

Origin of the ostracod fauna in the Okinawa Islands, southern Japan, inferred from the two genera *Loxoconcha* and *Xestoleberis* (Arthropoda:Crustacea)

メタデータ	言語: en
	出版者: Shizuoka University
	公開日: 2015-12-17
	キーワード (Ja):
	キーワード (En):
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URL	所属:
	https://doi.org/10.14945/00009285

THESIS

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June 2015

THESIS

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Loxoconcha and *Xestoleberis* (Arthropoda: Crustacea)
Loxoconcha 属と *Xestoleberis* 属から推察した沖縄の貝形
虫類相（節足動物：甲殻類）の起源

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2015 年 6 月

Abstract

This study was discussed with origin of the ostracod fauna in the Okinawa Islands, southern Japan, dealing with the two Recent genera *Loxoconcha* (Loxoconchidae) and *Xestoleberis* (Xestoleberididae). The genus *Loxoconcha* is one of the most diverse extant ostracod genera. Species of this genus are distributed in low to middle latitude areas of marine and brackish waters. The genus *Xestoleberis* is presently distributed in tropical to temperate zones worldwide. The total 22 species of the genus *Loxoconcha* and 13 species of the genus *Xestoleberis* were found around the coast of the Okinawa Island. In which, eight species of the former and seven species of the later were already described and published. Result of examination of maxillulan ontogeny in *Loxoconcha noharai*, *L. sesokoensis* and *L. japonica* shows the difference in the number of setae on the maxillula among three species starts in the instar A-4.

This character suggests to show the phylogenetic relationship of the genus *Loxoconcha*. The *Loxoconcha* species have been divided into three lineages based on the distributional pattern of the pore systems below eye tubercle, which is regarded as a highly reliable phylogenetic index. In these lineages, the Groups A and B were defined by Ishii et al. (2005) and the Group C was defined by Le & Tsukagoshi (2014).

The chaetotaxy on the maxillula in 17 species and dimensions of hinge elements of the left valve in 24 species of the genus *Loxoconcha* were also examined in the present study. From the fossil records and the tendencies of change in the total number of the chaetotaxy of three endites on the maxillula and the dimension of posterior tooth of hingement of the left valve, geological age of the Group A is considered as the oldest (average of 12.6 setae and 22.6 μm), the Group B as the median (average of 16.5 setae and 13.1 μm) and the Group C as the youngest (average of 16.8 setae and 11.5 μm). It is suggested that there are close relationships between the evolutionary process and the number of setae of three endites on the maxillula, and the size of posterior tooth of hingement of left valve in the genus *Loxoconcha*. The younger evolutionary origin of *Loxoconcha* species gets the more setae of three endites on its maxillula and the smaller dimension of posterior tooth of its left valve; while, the older evolutionary origin of the species bears the fewer setae of three endites of its maxillula and the longer posterior tooth of its left valve. Obviously, there are remarkable differences of these characters in the Groups B and C from the Group A, but only slight differences are shown between the Groups B and C. Moreover, the presence of an intermediate state of the

pore distributional pattern below eye tubercle between the Groups B and C was observed in the species *Loxoconcha* sp. Y. Therefore, it is strongly suggested that the two groups are closely related phylogenetically each other.

The total of 22 species of the genus *Xestoleberis* have been subdivided into three species groups (Groups A, B and C) based on types of pores on the carapace by Sato & Kamiya (2007). The fossil records and the tendency of change in the number of setae of the first podomere of maxillulan endopodite and the third podomere of mandibular endopodite indicate that the Groups A and B are older than the Group C.

In the genus *Loxoconcha*, the Group A is widely distributed all over the world, whereas the Groups B and C are distributed from Vietnam to Japan and from Australia to the Okinawa Islands, respectively. In the case of the genus *Xestoleberis*, the Group A is known to broadly inhabit at the coast from Australia to Japanese Island Arc, the Group B is found along the coast from Australia to the Okinawa Islands, and the Group C only along the coast around Japanese Island Arc (Sato & Kamiya, 2007). The distributional models of species groups of the two genera *Loxoconcha* and *Xestoleberis* remarkably show that the species of these genera from the Okinawa Islands are phylogenetically close to those from southern western Pacific (i. e., Vietnam, the Philippines and Australia) rather than Japanese Island Arc. These facts strongly reveal that the species of the two genera of the Okinawa Islands are established based on invasion of southern faunas and then these species continue to migrate to, speciate and colonize in Japanese Island Arc. The historical data about paleogeography, paleomarine climate (e. g., temperature, sea water level and currents), marine ecosystems and geographical distributions of other ostracods indicate that the invasion tendency from the south to the north applies not only for the genera *Loxoconcha* and *Xestoleberis*, but also for the general ostracod faunas in the Okinawa Islands and Japanese Island Arc. The present geographical distributional model of the three groups of the genus *Loxoconcha* also indicates that the area from Vietnam to the Okinawa Islands is an overlap area of the three Groups A, B and C. The historical data suggests the area from the Okinawa Island to Australia possesses the highest ostracod biodiversity and many ostracod species were originated from this area. Since this area can be said the “hot spot” of ostracod biodiversity in the western Pacific and plays an important role for study on the ostracod biodiversity.

Key words: *Loxoconcha*, *Xestoleberis*, species groups, chaetotaxy of maxillula, hingement, maxillulan ontogeny, ostracod origin, the Okinawa Islands

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1. Introduction

The Okinawa Islands are an island group in southern Japan, the West Pacific. The Okinawa Main Island is the largest one of the Okinawa Islands and the fifth largest island in Japan. The island is located in 26°30'N 127°56'E and has an area of about 1,200 km². Also, the island is mostly surrounded by highly diversified coral reefs. Thus, there have been various studies on Recent ostracods from the Okinawa Island, but most of them were conducted within some limited areas. Up to now, a comprehensive study on the Recent ostracod fauna in the Okinawa Islands has not been done yet. Since the 1970s, some studies on Recent ostracod assemblages from brackish waters and coral reefs of Okinawa Islands have been published (Nohara, 1976, 1981a, 1981b; Nohara & Tomoyose, 1977; Nohara & Tsukishima, 1980; Nohara & Yabu, 1983; Tabuki & Nohara, 1988). Nohara & Tsukishima (1980) reported the ostracod distribution and the structure of species composition in coral reefs of Komesu and southeast Sesoko Island. About 50 to 60 species were found on the coral reef of their areas. Tabuki & Nohara (1988) showed the ecology, the species composition and seasonal changes of intertidal and subtidal ostracods living in the moat of a coral reef off Sesoko Island. Regarding to fossil ostracods, Nohara (1981c) reported ostracods of Pleistocene Naha Limestone with 82 species belonging to 35 genera. Nohara & Miyagi (1983) showed 36 species of ostracods from Nakoshi Sand of the northern part of this island. Especially, Nohara (1987) described Neogene marine ostracods in this island and its adjacent areas, to make clear the stratigraphic distribution of Ostracoda, and to present information on the living environment.

Loxoconcha (Loxoconchidae) and *Xestoleberis* (Xestoleberididae) are the most diverse Recent ostracod genera. A total of 575 species and 344 species of the genus *Loxoconcha* and *Xestoleberis*, respectively have been identified around the world (Brandão et al., 2015). 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 common in the water areas around the Okinawa Islands. Among the 75 ostracod genera were classified from the Okinawa Island, the two genera *Loxoconcha* and *Xestoleberis* have the high biodiversity with 22 species and 13 species, respectively. Recently, there are several typical studies on the fauna of the two genera in Japan, the Okinawa Islands and adjacent areas. Tanaka & Ikeya (2002) pointed out the dispersal routes and evolutionary process in the *Loxoconcha japonica* group in East Asia.

They indicated that within the *L. japonica* group, only *L. japonica* was distributed in Japanese Island Arc, but four species (*L. japonica*, *L. shanhaiensis*, *L. lilljeborgii* and *L. tumulosa*) inhabited from the Okinawa Islands southward. Sato & Kamiya (2007) showed the geographical distribution of *Xestoleberis* species from Japan. They suggested that one group of this genus derived by the southern ancestral invasion to the north and there is a clear ancestral-descendant relationship within the group. The above two studies show obvious differences in the faunal structure of the genera *Loxoconcha* and *Xestoleberis* between the Okinawa Islands and Japanese Island Arc.

The ostracods are small bivalved crustaceans. The body of ostracods consists of many functional parts. Among them, pore systems on carapace, hingement, maxillula and mandible are very significant characters for taxonomy, ontogenetic and phylogenetic studies. Pore system is a sensory organ on carapace of ostracods and each valve carries hundreds of pores. Kamiya (1989) pointed out that the differences in the pore structure and morphology, and in the number of pores have a strong relationship with habitats of *Loxoconcha* species, especially pores are distributed more densely in the ventral area of bottom-dwelling species compared with those of the phytal species. Kamiya (1997) also determined the phylogenetic relationship among four families (Leptocytheridae, Cytheridae, Loxoconchidae and Xestoleberidae) from the differentiation of distributional pattern of pore systems. Ishii et al. (2005) divided the *Loxoconcha* species around Japan into the two groups based on the distributional pattern of pore systems below eye tubercle and showed the phylogeny and evolution of these two groups. And they showed that the interspecific differentiation in distributional patterns of pore systems on the carapace begins from the instar A-3 and this reflects the phylogeny of the genus *Loxoconcha*. Sato & Kamiya (2007) classified 13 Recent *Xestoleberis* species from Japan into three groups by the combination of pore types on their carapaces and this grouping is consistent with their estimated phylogeny and reflects phylogeny of this genus. Tsukagoshi & Kamiya (1996) examined the heterochrony of the hingement of the five major cytheracean families and showed the two types of hinge development. They classified hinge development of *Loxoconcha chinzeii* into the “leap type” and of *L. sp.* (*L. kosugii* Nakao & Tsukagoshi, 2002) into the “gradual type”. They also detected the differences in the origin and the geographical distribution between these two types. The maxillula is the fourth head appendage of ostracods. It consists of an endopodite, three endites and exopodite. Smith et al. (2005) examined a total of 168 species in six

superfamilies and indicated that the number of setae on the maxillulan exopodite is shown to have phylogenetic significance at superfamily level, even at family and genus levels. And they suggested that *Loxoconcha* is the youngest of the six examined genera and this genus has the smallest number of setae of maxillulan exopodite.

