandible	*N*
			Three endites	1st podomere of maxillular endopodite	Exopodite of the maxillula	3rd podomere of mandibular endopodite	
1	*Xestoleberis hanaii*	A	13	4	17	4	4
2	*Xestoleberis* sp. 1	A	13	4	16	4	3
3	*Xestoleberis* sp. 2	A	–	–	–	4	2
4	*Xestoleberis* sp. 5	A	12	4	–	–	4
5	*Xestoleberis* sp. 6	A	–	4	–	4	2
6	*Xestoleberis* sp. 7	A	14	5	16	4	2
7	*X. vietnamensis*	A	13	4	16	4	5
8	*X. munensis*	A	14	4	17–18	4	6
9	*X. magutiensis*[1]	A	12	4	13	4	2
10	*X. kamiya*[1]	A	11	4	15	4	2
11	*X. ikeya*[2]	A	11	4	17	4	2
12	*X. planuventer*	A	–	3	17	4	5
13	*X. ryukyuensis*	A	14	4	17	4	4
14	*X. sesokoensis*	A	12	4	17	4	3
15	*X. setouchiensis*[3]	A	11	4	16	4	2
16	*X. kuroshio*	B	11	4	17	6	5
17	*X. magnoculus*	B	13	4	17	6	3
18	*X. notoensis*[2]	C	–	2	16	2	2
19	*X. sagamiensis*[4]	C	14	2	16–17	2	
20	*X. ishizakii*[4]	C	–	2	–	2	
21	*X. iturupica*[4]	C	–	2	–	2	

[1]After Hirosaki, unpubl. (2013) and this study; [2] after Sato & Kamiya (2007) and this study; [3] after Okubo (1979) and this study; [4] after Sato & Kamiya (2007).

Discussion

Variation of morphological characteristics of muscle scars of the genus *Loxoconcha*. Athersuch & Horne (1984), Athersuch et al (1989) studied some species of *Loxoconcha* such as *L. rhomboidea*, *L. elliptica* and generalized this genus has four adductor scars in a vertical row. Hence, this is a typical characteristic of the genus *Loxoconcha*. In the present study, most of *Loxoconcha* species bear four adductor muscle scars arranging in a weakly curved sub-vertical row or a curved sub-vertical row and concave anteriorly. However, observation of plural individuals of the species *L. pulchra* showed this species carries five adductor muscle scars, in which the top one was divided into two