Actually, the single functional part of ostracod body was used as a useful tool to find out the different knowledge of ostracods in many previous reports. In the present study, the species of the two genera *Loxoconcha* and *Xestoleberis* are inferred in order to elucidate their geographical distribution, migratory route, speciation and evolutionary process in the light of the interspecific variation of the plural characters, i. e., pore systems, hingement, chaetotaxy of maxillula and mandible of 24 *Loxoconcha* species and 22 *Xestoleberis* species. This study must become an important clue to the high biodiversity and the geographical distribution in the western Pacific. This study also can present a model case for invasion, speciation and evolution of the ostracods and then reflect a new perspective and approach on macroevolution across many animal phyla in the western Pacific Ocean. Finally, the understanding of origin of the ostracod fauna in the Okinawa Islands must become an important tool for next studies on paleogeography, paleoceanography as well as paleo marine currents.

2. Materials and Methods

2.1. Materials

2.1.1. Primary materials

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. 1 and Table 1) and in Vietnam (Fig. 2 and Table 1). Two investigations were conducted in the Okinawa Island, one during 9th–13th May 2013 and another in the period from 28th May to 2nd June 2014. Two surveys were done in Vietnam, one at the coast of Ha Long Bay, Quang Ninh province, northern Vietnam in December 2013 and another 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 were 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 our laboratory were used in the present study (Fig. 1 and Table 1).

At the sampling points, the upper layer of sediment 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 of the collected specimens were fixed in 5–10% formaldehyde that had been neutralised 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.

Additionally, in this study, some ready dried specimens of the Philippines and Australia that were already preserved on cardboard slides at our laboratory were used to analyse the species groups of the genera *Loxoconcha* and *Xestoleberis* for these two areas.

2.1.2. Secondary materials

The previous data on genus, species composition, the setae and chaetotaxy of some species living in the Okinawa Islands, Japan, Vietnam, Australia, the Philippines, Malaysia and other faunas were collected from published literatures. Total about 20 published literatures were used as a source of secondary data in the present study.

2.2. Morphological observations

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 for the dissected specimens, soft parts were mounted on a slide glass in the “Neo Sigaral” agent and carapaces were on a cardboard slide with single hole. At the same time, the number of setae on appendages was counted and the chaetotaxy of appendages was also observed. Because the number of setae on the endopodite, endite and exopodite were unobvious in some cases, these setae were excluded for the comparison of the number of setae and chaetotaxy. The dimensions of the valves and hinge elements (e. g., tooth of anterior element, socket and tooth of posterior elements) (Fig. 3) were measured using some computer software such as ImageJ, Adobe Photoshop, and Paint....

Dried carapaces and individuals were coated with gold using a quick auto-coater (JFC-1500, Ion Sputtering Device) and were then observed with a scanning electron microscope (JSM-5600LV, JEOL). Scanning electron microscope photos were subsequently used for identification of carapace size, pore groups, muscle scars and hinge elements. Carapace length was a main index to divide the different instars.

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

2.3. Division of subgroups

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).

2.4. Data analysis

For the comparison of a genus or species composition between Okinawa Island fauna and other faunas, Similarity index (Sorensen index S-1948) was used. The index was calculated using a following equation:

$$S = \frac{2 * C}{A + B} * 100$$

In which: A and B: the total number of genus or species in first and second faunas, respectively.

C: the total number of genus or species which exists at the two faunas.

t-Test (Two-Sample Assuming Unequal Variances) was applied to find out the statistical comparison (different or no different) of the number of setae on the maxillula and of the length of hinge elements of left valve between the species groups or between two life modes.

3. Overview of ostracod fauna in the Okinawa Islands

There are many literatures on Recent ostracod fauna in the Okinawa Island, but most of them only show the species composition of small areas around the Okinawa Island and so far

there is a lack of comprehensive reports. In the present study, data on the genus composition and on the species of the two genera (*Loxoconcha* and *Xestoleberis*), species of the family Bairdiidae in the Okinawa Islands was shown by us, but the data on species composition of other genera was collected from the previous literatures, e. g., Nohara & Tsukishima, 1980; Nohara, 1987; Tabuki & Nohara, 1988; Nohara & Tabuki, 1990. Although Nohara & Tsukishima (1980) and Nohara (1987) pointed out about 50 to 60 species of Recent ostracods on the coral reefs of Komesu and southeast Sesoko Islands, but it is very difficult to refer species composition from their lists. Therefore, their results were omitted in this study. So far, 139 Recent species of ostracods, belonging to 75 genera and 28 families were classified in the Okinawa Island (Table 2). Most of species have not been described yet. Among them, the three genera *Loxoconcha*, *Xestoleberis* and *Paradoxostoma* are most abundant, with 22, 13 and 10 species, respectively; the five families Loxoconchidae, Xestoleberididae, Bairdiidae, Hemicytheridae and Paradoxostomatidae are the most common families, consisting of from 12 to 25 species each one (Table 2). Around the Okinawa Islands, ostracod species often lives in the numerous environments and habitats such as coral reefs, seagrass beds, seaweed beds, mangroves, sea beaches and river mouths....

4. Results

4.1. Similarity in ostracod composition between the Okinawa Island fauna and other faunas

Data on the species compositions of two genera *Loxoconcha* and *Xestoleberis* in the Okinawa Islands (Fig. 4 and Tables 1, 2) and Vietnam (Fig. 5 and Table 1), and the genus composition in the Okinawa Islands were classified by this study in the period from 2012 to 2015. The data on ostracod composition of other areas belonging to Pacific Ocean and Indian Ocean were collected at about 20 published literatures. A total of 22 *Loxoconcha* and 13 *Xestoleberis* species in the Okinawa Island, 20 *Loxoconcha* and 14 *Xestoleberis* species from Vietnam were found. Results of comparison about 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), respectively, are relatively high, ranges 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 as well as in other areas have not been described yet, hence the compared results in this study were not complete. The Sorensen values at species level are zero in 2 compared pairs, including the Okinawa Island with New South Wales, Southeast of Australia, and with Darwin and northwestern of Australia. In contrast, the Sorensen values are relatively high in the three compared pairs, including between the Okinawa Island fauna with Hiuchinada 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%). A comparison of the species composition of the genus *Loxoconcha* between two closely islands, Okinawa and Amami islands (both belonging to Ryukyu Islands), the Sorensen value is very high (over 50%). This fact indicates that the ostracod faunas of two islands are very close each other.

4.2. Interspecific comparison of the genus *Loxoconcha*

4.2.1. Hingement

The hingement of cytheracean ostracods has been regarded as a very significant character for taxonomy, especially at the generic or familial level. Tsukagoshi & Kamiya (1996) showed that the difference of hingement between the adult and the instar A-1 is generally inconspicuous in the *Loxoconcha* species and, in particular, there are few differences in the anterior and median elements. *L. chinzeii* is one of the species in which the hinge structure changes abruptly in the last moult (Tsukagoshi & Kamiya, 1996). Overall, the hingement of most *Loxoconcha* species does not change significantly throughout their ontogeny.

In the present study, hingement of the species of the genus *Loxoconcha* overall belongs to gongylodont which is characterized by bilobate terminal elements: an anterior tooth locates between two sockets and a posterior socket between two teeth in the right valve (Okubo, 1980; Athersuch & Horne, 1984; Athersuch et al., 1989). However, some variations in hinge structure were found. First, the tooth of posterior element of the left valve of *L. sp. 26* seems to be degenerated. Almost no tooth was observed in the posterior hinge element of the left valve in both male and female of this species (Fig. 6.25, 26). Second, the posterior tooth of hingement of the left valve of *L. pulchra* was divided into two separated teeth (Fig. 6.15).

A dimension of some elements of hingement of the left valves of 24 species of *Loxoconcha* was measured herein, in which, 21 species were collected in Japan (including the Okinawa Island) and three species in Vietnam (Fig. 6 and Table 4). The length of anterior

tooth of hingement of the left valve ranges from 11.3 to 25.8 μm , the length of posterior socket from 15.2 to 34.4 μm and of posterior tooth between 9.3 and 26.2 μm . A comparison among three groups showed that the length of posterior tooth of hingement is largest in the Group A, median in the Group B and smallest in the Group C, e. g., these numbers of the Group A from 17.9 to 26.2 μm , the Group B between 9.4 and 16.7 μm and the Group C between 9.3 and 13.7 μm . Statistical analysis (t test) indicated the length of posterior tooth of the left valve of the Group A (average of 22.6 μm) is much larger than that of the Group B (average of 13.1 μm) and the Group C (average of 11.5 μm), but there is no significant difference in this character between the Groups B and C (Table 5). The reduction tendency from the Group A to the Group C also is presented in the length of anterior tooth of hingement in the left carapace, but this tendency is not consistent. There is no clear difference in the length of posterior socket of hingement of the left valve among three pore groups (Table 5).

A comparison of the length of hinge elements of the left valve of phytal species and bottom dwelling species revealed no obvious differences between these species (Table 4). However, the significant different in the length of posterior tooth and of teeth of median element in left valve was found between *Loxoconcha japonica* species group (including *L. japonica*, *L. shanghaiensis*, *L. lilljeborgii*, *L. tumulosa* and *L. sp. 8*) and *L. uranouchiensis* species group (*L. uranouchiensis*, *L. noharai*, *L. santosi* and *L. sp. Y*). The length of posterior tooth of hingement of the former group ranges from 18.3–25.9 μm (average 22.3 μm) and is much larger than that of the later, ranges from 9.4–13.4 μm (average 11.3 μm) (Table 5). However, there are no differences in the length of socket of posterior element and tooth of anterior element of hingement. Observed under the microscope, the carapaces of species of *L. japonica* group seem to be thicker and heavier than that of *L. uranouchiensis* group (Kamiya, 1988), therefore the elements of hingement of the former are probably stronger and larger to connect conveniently two carapaces together during their life. Additionally, the shape of carapace in lateral view of *L. japonica* species group is a circle, whereas that of *L. uranouchiensis* species group is a rectangle or elongate rectangle (Kamiya, 1988). These observations indicate that the dorsal margin in the lateral view of *L. japonica* species group is a convex line, but of *L. uranouchiensis* species group is an almost straight line. Therefore, the former species group needs more power to open and close two valves than the later species

group does. This means that the hingement of *L. japonica* group is stronger, the teeth of median element and the tooth of posterior element of hingement of this group are larger.