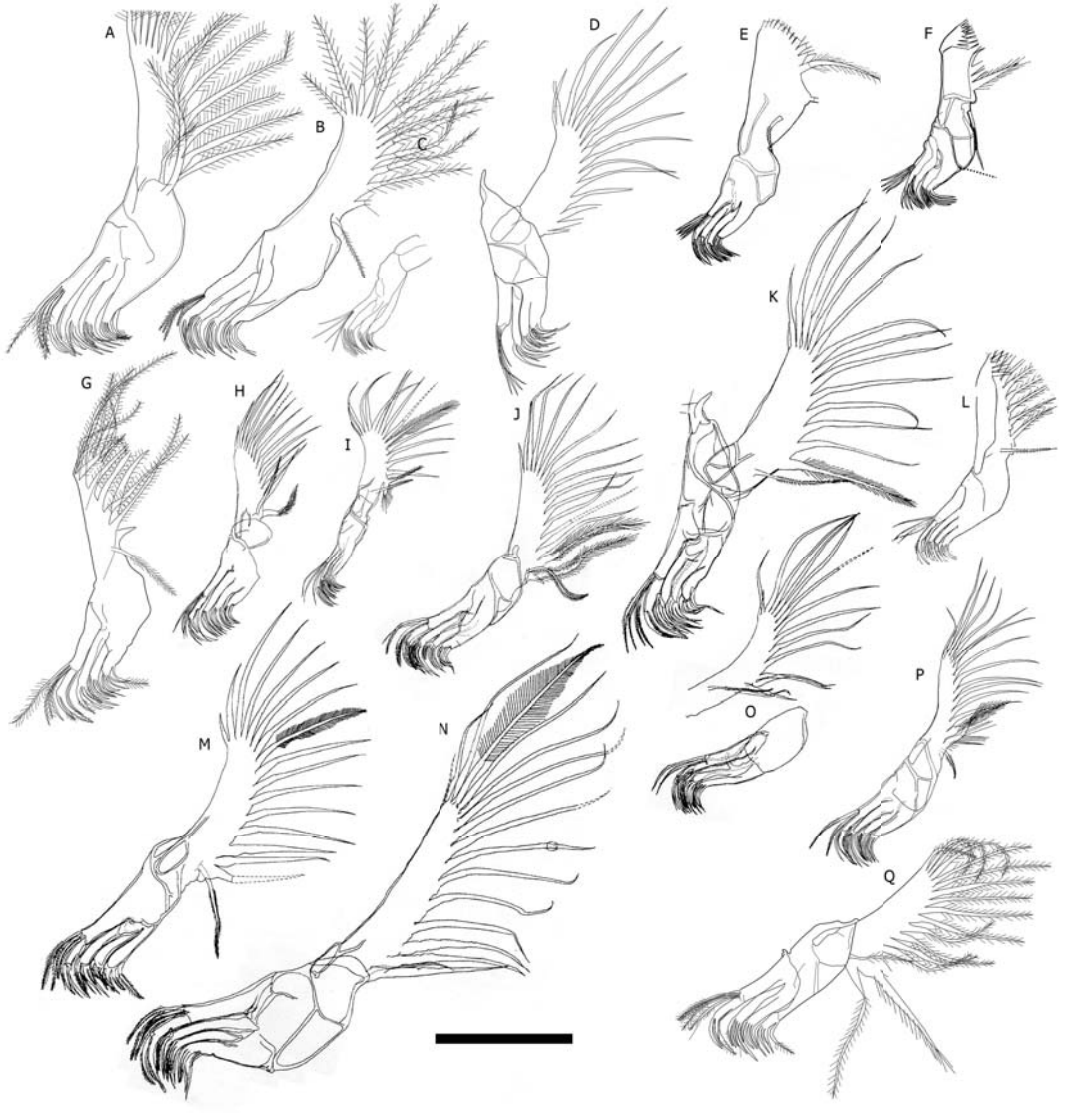

Fig. 9. Adult maxillula in 17 species of the genus *Xestoleberis*: A — *X. hanaii* (♂); B — *Xestoleberis* sp. 1 (♀); C — *Xestoleberis* sp. 5 (♂); D — *Xestoleberis* sp. 7 (♂); E — *X. maguitiensis* (♀); F — *X. kamiya* (♂); G — *X. vietnamensis* (♂); H — *X. ikeya* (♂); I — *X. planuventer* (♂); J — *X. ryukyuensis* (♂); K — *X. sesokoensis* (♂); L — *X. setouchiensis* (♂); M — *X. kuroshio* (♂); N — *X. magnoculus* (♂); O — *X. notoensis* (♂); P — *X. sagamiensis* (♂); Q — *X. munensis* (♂). Note: E, after Hirosaki (2013); L, after Okubo (1979); O, P, after Sato & Kamiya (2007). Scale 100 μm.

(fig. 7, M). This character may be a mutation phenomenon that was already mentioned in the species of *Parvocythere* by Higashi & Tsukagoshi (2012), of *Eucypris* by Schön et al. (2000), of Darwinulidae by Van Doninck et al. (2004). It also can be regarded as apomorphy in *Loxoconcha*.

According to Athersuch & Horne (1984), Athersuch et al. (1989), frontal scars of the genus *Loxoconcha* are characterized with C-shape. In the present study, most of species of the genus *Loxoconcha* have the frontal scar with C-shape, opening anteriorly (table 1 and fig. 7). However, the frontal scar with bean-shape or oval-shape was showed in the species of *L. japonica* group (*L. shanhaiensis*, *L. japonica*, *L.* sp. 8, *L.* sp. 9 and *L.* sp. 10) that was distinguished from other groups by carapace outlines, surface ornamentation patterns, hinge structures and muscle scar patterns (Tanaka & Ikeya, 2002). *L. japonica* group belongs to phytal species and the Group A (Ishii et al., 2005; Le & Tsukagoshi, 2014). The novel shapes of frontal scar of the *L. japonica* species group are probably derived from an ancestral shape, i. e., C-shape belonging to the Group B (Ishii et al., 2005; Le & Tsukagoshi, 2014). The oldest fossil records of the genus *Loxoconcha* show that species of Group A