Among the *Loxoconcha* species, there is no relationship between the length of tooth of hingement and the length of the carapace. For example, the tooth of posterior element of hingement of *L. sp. 8* (22.0 μm) is relatively equal with that of *L. tosaensis* (22.7 μm), but the length of the left carapace of the later (646 μm) is much larger than that of the former (514 μm) (Table 4).

The above discoveries suggest that the dimension of posterior tooth of hingement of the left valve on the species of the genus *Loxoconcha* is dependent on the pore groups (Groups A, B and C) and species groups, i. e., *L. japonica* and *L. uranouchiensis* species groups, but that is independent on the dimension of carapace.

The present study also showed the large variation in the number of tooth of median element of hingement of valve within each species of the genus *Loxoconcha*. This number is also not consistent with the three pore groups. For examples, these numbers are 39–49 in *L. japonica* (Group A), 47–58 in *L. santosai* (Group B) and 37–49 in *L. sesokoensis* (Group C) (Table 6).

4.2.2. Muscle scars

Carapaces of ostracods are closed by adductor muscles running through the central part of the body and attached to the inner surface of the calcified outer lamellae. The adductor muscle scar pattern is another important taxonomic character, particularly useful at superfamily level. As well as a pattern of adductor muscle 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 fulcrum point on the inside of the valve (Horne et al., 2002).

Muscle scars of a total of 23 species of the genus *Loxoconcha* were observed in this study (Fig. 7 and Table 7). Most of species of this genus consist of four adductor scars to arrange 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 top one was divided into two (Fig. 7.13). This character may be a mutation phenomenon that was already mentioned by several authors (e. g., Higashi & Tsukagoshi, 2012). It also can be regarded as apomorphy in *Loxoconcha*.

The four adductor muscle scars are normally unequal 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.* sp. 12 (Fig. 7.2, 4, 6–8, 10–12).

Most of species of the genus *Loxoconcha* have the frontal scar with C-shape, opening anteriorly. However, in the present study, the frontal scar with bean-shape or oval-shape was discovered in the species of *L. japonica* group. This group includes five species *L. shanghaiensis*, *L. japonica*, *L.* sp. 9, *L.* sp. 10 and *L.* sp. 8 that belong to phytal species and the Group A (Fig. 7.1, 3–5, 11 and Table 7). The novel shapes of frontal scar of the *L. japonica* species group are probably derived from an ancestral shape, i.e., C-shape of the genus *Loxoconcha*. Additionally, there was a variation about the shape of frontal scar in *L. kosugii* (Figs. 7.14, 8 and Table 7). Most of individuals of *L. kosugii* bear the frontal scar with C-shape (Fig. 8.1–3), but the frontal scar with Y-shape was found in several individuals of this species (Fig. 8.4). The frontal scar with Y-shape is a typical character of the genus *Palmoconcha* whose phylogeny is close to the genus *Loxoconcha*. The mandibular scar of the *Loxoconcha* species generally includes two scars with a lengthened circle shape or sub-circle shape. The dimension of two mandibular scars is somewhat equal or unequal each other.

4.2.3. Ontogeny of maxillula

The maxillula (referred as maxilla or first maxilla by some authors) is the fourth head appendage of ostracods. It lies immediately behind the mandible and has two main functions, feeding and, in some groups, respiration (Athersuch et al., 1989; Horne et al., 2002). In podocopan ostracods, the maxillula consists of a protopodite, bearing antero-medially an endopodite (commonly referred to as a palp; often segmented) and three endites (sometimes referred to as masticatory processes), all of which terminate in several short setae. The endites and endopodite assist the mandibles in moving food towards the mouth and removing waste particles from the mouth region. The maxillula also consists of an extremely well-developed exopodite with posteriorly radiating long, setulous, or feathery setae and several reflexed setae pointing forwards. The branchial plate beats continuously, circulating water within the body cavity and presumably assisting with respiration.

The maxillula of *Loxoconcha noharai* and *L. sesokoensis* is first born in instar A-7 as an anlage state and then goes through three stages (instars A-7, A-6 and A-5) before it reaches

the adult form (Fig. 11 and Table 13). First, in instar A-7, a small anlage of the maxillulan forms with simple body plan whose component parts (endopodite, exopodite, endites...) is not developed. The maxillula in this instar consists of elongated protrusion from body. Second, in instar A-6, the maxillula is undeveloped much. The second and third endites in this instar are formed and terminated with two thick, curved setae, meanwhile the first endite and the endopodite are still in a basic form. The exopodite consists of 6 setae. Third, in instar A-5, the first endite and the endopodite strongly develop to produce a form similar to that of the adult. Each endite carries several thick, curved setae. In instar A-5, the exopodite on the maxillula of *L. noharai* and *L. sesokoensis* bears 9 setae. From instar A-4 to adult, the number of setae of different parts on the maxillula gradually increases. The maximum setae of the endopodite gains in instar A-3, of three endites in instar A-2 and of the outer first podomere of the endopodite in instar A-1 in two species. However, the number of setae of the exopodite reaches to the maximum in instar A-1 in *L. noharai* and at the adult stage in *L. sesokoensis*.

Description of the maxillula of *Loxoconcha noharai* (Figs. 9–11 and Table 8)

Second instar (A-7) (Figs. 10.11 and 11.1):

Carapace length 105–122 μm , height 68–72 μm . Component parts (endopodite, endites, exopodite etc.) not developed in anlage state. Anlage consisting of simple elongated protrusion from body.

Third instar (A-6) (Figs. 10.2 and 11.2):

Carapace length 135–142 μm , height 93–96 μm . Consisting of endopodite, three elongate endites and exopodite. Endopodite undeveloped much, lengthening but bearing no setae. First dorsal endite terminating with well developed, 1 strongly curved claw. Second middle and third ventral endites each terminating with 2 thick, curved setae. Third ventral endite also bearing 1 additional curved seta (most ventral seta) protruding from inner edge. Exopodite consisting of 6 setae.

Fourth instar (A-5) (Figs. 10.3 and 11.3):

Carapace length 171–174 μm , height 102–106 μm . Endopodite developed with 1 seta protruding from inner edge of elongate podomere and 1 seta protruding from outer edge approximately at mid-length of this podomere. Endopodite terminating with 2 stout, curved setae. First endite adding with 2 stout, curved setae, bringing total to 3. Second and third endites remain unchanged, exception for most ventral seta protruding from inner edge of third

endite, which now stouter than in instar A-6. Exopodite with 3 additional, long setae, bringing total to 9, arranging around posterior edge.

Fifth instar (A-4) (Figs. 10.4 and 11.4):

Carapace length 196–206 μm , height 118–124 μm . Endopodite similar to instar A-5, with exception of 1 additional, long seta on outer edge, bringing total to 2 long setae from outer edge of first podomere. First and second endites remain unchanged. Third endite carrying 1 additional, stout seta, now it terminating with 3 stout, curved setae. Most ventral seta of third endite now stouter, bearing several long setuleae and lengthening to make club-like process. Exopodite bearing 2 additional, long setae, now it consisting of 11 long setae, arranging along posterior edge.

Sixth instar (A-3) (Figs. 10.5 and 11.5):

Carapace length 231–254 μm , height 139–154 μm . Endopodite now terminating with 1 additional stout, curved seta, producing group of 3. Setae on dorsal edge of endopodite now annulated, bearing setules. First and third endites similar to instar A-4, each terminating with 3 setae. Second endite now adding 1 stout, curved seta, producing total to 3. Exopodite with 2 additional long setae, producing total to 13 long setae, arranging along posterior edge.

Seventh instar (A-2) (Figs. 10.6 and 11.6):

Carapace length 296–320 μm , height 178–189 μm . Endopodite similar to instar A-3, with exception of 1 additional, long seta on outer edge of long first podomere, bringing total to 3. First endite bearing 3 additional, stout, curved setae distally, bringing total to 6. Second endite now terminating with 6 stout, curved setae with addition 3 stout, curved setae in this instar. Third endite carrying 1 additional seta, producing total of 4 stout, curved setae distally. Exopodite with 2 additional long setae in this instar, bringing total to 15, arranging around posterior edge.

Eighth instar (A-1) (Figs. 10.7, 8 and 11.7):

Carapace length of males 400–410 μm , length of females 372–394 μm , height of males 232–240 μm , height of females 225–235 μm . Endopodite with 1 additional setulous seta on outer corner of first podomere, bringing total to 4, which now annulated. Chaetotaxy of three endites unchanged. Ventral most seta of third endite now stouter than in instar A-2 and

bearing long setuleae arranged in a cluster. Exopodite adding 1 long seta on poster edge, producing total of 16, arranging around posterior edge.

Ninth instar (Adult) (Figs. 10.9, 10 and 11.8):

Carapace length of males 502–529 μm , length of females 436–483 μm , height of males 271–290 μm , height of females 271–294 μm . Chaetotaxy of maxillula similar to that of instar A-1. Maxillula strongly developed here.

4.2.4. Maxillula and mandible of adult stage

A total of 19 species of the genus *Loxoconcha*, in which 13 species living in the coast of Japan (including the Okinawa Islands), two species inhabiting in the European and Mediterranean coasts, one species from Australian coast and three species from Vietnam were represented in this study. The data of eight species were referred from the previous literatures and of 11 species are new. The number of setae of some structural parts on the maxillula and mandible were summarized in Table 9 and Fig. 12. The *Loxoconcha* species shows the variation in the number of setae of some parts on the maxillula and mandible within this genus. In maxillula, the total number of setae of three endites ranges from 10 to 18, of the outer first podomere of the endopodite from 3 to 5 and of exopodite between 15 and 17.

According to Okubo (1980), three endites on the maxillula of the *Loxoconcha* species consist of 6 stout setae each, but the present study indicated the variation in number of setae of each endite among the *Loxoconcha* species. The number of setae of the first endite is from 3 to 7, while the number is between 4 and 7 in the second, and between 3 and 6 in the third endite. Also, Okubo (1980) reported the numbers of setae of the outer first podomere of the endopodite and of the exopodite on the maxillula are constant, equivalent to 4 and 16, respectively.

Based on the distributional pattern of the pore systems below eye tubercle (Ishii, 2014; Ishii et al., 2005), 17 recent *Loxoconcha* species were divided into three phylogenetic groups. The Groups A and B defined by Ishii (2004) and Ishii et al. (2005), whereas the Group C defined by Le & Tsukagoshi (2014).

The total number of setae of three endites on the maxillula is low in the Group A (ranges from 10 to 14 with average of 12.6 setae), median in the Group B (from 16 to 17 with average of 16.5 setae) and high in the Group C (between 16 and 18 with average of 16.8 setae) (Fig. 13 and Table 9). Statistical analysis (t test) showed the significant difference in

the number of setae of three endites between the Groups A and B, and between the Groups A and C, but no significant difference between the Groups B and C. This analysis also indicated the similar numbers of setae of the outer first podomere of the endopodite and of exopodite on the maxillula among three groups (Fig. 13 and Tables 9, 10). With exception of the two bottom species (*Loxoconcha elliptica* and *L. harimensis*), the total number of setae of three endites on the maxillula of bottom-dwelling species (average of 16.5 setae) is significant higher than that of phytal species (average of 12.4 setae) (Fig. 14 and Tables 9, 10). The number of setae of the outer first podomere of the maxillulan endopodite, maxillulan exopodite and the third podomere of the endopodite on the mandible is independent with three groups and with life modes.

4.3. Interspecific comparison of the genus *Xestoleberis*

The maxillula and the mandible of a total of 22 *Xestoleberis* species were observed in the present study (Figs. 15, 16 and Table 11). Among them, 19 species inhabited in Japan coast (including the Okinawa Islands) and three species (*X. sp. 7*, *X. sp. 8* and *X. sp. 20*) from Vietnam. Data on the chaetotaxy of the maxillula and the mandible of 12 species were referred from the previous studies and partly added, and of ten species were showed herein for the first time. The checked results of soft appendences 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 11).

Based on the combination of the morphological types of pore systems (Sato & Kamiya, 2007), the 22 species of *Xestoleberis* were divided into three groups. The Group A has both sieve-type and lip-type pores and comprises 15 species. The Group B has only sieve-type pore, and consists of two species. The Group C has simple-type and sieve-type pores and includes four species (Table 11). The pore types of the genus *Xestoleberis* were referred from Puri (1974). 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 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 11).

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

The groups of the genus *Loxoconcha* living around the Okinawa Islands include the Groups A, B and C, meanwhile those around Japanese Island Arc fauna are the Groups A and B. For the case of the genus *Xestoleberis*, the species of the older taxonomic groups (Groups A and B) are abundantly found in the Okinawa Islands, whereas most of species around Japanese Island Arc belong to the derived taxonomic Group C and few species classify into the Group A. Along the coast of Vietnam, the species of the genus *Loxoconcha* belong to the Groups A, B and C; of genus *Xestoleberis* to the 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) (Table 12). Overall, geographical distribution of the pore groups of the species of two genera *Loxoconcha* and *Xestoleberis* in the Okinawa Island is close to southern faunas (Vietnam, the Philippines and Australia) rather than Japanese Island Arc faunas.

5. Discussions

5.1. Comparison of maxillulan chaetotaxy throughout the ontogeny among three species of the genus *Loxoconcha* and of *Loxoconcha* species with other podocopan taxa

*5.1.1. Comparison of maxillulan ontogeny among three species of the genus *Loxoconcha**

In the three species *Loxoconcha noharai*, *L. sesokoensis* and *L. japonica* whose ontogeny was described by Smith & Kamiya (2003), the maxillula first appears in the instar A-7 in an anlage state, with a simple structure. The general development of these three species and the number of setae of the maxillula from A-7 to A-5 are completely identical between three species. From A-4 to adult stages, the numbers of setae on some parts (endopodite, three endites, exopodite and the outer first podomere of the endopodite) of the maxillula are slightly different among three species (Figs. 17 and 18). However, there are some similar developmental trends in the three species in this period (Tables 13 and 14). Specifically, the number of setae on the endopodite peaks in the instar A-3 in the three species, whereas the number of setae of outter first podomere of the endopodite peaks in the instar A-1.

Additionally, in the three species, the chaetotaxy of three endites remains unchanged from the instar A-2 to the adult stage. Only one seta on the inner first podomere of the endopodite on the maxillula is observed in the three species throughout the ontogeny stages, and this seta first forms in the instar A-5 (Fig. 11.3). According to Ishii et al. (2005), the same number of pore systems is found on the carapaces of all species of the genus *Loxoconcha* from the instar A-8 to A-4, and differences in the number of pores among these species appear from the instar A-3 onwards. However, in the present study, differences in the number of setae on the maxillula were first observed in the instar A-4 (Fig. 17 and Table 13). These observations indicate that species-specific features of the genus *Loxoconcha* are established earlier on the maxillula than in the pores on carapace. These divisions of the chaetotaxy of the maxillula beginning in the instar A-4 may be useful for phylogenetic estimation of the genus *Loxoconcha*.

5.1.2. Comparison of maxillulan ontogeny of the genus *Loxoconcha* and other podocopid taxa

Within the order Podocopida, the general development of the maxillula of *Loxoconcha noharai*, *L. sesokoensis* and *L. japonica* (Cytheroidea) is similar to that of *Eucypris virens* (Cypridoidea), *Nenesidea oligodentata* (Bairdioidea). The maxillula appears in the instar A-7 as an anlage stage and then goes through three stages (A-7, A-6 and A-5) before it reaches the adult form (Smith & Martens, 2000; Smith & Kamiya, 2002) (Fig. 11.1–3 and Table 13). First, in the instar A-7, a small anlage of the maxillula is formed (Fig. 11.1). Second, in the instar A-6, the second and third endites are formed, while the first endite and the endopodite are still in an undeveloped basic form (Fig. 11.2). Third, in the instar A-5, the first endite and the endopodite strongly develop into a form that is similar to that of the adult (Fig. 11.3). However, some slight differences during maxillulan ontogeny are observed among the three taxa. The number of setae of most parts on the maxillula of *L. noharai*, *L. sesokoensis* and *L. japonica* reaches to the maximum at pre-adult stages, e. g., the number of setae of three endites gets the maximum in the instar A-2 (Fig. 11.6 and Table 13), while that of the endopodite in the instar A-3 (Fig. 11.5 and Table 13). In contrast, in the two other taxa, the number of setae of some parts on the maxillula increases continuously throughout ontogeny and only peaks at the adult stage; e. g., the first endite, exopodite and the outer first podomere of the endopodite in *E. virens*, and the second endite, third endite and exopodite in *N. oligodentata* (Table 13). From the instar A-4 to the adult stage, the total number of setae on the maxillula of *E. virens* and *N. oligodentata* is much greater than of *Loxoconcha* species.

For example, at the adult stage, the total number of setae on the maxillula of *L. noharai* and *L. sesokoensis* is 40, of *L. japonica* is 37, while the number is 71 in *E. virens* and 57 in *N. oligodentata* (Fig. 19 and Table 13).

In the superfamily Cytheroidea, although the ontogeny of the Entocytheridae shown in some previous reports is often fragmentary (e. g., Paris, 1920; Rioja, 1940; Roelofs, 1968; Hart et al., 1985), it differs from that of *Loxoconcha noharai*, *L. sesokoensis* and *L. japonica*. Smith & Kamiya (2005) reviewed the ontogeny of entocytherid species and indicated that many of these accounts are probably inaccurate. However, the maxillula is formed in the instar A-7 in *L. noharai*, *L. sesokoensis* and *L. japonica* (Loxoconchidae) and *Limnocythere inopinata* (Limnocytheridae) (by Scheerer-Ostermeyer, 1940), but at a later stage (instar A-6) in *Uncinocythere occidentalis* (Entocytheridae) (Tables 13 and 14). Additionally, Smith & Kamiya (2005) showed that the entocytherid ostracod *U. occidentalis* exhibits clearly different development of the maxillula compared with of other cytheroidean species, with “post-displacement” development occurring in the exopodite and the first endite. In *U. occidentalis*, the exopodite appears in the instar A-5 as an anlage, and the first endite first forms in the instar A-3 with only 1 terminal seta. The maxillula of many other cytheroidean species (e. g., *L. noharai*, *L. sesokoensis*, *L. japonica*, *Xestoleberis* species, *Pontocythere xiphoidea*, *Semicytherura wakamurasaki* and *Anguilicytheruta? miii*) consists of three endites, but that of *U. occidentalis* carries only one endite (the first endite) (Figs. 11, 12, 15 and Table 13) (Nakao & Tsukagoshi, 2002; Sato & Kamiya, 2007).

A comparison of the ontogeny of the maxillula of *Loxoconcha noharai*, *L. sesokoensis* and *L. japonica* (Podocopida) with *Keijcyoidea infralittoralis* (Platycopida) revealed large differences between these species. The maxillula first appears in the instar A-7 in an anlage state in *Loxoconcha* species, but in the instar A-8 in an intermediate form between an anlage and a functional condition in *K. infralittoralis* (Table 13). This intermediate form of *K. infralittoralis* was described by Okada et al. (2008) as follows: “Maxillula consists of lobe with numerous setulae along the posterior margin and one very long, curved, smooth seta with widened, proximal portion protruding from the middle of the posterior margin”. The aforementioned characters most likely represent the difference in maxillulan ontogeny between the orders Platycopida and Podocopida; i. e., the maxillula is born in the instar A-8 in the former taxon, but in the instar A-7 in the latter taxon with the exception of *U. occidentalis*.