Fig. 10. Adult mandible in 17 species of the genus *Xestoleberis*: A — *X. hanaii* (♂); B — *Xestoleberis* sp. 1 (♀); C — *Xestoleberis* sp. 6 (♂); D — *Xestoleberis* sp. 7 (♂); E — *X. magutiensis* (♀); F — *X. kamiya* (♂); G — *X. vietnamensis* (♂); H — *X. ikeya* (♂); I — *X. planuventer* (♂); J — *X. ryukyuensis* (♂); K — *X. sesokoensis* (♂); L — *X. setouchiensis* (♂); M — *X. Kuroshio* (♂); N — *X. magnoculus* (♂); O — *X. notoensis* (♂); P — *X. sagamiensis* (♂); Q — *X. munensis* (♂). Note: E, F, after Hirosaki (2013); L, after Okubo (1979); O, P, after Sato & Kamiya (2007). Scale 100 μm.

have appeared around Japan since the late Pliocene, meanwhile, species of Group B have inhabited areas around Japan since the early Miocene (approximately 18 Ma) (Yamada et al., 2001; Irizuki et al., 2004; Ishii et al., 2005).

Additionally, there was a variation about the shape of frontal scar in *L. kosugii* (table 1, figs 7, N and 8) in this study. The frontal scar of most individuals of *L. kosugii* was recorded with C-shape (fig. 8, A–C), but the frontal scar with Y-shape was shown in few individuals (fig. 8, D). The frontal scar with Y-shape is a typical character of the genus *Palmoconcha* whose phylogeny is close to the genus *Loxoconcha* (Ishii, 2004).

Initial assumptions about evolutionary trend of the genus *Xestoleberis*. The morphological characteristics of maxillula and mandible of the genus *Xestoleberis* in the present study have almost no difference compared to previous studies except the total number of setae of exopodite on the maxillula. Following to Smith et al. (2005), this number of the family Xestoleberididae is 16.

Based on the combination of the morphological types of pore systems on carapace (Sato & Kamiya, 2007), the species of *Xestoleberis* were divided into three groups, i. e., Groups A, B and C. The Group A has both sieve-type and lip-type pores. The Group B has only sieve-type pore. The Group C has simple-type and sieve-type pores. The pore types of the genus *Xestoleberis* were referred from Puri (1974). The present study shows the number of setae on the first podomere of maxillulan endopodite of the Group C is fewer than that of Group A and Group B. Similarly, Group C has a fewer number of setae of the third podomere of the mandibular endopodite than Groups A and B. Additionally, Sato & Kamiya (2007) already pointed out the lower total number of pores on carapace of the Group C.

The old records of *Xestoleberis* worldwide (and the assignment of the species group based on their carapace morphology) include: *X.* sp. 1 (Group A) from the Barremian, France (Babinot et al., 1985); *X. minuta* (Group A) from the upper Cretaceous Rosario Formation, U.S.A, East Pacific Ocean (Holden, 1964); *X. opina* (Group B) from the Campanian Ozan Formation, U.S.A. (Brouwers & Hazel, 1978); *X. convexa* (Group B) from the Thanetian, France (Ducasse et al., 1985); *X. tunisiensis* (the Group A) from the late Paleocene, Egypt (Bassiouni & Morsi, 2000). In Japan, the oldest records of *Xestoleberis* so far are *X.* spp. (Group A) from the early Miocene Akeyo Formation (Irizuki et al., 2004; Sato & Kamiya, 2007). Up to now, no fossil record of the Group C has been found yet. The absence of Group C in the above fossil records, the fewer number of setae on the maxillula and mandible of the Group C from the present study, and the lower total number of pores on carapace of this group (Sato & Kamiya, 2007) suggest that geologic age of the Group C is younger than that of the Group A and B; and the Group A or B is an ancestor of the genus *Xestoleberis*, and the Group C is a derived group. Hence, a phylogenetic trend of the genus *Xestoleberis* is shown: among the different species of this genus, the smaller number of setae of outer first podomere of maxillulan endopodite as well as the number of setae of the third podomere of mandibular endopodite are probably distributed in the species of the derived taxonomic group.

Conclusion

Most species of the genus *Loxoconcha* bear four adductor scars to arrange in a curved sub-vertical row and concave anteriorly, except *L. pulchra* carrying five, in which the top one is divided into two. The frontal scars with C-shape, opening anteriorly are typical of most of *Loxoconcha* species, however, the frontal scar with bean shape or oval shape is

found in *L. japonica* group. Most of *L. kosugii* consist of the frontal scar with C-shape, but the frontal scar with Y-shape is found in several individuals. For the case of the genus *Xestoleberis*, character of chaetotaxy of setae on most appendages is typical of this genus, except for setae of exopodite on the maxillula. The number of setae of exopodite on the maxillula ranges from 13 to 18.