Because, *K. infralittoralis* uses the maxillula for walking on plane surfaces in the earliest instar (A-8), its maxillula must be adapted to the sediment surface, rather than to the spaces between sand grains, as in adults. Therefore, the maxillula in *K. infralittoralis* in the early instars (A-8 and A-7) is somewhat developed, with a very long and robust seta (Tsukagoshi et al., 2006; Okada et al., 2008). One additional difference in the ontogenetic development of the maxillula was found between the two taxa: the number of setae on most parts of the maxillula of *L. noharai*, *L. sesokoensis* and *L. japonica* peaks at pre-adult stages (Fig. 11 and Table 13), whereas in *K. infralittoralis*, the number of setae on some parts of the maxillula continuously increases throughout all ontogenetic stages and only peaks at the adult stage (e. g., the endopodite and exopodite) (Table 13).

5.2. Phylogeny according to the subgroups of *Loxoconcha* and *Xetoleberis* species

Although many *Loxoconcha* species were described from the Paleogene and Late Cretaceous (e. g., Alexander, 1934; Howe & Chambers, 1935; Hazel et al., 1980; Bassiouni & Elewa, 1999), but most of them seem to be not *Loxoconcha* but *Palmoconcha* and *Sagmatocythere*, on the basis of their external carapace morphology (Ishii, 2004, unpublished doctoral thesis, Kanazawa University). So far, the oldest *Loxoconcha* species have been found in Indo-West Pacific Region in the Oligocene (possibly the Late Eocene) (Ahmad et al., 1991; McKenzie et al., 1991, 1993; Ayress, 1995). This species has typical carapace shape of phytal species and belongs to the Group A. The oldest fossil record of the Group B in the world is species *L. pulchra* that was found from the Miocene in Japan (Yamada et al., 2001; Ishii et al., 2005). These facts suggest that in the world, the Group A has appeared before the Group B and the Group A is an original group of *Loxoconcha* s. s (Ishii, 2004). Around Japan, the oldest fossil record of the Group A is species *L. nozokiensis* that was collected from the Early Miocene Akeyo Formation, Mizunami Group and Toyama Formation, Iwamura Group, Central Japan (ca. 18 Ma) (Irizuki et al., 2004; Ishii, 2004). Therefore, in Japan, the Group B seems as old as the Group A according to the fossil records.

The data in the Table 4 indicates that the average length of posterior tooth of hingement of left valve in species of the Group A (22.6 μm) is larger than that of the Group B (13.1 μm) and the Group C (11.5 μm) (Fig. 20). The data in the Table 9 shows that the total number of setae of three endites on the maxilla of the Group A (average 12.6 setae) is smaller than that of the Group B (average 16.5 setae) and the Group C (16.8 setae) (Fig. 13). These characters

indicate a possible trend that an evolutionary process may be a cause of change in the size of hinge element and the number of maxillulan setae of *Loxoconcha* species (Higashi & Tsukagoshi, 2012), the younger evolutionary origin of the species is the more setae of three endites of its maxillula and smaller dimension of posterior tooth of its valve get, on the other hand the older evolutionary origin of the species is the fewer setae of three endites of its maxillula and bigger length of posterior tooth of its valve have. Although there is a lack of fossil records of the Group C, but based on the possible relationships between evolutionary trend and the number of setae on the three endites on the maxillula, between evolutionary trend and the dimension of posterior tooth of hingement of left valve can suggest a possibility that the species of the Group C might have appeared after the species of the Group B and the Group A because its dimension of posterior tooth of hingement of left valve is smaller and its total number of three endites on the maxillula is higher than that of Groups A and B. It means that among three groups of the genus *Loxoconcha*, the Group C is youngest. Therefore, a further work on evolutionary origin of the Group C is needed to exploit its full potential.

Generally, among the species of *Loxoconcha*, the size of posterior tooth of hingement of left valve and the number of setae of three endites are changeable but the size of other hinge elements and the number of setae of outer first podomere of endopodite and of exopodite on the maxillula are nearly stable. Reasons to explain these facts probably include a genetic structure and a function of them. The genetic structure of posterior tooth of hingement of the left valve and three endites of the maxillula seem to change easier than their other parts. For the case of the maxillula, this opinion may be supported by the observation of maxillulan ontogeny of three species *L. noharai*, *L. sesokoensis* and *L. japonica* (Table 13). Within the three species of the genus *Loxoconcha*, the difference in the number of setae of three endites appears in the earlier instar than that of other parts on the maxillula, i. e., the number of setae of three endites starts to differentiate in the instar A-4, of the outer first podomere of the endopodite in the instar A-2, of exopodite in the instar A-3 (Table 13). Also the main functions of three endites are collecting food and transporting them forwards the mouth. Thus the number of setae of three endites should be quickly adjusted in order to adapt to the different micro environments. However, the relationship between the size of different parts of hingement and their functions cannot be explained in this study yet.

In the genus *Xestoleberis*, the number of setae of outer first podomere of maxillulan endopodite is low in the Group C (average of 2) and high in the Group A (average of 4) and

the Group B (average of 4). The number of setae of third podomere of mandible is low in the Group C (average of 2), median in the Group A (average of 4) and high in the Group B (average of 6) (Table 11). The oldest records of *Xestoleberis* so far of Japan are *X. spp.* from the early Miocene Akeyo Formation (Irizuki et al., 2004). Examination of the carapace shape and the morphology of pores of *X. spp.* revealed that the species belongs to the Group A (Sato & Kamiya, 2007). 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). Up to now, no fossil record of the Group C have been found yet. The above fossil records and the tendencies of change in the number of setae on the maxillula and mandible suggest that geologic age of the Group A and B is older than that of the Group C and the Group A or B is an ancestor of the genus *Xestoleberis*, and the Group C is a derived group according to fossil records. 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.

There have been so far some already known literatures on phylogenetic relationships and evolutionary trends of ostracod setae at different taxonomical levels. The number of setae of appendages in adults may reflect their evolutionary origin. At superfamily level, the Bairdioidea, Darwinuloidea and Cytherelloidea have the larger number of setae on maxillulan exopodite than the superfamily Cytheroidea. These three superfamilies are older than Cytheroidea, they are also often considered the most plesiomorphic because of their long fossil records (Palaeozoic-Recent) showing relatively little change in carapace morphology (Smith et al., 2005). At the family level, within the superfamily Cytheroidea, the Bythocytheridae are the most ancient family (Ordovician-Recent) and have the largest number of setae on maxillulan exopodite than other families (Smith et al., 2005). The comparatively low numbers of setae in some cytheroidean families may present apomorphies of their groups. Among the genera *Uncinocythere*, *Neonesidea*, *Eucypris*, *Heterocypris*, *Keijcyoidea* and

Loxoconcha, the *Loxoconcha* is the youngest genus (Neogene-Recent; Athersuch & Horne, 1984), this genus has been slowing down in the rate of exopodite development in ontogeny and fewer number of setae of exopodite on the maxillula in comparison with more ancient genera (Smith et al., 2005). At the species level, Higashi & Tsukagoshi (2012) indicated the reduction of antennal distal claw in the derived groups of the genus *Paravocythere*. They also showed the heterochronic changes of antennula and the forming of the asymmetric male copulatory organ occurred as an evolutionary tendency within the genus *Paravocythere* (Higashi & Tsukagoshi, 2012).

5.3. Phylogeny according to life modes of *Loxoconcha* species

17 species of the genus *Loxoconcha* were subdivided into two groups based on the life modes, of which four phytal species and 13 bottom-dwelling species (Table 9). Overall, the number of three endites' setae on the maxillula of bottom-dwelling species is higher than that of phytal species (with except for two bottom-dwelling species *L. elliptica* and *L. harimensis*) (Table 9). The average number of setae of two life modes are 16.5 setae and 12.4 setae, respectively (Fig. 14). This result may suggest that there is a variation in the number of setae on the three endites of the maxillula following the microhabitat, the number of setae on three endites seems to be dependent on microhabitats. Ostracoda display a variety of feeding habits. They include a filter-feeder, scavenger, detritivore, herbivore and predaceous carnivore (Athersuch et al., 1989). Up to now, there have been no full report on food of the ostracods in general and of the *Loxoconcha* in particular yet, but whose foods are probably diatoms, bacteria, detritus and sediment. The main functions of the maxillula, in particular of three endites are collecting food and transporting them forwards the mouth. The bottom-dwelling species normally live and crawl on the surface of rough bottoms where have many barricades such as rocks, dead coral, rubble...therefore they need more setae to catch food easily and then transport food particles to the filter-screens and combs on the mandible and the maxillula. For the case of two bottom-dwelling species, *L. elliptica* and *L. harimensis*, an influence of microhabitat to the number of setae of three endites on the maxillula seem be not as strong as an influence of phylogeny to that.

Contrary to three endites, the species living in the two microhabitats often have similar numbers of setae of the outer first podomere of the endopodite and exopodite on the maxillula.

For an example, six bottom-dwelling species including four brackish water *Loxoconcha pulchra*, *L. noharai*, *L. santosi*, *L. uranouchiensis* and two marine water *L. sp. Y* and *L. sesokoensis* have the same number of setae of the outer first podomere of the endopodite and exopodite on the maxillula as one phytal, marine species *L. shanhaiensis* (climbing on seagrass), these data are corresponding to 4 and 16 (Table 9). These two characters thus seem to be independent on microhabitat and environmental factors (Smith et al., 2005).

Species living in the different microhabitats have the different number of setae of three endites, but similar numbers of setae of the outer first podomere of the endopodite and exopodite. These facts may point out the possible trend that within the different parts of the maxillula, three endites probably play the more important function in feeding than other parts. Also, genetic structure of three endites may be not as stable as other parts of the maxillula.

The larger the instar the more setae on the exopodite, three endites, outer first podomere of endopodite and endopodite (Smith et al., 2005; Smith & Kamiya, 2003; Le & Tsukagoshi, in submission). It means that within each species, there is a strong relationship between size (i. e., instar stages) and the number of setae of some parts on the maxillula, however this trend is not reflected between the different species. The carapace length of the adult species in this study widely ranges from 465 μm to 694 μm , but there is no obvious correction between the size of adults and the number of their setae. For instance, *Loxoconcha mutsuensis* is approximately 694 μm long and has 10, 5 and 16 setae on three endites, the outer first podomere of the endopodite and exopodite on the maxillula, respectively; whereas *L. sp. Y* is much shorter (465 μm long), also has 17, 4 and 16 setae, respectively (Table 9).

5.4. Evolutionary relationship among three species groups of the genus *Loxoconcha*

Based on the distributional pattern of pore systems below eye tubercle, the species of the genus *Loxoconcha* around Japan, so far, were divided into the two groups (A and B) by Ishii et al. (2005), further, Le & Tsukagoshi (2014) showed the third group C. Regarding the chaetotaxy of the maxillula, 17 species of the genus *Loxoconcha* were examined in this study, in which, the Group A includes 7 species, the Group B (6 species) and the Group C (4 species) (Table 9). Our results showed that the total number of setae of three endites on the maxillula of the species of the Group B (average of 16.5 setae) and of the Group C (average of 16.8 setae) are much larger than that of the Group A (average of 12.6 setae), and the

difference in this character is very small between the Group B and the Group C. On the other hand, there are no statistical differences in the number of setae of exopodite and of the first podomere of the endopodite on the maxillula among the three species groups (Fig. 13 and Tables 9, 10).

Showing sexual dimorphism on the anterior hingement with paedomorphosis, one *Loxoconcha* phylogenetic group which belongs to the Group A and is distinguished from the other species group by the ontogenetic distributional pattern of pores and two ridges on the anterior part of valve is recognized, e. g., *L. mutsuensis* and *L. kamiyai* (Ozawa & Ishii, 2008; Ozawa, 2013). Following them, the morphology of tooth of anterior element of hingement is different between male and female, and dimensions of tooth of anterior element of female are larger than those of male. In the present study, for the homogeneity of data, only left valves in the 24 species were examined, among them, the three species including *L. sp. 1* (male), *L. sp. 7* and *L. mutsuensis* (male) belong to the above mentioned phylogenetic group (Fig. 4 and Table 4). The length of the tooth of posterior element on hingement of left valve of the Group A (average of 22.6 μm) is much larger than that of the Group B (average of 13.1 μm) and the Group C (average of 11.5 μm), and, the difference between the Groups B and C is not significant (Fig. 20 and Tables 4, 5).

The pore pattern below eye tubercle of *Loxoconcha* sp. Y is unique, as few specimens show an intermediate form between the Groups B and C (i. e., belonging to neither Group C nor Group B) (Le & Tsukagoshi, in press). Indeed intra-specific variation of the pore pattern is observed in multiple individuals in this new species (Fig. 21). The pore pattern of a total of 13 valves was examined here. Nine of the valves belong to the Group C (Fig. 21.1, 4) and only two valves to the Group B (Fig. 21.2, 5) and two valves to an intermediate form (Fig. 21.3, 6). Of course, all of the specimens were classified based on the male copulatory organ or other species-specific characters. They mean that the pattern of Group C is probably major in this new species, and Group C is may be varied due to its genetic unstableness in the water environment around the Okinawa Islands. These above discoveries also strongly suggest that the Groups B and C are closely related to each other and shows the intermediate feature of the pore distribution below eye tubercle between them. These two groups must be descendants of the Group A (as ancestor) according to fossil record.

Ishii (2004) and Ishii et al. (2005) indicated that species of the Group B were restricted within the coasts around Japan from Miocene to present. The species of the Group B also

mainly inhabited brackish water environments. However, these opinions are probably inaccurate. In the present study, the three species belonging to the Group B were recognized in normal marine water. They include *Loxoconcha* sp.11 (Fig. 5.1) at Ha Long Bay, Quang Ninh province, northern Vietnam; *L.* sp. 26 (Fig. 5.13) at Hon Mun Island, Nha Trang Bay MPA, central Vietnam; *L. kosugii* (Fig. 4.7) at Sesoko Island, the Okinawa Islands, southern Japan. In addition, Tanaka et al. (2009) showed the two species of the Group B, *L. uranouchiensis* and *L. ocellata* (Fig. 5.7) distributed in marine water environment along the northern coastline in the Gulf of Tonkin, northern Vietnam. *L. uranouchiensis* also is found within coral reefs of the Sekisei-sho area, Ryukyu Islands, Japan (Tabuki & Nohara, 1990; Tabuki et al., 1993) and in China (Hartmann, 1988). *L. ocellata* is also found in bottom sediment of the East China Sea (Wang & Zhao, 1985). Obviously, the species of the Group B can live in marine and brackish water environments, and this group also is distributed in other adjacent areas outside Japan.

In the genus *Loxoconcha*, the number of setae of three endites on the maxillula increases from the oldest group (the Group A) to the youngest group (the Group C) (Fig. 13), on the other hand, the size of the posterior tooth on hingement of left valve decreases from the Group A to the Group C (Fig. 20). The Group A is obviously distinguished from Groups B and C on the evidences of the chaetotaxy of the maxillula and dimension of hinge element. The Group B and C are closely related phylogenitically each other by these evidences and by character of pore patterns of the species *L.* sp. Y. Since, the evolutionary tendency of three groups of the genus *Loxoconcha* can be interpreted as follows: The Group A has appeared in the Oligocene in Indo-West Pacific Region (Ahmad et al., 1991; McKenzie et al., 1991). The Group B was derived from the Group A mainly due to an adaptation of the Group A to the brackish water environment in the early Miocene (Ishii et al., 2005). Then, the Group C was probably born recently from the Group B in the western Pacific (Fig. 22).

5.5. Origin of the genera *Loxoconcha* and *Xestoleberis* of the Okinawa Islands

It is possible that the species of the Group B distributes along the coast of the Philippines and Australia, but due to limitation of specimens this group was not found in these locations in this study yet. So far, in the genus *Loxoconcha*, the Group A widely distributes around the world (e. g., Swain, 1955; Hulings & Puri, 1965; Benson, 1965; Baker & Hulings, 1966; Hulings, 1966, 1967; Swain & Gilby, 1967; Ishizaki & Gunther, 1976; Bate et al., 1981; Ishii et al., 2005), whereas the descendant Groups B and C distribute within narrow

areas, from Vietnam to Japanese Island Arc and from Australia to the Amami Island, respectively. Therefore, an area from Vietnam to the Amami Island is an overlap area of three groups of this genus (Fig. 23 and Table 12).

The geographical distribution of three species groups of the two genera in the Table 12 suggests that the *Loxoconcha* and *Xestoleberis* faunas in the Okinawa Islands are close rather to southern faunas than Japanese Island Arc fauna and origin of two genera is from the south. This suggestion is strongly supported by Tanaka & Ikeya (2002) when they studied on migration and speciation of the *L. japonica* species group in East Asia. 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, processes of speciation and evolution of species within this group were done from the south to the north in the west Pacific (Tanaka & Ikeya, 2002). The above migration tendency is supported by Ishii (2004) when he stated that 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 has moved out from subtropical-warm temperate shallow marine into harsh environments, such as high latitude colder area and/or deep sea, to survive around Japan (Ishii, 2004, unpublished doctoral thesis, Kanazawa University). The fauna of *Loxoconcha* in the Okinawa islands is probably older than that in Japanese Island Arc, for example, the oldest fossil records of *L. kattoi* and *L. uranouchiensis* are known from the Miocene in the Okinawa Islands (Nohara, 1987), but from the Pliocene in Japanese Island Arc (Ishii et al., 2005). The present study shows the far difference in species composition of the genera *Loxoconcha* and *Xestoleberis* between the Okinawa Islands and Japanese Island Arc, exception for the species *L. japonica* and *X. hanaii*, the two species distribute in the Okinawa s as well as in Japanese Island Arc (Tanaka & Ikeya, 2002; Sato & Kamiya, 2007). There are three possible reasons to explain the processes of speciation and evolution; and the difference in species composition between two faunas. First, they are partly explained by an effect of Kuroshio Current in the western Pacific. Most of ostracods migrate by passive way following this current, but within each genus, a few of ostracods successfully migrate from this location to other locations. If a small population could colonize incidentally in a new habitat during many times of ineffective dispersal, the new population might take on a novel genetic composition by “the Founder Effect” (Tanaka, 2012). As a result, the speciation might occur in a limited area. Second, although paleomarine climates of glacial periods in tropical areas during the Quaternary as

well as paleogeographic reconstructions during the Late Miocene are so far not fully understood into this study, migration and speciation processes from the south to the north can be explained by some factors such as the changes of temperature and sea levels, emerging of land, cutting of the sea and isolating of ostracod population during an interglacial or glacial period. During an interglacial a tropical population managed to survive the following glacial period by adapting to cooler subtropical climate. Then, the new subtropical species would have proceeded northward in the following interglacial period spread by drifting seaweed, seagrass, wood raft, water currents... (Tanaka & Ikeya, 2002; Sato & Kamiya, 2007). Sato & Kamiya (2007) also pointed out during an interglacial and high sea level a species could be distributed in the Japan Sea and along the Pacific coast. Following them, when sea levels falled and the climate became colder, the Pacific population could retreat southwards, but the Japan Sea population was be kept and isolated due to emerging land cutting the sea off at the southern end. Most populations of warm-water species would probably have been extinguished in the cold Japan Sea, some demes might mutate to adapt cold or warm tolerance and only the deme with cold-tolerant ability could evolve into a cooler-water species after natural selection under a cold climate (Sato & Kamiya, 2007). Then, the speciation and evolution also are made by an interruption in genetic exchange between the different sea areas. The possible examples for these processes are the pairs of closely related species, *Xestoleberis planuventer* (tropical) - *X. setouchiensis* (subtropical-subarctic), *X. ikeyai* (tropical) - *X. dentate* (subtropical), *X. ishizakii* (subtropical; warm Kuroshio species) - *X. sagamiensis* (warm-, mild- and cool-temperate; Japan Sea species), *L. japonica* - *L. shanhaiensis*. Third, Japanese Island Arc fauna belongs to temperate zone that is far different with tropical zone of the Okinawa Island fauna (Sato & Kamiya, 2007; <http://www.cgrove417.org/fry/Science/Climate/climatezones.html>). Additionally, the reef ecosystem is very rare in Japanese Island Arc, but very common in the Okinawa Islands (Omori et al., 2004). Thus, the obvious differences about the climatic zone and presence level of the coral reef between two faunas may cause the isolation in the ostracod composition between them. On the contrary, the similarity of ostracod fauna between the Okinawa Islands and southern parts such as Vietnam, the Philippines, and Australia...is probably explained by the climatic resemblance. Area from the Okinawa Islands to northern Australia is presently classified into the tropical zone (<http://www.cgrove417.org/fry/Science/Climate/climatezones.html>) that has the warmest average temperature. Marine ecosystems such as coral reef, mangrove forest, seagrass bed and

tidal beach... are very common in the Okinawa Islands as well as in Vietnam, the Philippines and Australia.