Declaration of competing interest

The author declare that he has no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of funding

This research did not receive any specific funding.

Acknowledgements

I thank Prof. Akira Tsukagoshi (Shizuoka University), Prof. Takahiro Kamiya and Dr. Tohru Ishii (Kanazawa University) for their invaluable advice and continuous encouragement. We also appreciate Dr. Hayato Tanaka (University of Tokyo) and the members of the Ostracod Research Team of Shizuoka University for helpful comments and assistance. Thanks also go to Research Institute for Marine Fisheries, the Provincial People's Committees of Quang Ninh, Khanh Hoa and Kien Giang for their help during our field trips in Vietnam. Finally, we are deeply grateful to the editor and the reviewers who carefully reviewed our manuscript.

References

Athersuch, J. & Horne, D. J. 1984. A review of some European genera of the Family Loxoconchidae (Crustacea: Ostracoda). *Zoological Journal of the Linnean Society*, **81**, 1–22. https://doi.org/10.1111/j.1096-3642.1984.tb02557.x

Athersuch, J., Horne, D. J. & Whittaker, J. E. 1989. *Marine and Brackish Water Ostracods*. E. J. Brill, Leiden (*Synopses of the British Fauna (new series)*, **43**, 1–343.

Babinot, J.-F., Damotte, R., Donze, P., Grosdider, E., Oertli, H. J. & Scarenzi-Carboni, G. 1985. Crétacé inférieur. *In*: Oertli, H. J., ed. *Atlas des Ostracodes de France*. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine: Pau, Pyrénées-Atlantiques, 163–209.

Bassiouni, M. A. & Morsi, A. M. 2000. Paleocene-Lower Eocene ostracodes from El Quss Abu Said Plateau (Farafra Oasis), western Desert, Egypt. *Paleontographica (A)*, **257**, 27–84.

Brandão, S. N., Angel, M. V., Karanovic, I., Parker, A., Perrier, V., Sames, B. & Yasuhara, M. 2015. World Register of Marine Species. Available at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=127643 on 2015-04-27 [Date Accessed 15 April 2015].

Brouwers, E. M. & Hazel, J. E. 1978. Ostracoda and correlation of the Severn Formation (Navarroan: Maestrichtian) of Maryland. *Paleontology*, **52** (6), 1–52.

Ducasse, O., Guernet, C. & Tambareau, Y. 1985. Paléogéne. *In*: Oertli, H. J., ed. *Atlas des Ostracodes de France*. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine: Pau, Pyrénées-Atlantiques, 163–209.

Higashi, R. & Tsukagoshi, A. 2012. Two new species of the interstitial genus *Parvocythere* (Crustacea, Ostracoda, Cytheroidea) from Japan: an example of morphological variation. *Zookeys*, **193**, 27–48. https://doi.org/10.3897/zookeys.193.2842

Hirosaki, M. 2013. *Taxonomy of two new species of ostracod gene Xestoleberis and study about the stages of an interstitial adaptation*. Shizuoka University, BSc (Hons), Thesis, 1–136. [In Japanese with English abstract].

Holden, J. C. 1964. Upper Cretaceous ostracods from California. *Palaeontology*, **7** (3), 393–429.

Horne, D. J., Cohen, A. & Martens, K. 2002. Taxonomy, morphology and biology of Quaternary and living ostracoda. *In*: Holmes, J. A. & Chivas, A., eds. *The ostracoda: Applications in Quaternary Research*. American Geophysical Union, Washington DC, 6–36.

Irizuki, T., Yamada, K., Maruyama, T. & Ito, H. 2004. Paleoecology and taxonomy of Early Miocene ostracoda and paleoenvironments of the eastern Setouchi province, central Japan. *Micropaleontology*, **50** (2), 105–147.

Ishii, T. 2004. *Phylogeny and evolution of the genus Loxoconcha and related genera (Ostracoda, Crustacea)*. Kanazawa University: PhD Thesis, 1–85.

Ishii, T., Kamiya, T. & Tsukagoshi, A. 2005. Phylogeny and evolution of *Loxoconcha* (Ostracoda, Crustacea) species around Japan. *Hydrobiologia*, **538**, 81–94. https://doi.org/10.1007/s10750-004-4939-3

Kempf, E. K. 1986 a. *Index and Bibliography of Marine Ostracoda, 1. Index A*. Geologisches Institut der Universität Köln, Sonderveroeffentlichungen, Köln, **50**, 1–762.