The migration and speciation tendencies of species of the genera *Loxoconcha* and *Xestoleberis* from southern to northern parts of Japan also are supported by many authors in previous papers. Many species of the genera *Loxoconcha* and *Xestoleberis* were formerly found in the southern part of the Okinawa Islands, but at present they do not appear around this island and they are living around Japanese Island Arc (Nohara, 1987; Kamiya, 1988; Ishii et al., 2005; Sato & Kamiya, 2007). The oldest fossil records of *L. kattoi* and *L. uranouchiensis* also were found from Miocene in southern Okinawa (Nohara, 1987) and from Pliocene in Japan Island Arc (Ishii et al., 2005), but instead of living in the Okinawa Islands, these species are recently found in Japanese Island Arc (Kamiya, 1988; Ishii et al., 2005). *L. hattorii* and *L. modesta* were shown from Pleistocene Naha Limestone of the Okinawa Islands (Nohara, 1981c), but the two species are living at Tsukumo Bay, Ishikawa Prefecture, Japan (Ishii et al., 2005). *X. sagamiensis* was very abundant in Shinzato Formation, southern Okinawa in Pliocene (Nohara, 1987), but presently this Recent species is only living from Kyushu northward (Sato & Kamiya, 2007). These above evidences clearly suggest that the migration and adaptation of many species of *Loxoconcha* and *Xestoleberis* was done from the Okinawa Islands to Japanese Island Arc and the fauna of these two genera in the Okinawa Islands is older than that in Japanese Island Arc.

5.6. Role of western Pacific Ocean and origin of ostracod fauna in the Okinawa Islands

In the Pacific Ocean, although taxonomic data has not been fully known yet, Benson (1965) showed that the ostracod biodiversity of western parts of this ocean is higher than that of eastern parts. Especially, among the western parts, the Indo-Pacific Realm that is defined from Sumatra on the west to Samoa on the east including the Philippine Islands to the north and northern Australia to the south has the highest ostracod biodiversity (Benson, 1965), many ostracod species, e. g., *Triebelina sertata*, *Tanella gracilis*, *Neocyprideis spinulosa*, *Quadracythere* sp., *Xestoleberis* sp., *Cytherella semitalis* and *Loxoconcha henonislandensis*... were originated from this location (Titterton & Whatley, 1988). Additionally, Titterton & Whatley (1988) divided the marine ostracods of the Indo-Pacific into 13 zoogeographical provinces and then they pointed out that the biodiversity level of ostracods of three zoogeographical provinces (E, Da and F) were higher than that of other. All three provinces with higher biodiversity level locate from the Japanese Island Arc to Australia. The ostracod

faunas of the Indo-Pacific Realm are heterogeneous and probably reflect the numerous environments and habitats of this geographically and ecologically complex area (Benson, 1965). Complication of topography in western parts of the Pacific Ocean, especially of the Indo-Pacific Realm is shown with many small islands, many lagoons, bays and sinuous coasts... Therefore, competition for survival among plentiful species and the complication of topography of the areas from Japanese Island Arc to Australia may be causes to make the higher biodiversity in these areas. The Groups B and C of the genus *Loxoconcha* so far living from the Okinawa Islands to Australia are probably derived by the above mentioned causes. Since, it is suggested that area from the Okinawa Islands to Australia can be said the “hot spot” of ostracod biodiversity and this area plays an important role for study on the ostracod biodiversity.

Along the coast of the western Pacific Ocean, several warm ocean currents (e. g., Kuroshio Current-Fig. 25), nearshore currents and longshore currents run from the south to the north (Titterton & Whatley, 1988; Oba et al., 1991; Omori et al., 2004; Ogoh & Ohmiya, 2005; Sato & Kamiya, 2007; Tanaka, 2012; http://en.wikipedia.org/wiki/Ocean_current#/media), thus ostracod species probably migrate passively using these currents. The geographic distributions of the genus *Xestoleberis* (Sato & Kamiya, 2007), *Neonesidae* (Obata & Kamiya, 2001) and *Paradoxostoma* (Takenata Tomoatsu) suggested that the distribution of closely related species in accordance with the marine zoogeographic divisions with a species group seems to be a general character for the intertidal ostracods around Japan and the species distributed toward the south would be ancestral to the more northern species. The ostracod fauna of the Okinawa Islands consists of some relict genera as *Cardobairdia*, *Manawa*, *Nemoceratina* and *Tongacythere* whose origination is from the south (Nohara, 1987). The oldest record of the genus *Manawa* known from Australia and New Zealand, of the genus *Nemoceratina* from England and Germany (Liebau, 1977; Neale, 1978) and of the genus *Tongacythere* from Eocene deposits of Tonga in the South Pacific (Nohara, 1987). Because the ostracod fauna of the Okinawa Islands consists of many warm water genera as *Ambocythere*, *Cytherelloidea*, *Saida*, *Triebelina*, *Kangarina*, *Cardobairdia* and *Phlyctenophora*, the presence of these genera may reveal that they were established by invasion from the south by the Paleokuroshio Current flowed along the Okinawa Islands and adjacent areas (Nohara, 1987). Ostracod fauna in the Okinawa Islands seem to be older than in Japanese Island Arc (Nohara, 1987; Tsukagoshi & Kamiya, 1996).

The species *Cytherelloidea munechikai* is found from Pliocene Shinzato and Somachi Formations in the Okinawa Islands, the Recent species lives at Uranouchi Bay, Kochi Prefecture, Japan (Nohara, 1987). Tsukagoshi & Kamiya (1996) suggested that the ancestral “leap-type” taxa originally lived in the low latitudinal areas from the distribution of cytheracean families around Japan. Based on the geographical distribution of 14 recent intertidal species of the genus *Cythere* around Japan, Tsukagoshi (1988, 1996) indicated invasion of southern fauna to the north.

Japanese Island Arc belongs to temperate zone, meanwhile the area from the Okinawa Islands to the northern part of Australia belongs to tropical zone (Sato & Kamiya, 2007; <http://www.cgrove417.org/fry/Science/Climate/climatezones.html>). Hence, marine habitats in the Okinawa Islands are more similar to those rather in southern parts than in Japanese Island Arc. These above facts about marine currents, geographical distribution of other ostracod genera, climatic zones and marine habitats recommend that the ostracod faunas of Japanese Island Arc and the Okinawa Islands must be derived from the south. However, the origin of different genera is different, i. e., Indo-Pacific Ocean for the genus *Loxoconcha*, Atlantic Ocean for the genus *Nemoceratina*, Australia and New Zealand for the genus *Manawa* and Caribbean sea for the genus *Cardobairdia*.

6. Conclusion

- The total of 22 species of the genus *Loxoconcha* (family Loxoconchidae) and 13 species of the genus *Xestoleberis* (family Xestoleberididae) were found around the coast of the Okinawa Island, southern Japan.
- The species of the genus *Loxoconcha* have been divided into three lineages based on the distribution pattern of the pore systems below eye tubercle, which is regarded as a highly reliable phylogenetic index and generally shows the phylogenetic relationship. In these lineages, the Group C was established in this study.
- Within the genus *Loxoconcha*, the Group A is considered as the oldest group (appeared in Oligocene), the Group B as the median (appeared in Miocene) and the Group C as the youngest based on the fossil records, features of the chaetotaxy of three endites on the maxillula and the dimension of posterior tooth on hingement of the left valve.
- The differences of the setae of three endites on the maxillula and the length of tooth of posterior element of the left valve of the genus *Loxoconcha* are consistent with the

taxonomical divisions which are estimated by the distribution pattern of pore systems on carapace. The larger numbers of the setae on three endites of the maxillula and smaller dimension of posterior tooth of hingement of the left valve are distributed in the species of the derived groups, i. e., the Groups B and C. While, the older evolutionary origin of the species is, the fewer setae of three endites on its maxillula and the longer posterior tooth of its valve have.

- The number of setae of three endites on the adult maxillula of the genus *Loxoconcha* is consistent with the life modes, i. e., the bottom species have more setae than phytal species. The posterior tooth of hingement of left valve of *L. japonica* species group is larger than that of *L. uranouchiensis* species group.

- The reductions of the number of setae of the outer first podomere of the endopodite on the maxillula and of the third podomere on the mandible in derived groups are occurred as an evolutionary tendency within the genus *Xestoleberis*.

- The general development and the number of setae of the maxillula from the instar A-7 to A-5 are completely identical among three species *Loxoconcha japonica*, *L. noharai* and *L. sesokoensis*. From A-4 to adult stage, the number of setae on some parts on the maxillula (the endopodite, three endites, exopodite and the outer first podomere of the endopodite) is slightly different among three species. These divisions of the chaetotaxy of the maxillula beginning in the instar A-4 may be useful for phylogenetic estimation of the genus *Loxoconcha*.

- In the genus *Loxoconcha*, the Group A has appeared in the Indo-West Pacific Region since the Oligocene. The Group B was derived from the Group A mainly due to an adaptation of the Group A to the brackish water environment in the western Pacific Ocean in the Early Miocene. Then, the Group C has been established recently from the Group B in the southernwest Pacific Ocean.