Kempf, E. K. 1986 b. *Index and Bibliography of Marine Ostracoda, 2. Index B*. Geologisches Institut der Universität Köln, Sonderveroeffentlichungen, Köln, **51**, 1–708.

Le, D. D. & Tsukagoshi, A. 2014. Three new species of the genus *Loxoconcha* (Crustacea, Ostracoda, Podocopida) from the Okinawa Islands, southern Japan. *Zootaxa*, **3796**, 147–165. https://doi.org/10.11646/zootaxa.3796.1.7

Okubo, I. 1979. Three species of *Xestoleberis* (Ostracoda) from the Inland Sea of Japan. *Proceedings of the Japanese Society of Systematic Zoology*, **16**, 8–16. https://doi.org/10.19004/pjssz.16.0_9

Puri, H. S. 1974. Normal pores and the phylogeny of Ostracoda. *Geoscience and Man*, **6**, 137–151.

Sars, G. O. 1866. Oversigt af Norges marine Ostracoder. *Forhandlinger i Videnskabs-Selskabet i Christiania*, **1865**, 1–130.

Sato, T. & Kamiya, T. 2007. Taxonomy and geographical distribution of recent *Xestoleberis* species (Cytheroide, Ostracoda, Crustacea) from Japan. *Paleontological Research*, **11** (2), 183–227. https://doi.org/10.2517/1342-8144(2007)11[183:TAGDOR]2.0.CO;2

Schön, I., Gandolfi, A., Masso, E. D., Rossi, V., Griffiths, H. I., Martens, K. & Butlin, R. K. 2000. Persistence of asexuality through mixed reproduction in *Eucypris virens* (Crustacea, Ostracoda). *Heredity,* **84**, 161–169. https://doi.org/10.1046/j.1365-2540.2000.00647.x

Schön, I. & Martens, K. 2016. Ostracod (Ostracoda, Crustacea) genomics — Promises and challenges. *Mar Genomics*, **29**, 19–25. https://doi.org/10.1016/j.margen.2016.03.008

Smith, R. J., Kamiya, T., Horne, D. J. & Tsukagoshi, A. 2005. Evaluation of a new character for the phylogenetic analysis of Ostracoda (Crustacea): the podocopan maxillular branchial plate. *Zoologischer Anzeiger*, **243**, 139–153. https://doi.org/10.1016/j.jcz.2004.07.005

Tanaka, G. & Ikeya, N. 2002. Migration and speciation of the *Loxoconcha japonica* species group (Ostracoda) in East Asia. *Paleontological Research*, **6** (3), 265–284. https://doi.org/10.2517/prpsj.6.265.

Tanaka, H. & Tsukagoshi, A. 2013. The taxonomic utility of the male lip morphology in the ostracod genus *Parapolycope* (Crustaces), with description of two new species. *Journal of Natural History*, **47**, Nos. 13–6, 963–986. https://doi.org/10.1080/00222933.2012.743615

Tsukagoshi, A. 1988. Reproductive character displacement in the ostracod genus *Cythere*. *Journal of Crustacean Biology*, **8** (4), 563–575. https://doi.org/10.1163/193724088X00413

Tsukagoshi, A., Okada, R. & Horne, D. 2006. Appendage homologies and the first record of eyes in platycopid ostracods, with the description of a new species of *Keijcyoidea* (Crustacea: Ostracoda) from Japan. *Hydrobiologia*, **559**, 255–274. https://doi.org/10.1007/s10750-005-1139-8

Tran, V. P., Anselmetti, Y., Bast, J., Dumas, Z., Galtier, N., Jaron, K. S., Martens, K., Parker, D. J., Robinson-Rechavi, M., Schwander, T., Simion, P. & Schön, I. 2021. First annotated draft genomes of nonmarine ostracods (Ostracoda, Crustacea) with different reproductive modes. *G3 Genes/Genomes/Genetics*, **11** (4), 1–9. https://doi.org/10.1093/g3journal/jkab043

Van Doninck, K., Schön, I., Martens, K. & Backeljau, T. 2004. Clonal diversity in the ancient asexual ostracod *Darwinula stevensoni* assessed by RAPD-PCR. *Heredity*, **93**, 154–160. https://doi.org/10.1038/sj.hdy.6800486

Yamada, K., Irizuki, T. & Nakajima, S. 2001. Spatial and temporal distribution of fossil ostracodes assemblages and sedimentary facies in the Lower Miocene Arakida Formation, Tomikusa Group, Nagano Prefecture, central Japan. *The Journal of the Geological Society of* Japan, **107** (1), 1–13 [In Japanese with English abstract].

Received 8 November 2022
Accepted 20 Feebruary 2023

Appendix 1. List of examined species in this study and their sampling location, habitat and habitat salinity to which they belong

Species name	Sampling location	Habitat	Salinity
Loxoconcha japonica	Sesoko Island, Okinawa Islands, southern Japan	Phytal	m
L. shanhaiensis	Sesoko Island, Okinawa Islands, southern Japan	Phytal	m
Loxoconcha sp. 1	Sesoko Island, Okinawa Islands, southern Japan	Phytal	m
L. kosugii	Sesoko Island, Okinawa Islands, southern Japan and Kisarazu city, Chiba Pref., central Japan	Bottom	b–m
L. noharai	Ohura estuary, Okinawa Islands, southern Japan	Bottom	b
L. santosi	Ada, Okinawa Islands, southern Japan	Bottom	b
Loxoconcha sp. 3	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
L. yoshidai	Bise beach, Motobu town, Okinawa Islands, southern Japan	Bottom	m
L. sesokoensis	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m

Loxoconcha sp. 8	Sesoko Island, Okinawa Islands, southern Japan	Phytal	m
Loxoconcha sp. 9	Sesoko Island, Okinawa Islands, southern Japan	Phytal	–
Loxoconcha sp. 10	Sesoko Island, Okinawa Islands, southern Japan	Phytal	–
Loxoconcha sp. 13	Sesoko Island, Okinawa Islands, southern Japan	–	–-
L. mutsuensis	Miyazaki, Miyazaki Pref., southern Japan	Phytal	m
L. harimensis	Miura City, Kanagawa Pref., central Japan	Bottom	m
L. tosaensis	Miura City, Kanagawa Pref., central Japan	Bottom	m
L. pulchra	Kisarazu City, Chiba Pref., central Japan	Bottom	b
L. uranouchiensis	Miura, Kanagawa Pref., central Japan	Bottom	b-m
Loxoconcha sp. 4	Miura, Kanagawa Pref., central Japan	Bottom	b-m
Loxoconcha sp. 5	Obitsu river estuary, Chiba Pref., central Japan	Bottom	b
Loxoconcha sp. 30	Uranouchi Bay, Kochi Pref., southern Japan	–	–
L. damensis	Dam Ngoai Island, Phu Quoc MPA, Phu Quoc Island, Kien Giang Pro., southern Vietnam	Phytal	m
Loxoconcha sp. 26	Saraku resort, Nha Trang city, central Vietnam	Bottom	m
Xestoleberis hanaii	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
X. sesokoensis	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
X. ryukyuensis	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
X. planuventer	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
X. ikeya	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
Xestoleberis sp. 1	Midland Island, Okinawa Islands, southern Japan	–	m
Xestoleberis sp. 2	Sesoko Island, Okinawa Islands, southern Japan	–	m
Xestoleberis sp. 5	Sesoko Island, Okinawa Islands, southern Japan	–	m
Xestoleberis sp. 6	Sesoko Island, Okinawa Islands, southern Japan	–	m
X. kuroshio	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
X. magnoculus	Sesoko Island, Okinawa Islands, southern Japan	Bottom	m
Xestoleberis sp. 7	Sung Sot cave, Ha Long Bay, Ha Long city, Quang Ninh Pro., northern Vietnam	Bottom	m
X. vietnamensis	Dam Ngoai island, Phu Quoc MPA, Phu Quoc Island, Kien Giang Pro., southern Vietnam	Bottom	m
X. munensis	Hon Mun island, Nha Trang Bay MPA, Nha Trang City, central Vietnam	-	m
X. magutiensis	Shimo-Matsuura, Miura City, Kanagawa Prefecture, Japan	Bottom	m
X. kamiya	Shimo-Matsuura, MiuraCity, Kanagawa Prefecture, Japan	Bottom	m
X. notoensis	Ogi Uchiura, Ishikawa, Japan	Phytal	m
X. setouchiensis	Iseki Nishinoomote, Tanegashima Island Kagoshima, Japan	Phytal	m

Note: b — brackish water; m — marine water.