- The species of the genera *Loxoconcha* and *Xestoleberis* from the Okinawa Islands are phylogenetically close to those from the south western Pacific Ocean (i.e., Vietnam, the Philippines and Australia) rather than Japanese Island Arc. Therefore, the species of the two genera in the Okinawa Islands were established by the invasion of the southern ancestral fauna. Additionally, the fossil records and the geographical distribution of other ostracods, marine currents and marine habitats suggest that the ostracod fauna of the Okinawa Islands must be derived from the south.

- Within the genus *Loxoconcha*, the species of the Group A widely distribute around the world, whereas the Group B inhabits from Vietnam to Japanese Island Arc and the Group C from Australia to the Okinawa Islands. Since the area from Vietnam to the Okinawa Islands is an overlap area of three groups. This area can be said the “hot spot” of *Loxoconcha* biodiversity as well as ostracod biodiversity in the western Pacific and plays an important role for study on the ostracod biodiversity.

7. Systematic description

Superfamily Cytheroidea Baird, 1850

Family Loxoconchidae Sars, 1925

Genus *Loxoconcha* Sars, 1866

Loxoconcha noharai Le & Tsukagoshi, 2014

(Figs. 26–29)

Type series. All specimens were collected at Ohura estuary, Okinawa Islands, southern Japan, 26°33'0"N, 128°2'30"E on 19 March 1992. Holotype: SUM-CO-2137 (soft parts and a right valve of adult male; soft parts were enveloped on a slide glass in the “Neo Sigaral” as mounting agent and carapace was on a cardboard slide with single hole). Paratypes: 8 males (SUM-CO-2135, 2136, 2138, 2141, 2143, 2144, 2147, 2148), 5 females (SUM-CO-2139, 2140, 2142, 2145, 2146) and one an A-1 instar (SUM-CO-2149); also as for the dissected specimens, soft parts were mounted on a slide glass in the “Neo Sigaral” agent and carapaces were on a cardboard slide with single hole; other specimens, carapaces were kept on a cardboard slide with single hole.

Etymology. Named in honour of the late Prof. Tomohide Nohara (University of the Ryukyus), in recognition of his significant contribution to ostracod research in Okinawa.

Diagnosis. Carapace rhomboid in lateral view, covered with distinct reticulations and sieve-type pore canals sparsely distributed. Number of pore systems 74 per valve. 4 adductor muscle scars in little curved sub-vertical row, concave anteriorly. Possessing gongylodont hingement with clear crenulations in median element. Plumose seta at posterior margin of first podomere of the three limbs bears several long setulae. In the male, copulatory organ with

large and thin distal lobe (DI); clasping apparatus (Ca) large, thin and partly overlapping the distal lobe, and copulatory duct (Cd) not clear, fine and short, about one fourth as long as length of copulatory organ itself.

Description. *Carapace* (Figs. 26 and 27). Carapace rhomboid in lateral view, showing distinct sexual dimorphism; male more elongate and with less compressed postero-ventral marginal area than female. Surface covered with distinct reticulations. Right and left valves showing asymmetry in outline. Both valves slightly tapering backward; greatest height at anterior-most third. Dorsal margin very slightly convex. Ventral margin nearly straight. Anterior margin broadly rounded. Posterior margin somewhat narrowly rounded, extremity at more than half of height, with slight caudal process. Marginal infold moderately developed. List developing along middle of marginal infold in both valves. Shallow vestibula in anterior and posterior areas of valves (Fig. 26). Fused zone almost as wide as infold (Fig. 26). All lateral pore canals of sieve-type and scattered sparsely with 74 pores per valve. Muscle scars (Fig. 27.9, 12): the smaller one of 2 separate frontal scars round and larger one with curved shape, opening anteriorly; 2 mandibular scars of equal dimensions; 4 adductor muscle scars in weakly curved sub-vertical row, concave anteriorly. Hinge gongylodont with clear crenulations in median element.

Antennula (Fig. 28.1). Five articulated podomeres, length ratios from proximal to distal 16:15:6:13:13, width decreasing gradually in this order. First podomere stout without seta. Second podomere with 1 postero-distal seta and setulae along anterior margin. Third podomere with 1 seta antero-distally. Fourth podomere showing vestigium of segmentation as a ledge with 1 seta and median one, and with 1 very long postero-distal seta, 3 setae antero-distally. Fifth podomere slender, with 3 long setae and 1 aesthetasc distally.

Antenna (Fig. 28.2). Four articulated podomeres, length ratios from proximal to distal 25:12:38:5, width decreasing gradually in this order. First podomere stout with very long exopodite (=spinneret) at anterior distal end. Second podomere with 1 long seta postero-distally and a bunch of long setulae along anterior proximal margin. Third podomere very long, with 2 setae on anterior margin, 2 setae and 1 aesthetasc on posterior ledge, 1 seta at postero-distal end, and setulae along posterior margin. Fourth podomere very small and short with 2 distal claws of sub-equal length.

Mandibula (Fig. 28.3, 3a). Five articulated podomeres. Coxa stout, bearing teeth on medial edge and 1 long seta on anterior margin. Basis bearing exopodite as bunch of 4 plumose setae (3 long plumose and 1 shorter setae) and 1 long ventro-distal seta. First podomere of endopodite with 1 annulated seta antero-distally, 2 very long and 2 short setae ventrally. Second podomere of endopodite with 5 annulated setae antero-distally, 2 setae of unequal length ventrally. Third podomere of endopodite bearing 4 simple setae.

Maxillula (Fig. 28.4, 4a). Thin branchial plate with 16 long plumose setae. Basal podomere bearing a palp and 3 endites; palp with 4 setulose annulated setae antero-distally, 1 seta ventro-distally, 1 strong claw-like and 2 stout setae on distal end; 3 endites bearing 6, 6, and 4 setae, respectively; especially most ventral seta of 3rd endite bearing long setulae arranged in a cluster and terminating in a club-like process.

Fifth limb (Fig. 28.5). Four articulated podomeres, length ratios from proximal to distal 26:23:12:15. First podomere with 2 setulose setae at anterior margin, 2 short setulose setae at anterior distal end, and 1 setulose seta with several long setulae at posterior margin. Second podomere with 1 simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with very short setulae along anterior margin. Fourth podomere with 1 long, stout distal claw and setulae along anterior margin.

Sixth limb (Fig. 28.6). Four articulated podomeres, length ratios from proximal to distal 34:32:11:16. First podomere with 2 setulose setae along anterior margin, 1 setulose seta at anterior distal end, and 1 setulose seta at one third from proximal end of posterior margin consisting of several long setulae. Second podomere with 1 long simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with very short setulae along anterior margin. Fourth podomere with 1 long, stout distal claw and setulae along anterior margin.

Seventh limb (Fig. 28.7). Four articulated podomeres, length ratios from proximal to distal 29:28:13:19. First podomere with 2 setulose setae along anterior margin, 1 short setulose seta at anterior distal end, and 1 setulose seta with several long setulae at posterior proximal end. Second podomere with 1 simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with very short setulae along anterior margin, posterior

distal end extending to make small process. Fourth podomere with 1 long and stout distal claw and setulae along anterior margin.

Male copulatory organ (Fig. 29). Outline sub-circular. Basal part relatively large, and as a blunt triangle. Thin distal lobe triangular. Clasp apparatus thin and large, overlapping partly with the distal lobe, with distal end extending posteriorly. Copulatory duct not clear, fine structure, folded inside and short, about one fourth as long as length of copulatory organ itself.

Dimensions. See Table 15.

Remarks. No brush-shaped organ was observed in any of the 7 male dry specimens and 4 male wet specimens examined. The species *Loxoconcha noharai* resembles *L. uranouchiensis* Ishizaki, 1968 in features of the carapace morphology, but it can be clearly distinguished from this species by some features of the male copulatory organ (see Okubo 1980), and small differences which are found in the chaetotaxy of 5th to 7th limbs and the maxillula. In the male copulatory organ, the distal lobe of *Loxoconcha noharai* has a blunt triangular-like shape, whereas that of *L. uranouchiensis* is sub-quadrangular in shape and forming a small process at the anterior end. Clasp apparatus of both species overlapping the distal lobe, however, part of the clasp apparatus extending outside the distal margin of *Loxoconcha noharai* is longer and larger than that of *L. uranouchiensis*. In *L. noharai*, the plumose seta at the posterior margins of the first podomeres of three limbs bears several long setulae. The maxillula of this species has the ventral-most seta of the 3rd endite bearing long setulae arranged in a cluster and terminating in a club-like process.

Loxoconcha santosi Le & Tsukagoshi, 2014

(Figs. 30–33)

Type series. All specimens were collected at A Da, Nakasu Rikugawa estuary, Okinawa Islands, southern Japan, 26°44'30"N, 128°18'50"E on 21 March 1992. Holotype: SUM-CO-2151 (copulatory organs and both valves of adult male; copulatory organs were enveloped on a slide glass in the "Neo Sigaral" as mounting agent and carapaces were preserved on a cardboard slide with single hole). Paratypes: 7 males (SUM-CO-2154, 2156, 2157, 2160,

2161, 2162, 2163), 6 females (SUM-CO-2150, 2152, 2153, 2155, 2158, 2159) and one A-1 instar (SUM-CO-2164); also as for the dissected specimens, soft parts were mounted on a slide glass in the “Neo Sigaral” agent and carapaces were on a cardboard slide with single hole; other specimens, carapaces were kept on a cardboard slide with single hole.

Etymology. Named after Prof. Jorge Santos (University of Tromsø, Norway), who was the supervisor of the first author.

Diagnosis. Carapace rhomboid in lateral view, covered with distinct reticulations and sieve-type pore canals sparsely distributed. Number of pore systems 74 per valve. 4 adductor muscle scars in curved sub-vertical row, concave anteriorly, the second scar from bottom smaller than other three. Gongylodont hingement with strong crenulations in median element. Exopodite of mandible formed as a bunch of 3 long plumose setae and 1 very small degenerated seta. On the first podomere of fifth and sixth limbs, plumose seta at posterior margin bearing several long setulae. Seventh limb much longer and larger than fifth and sixth limbs. In the male, copulatory organ with large and thin distal lobe; clasping apparatus large, thin and overlapping partly the distal lobe and making large tip; copulatory duct fine, folded inside and short, about one fourth as long as length of capsule.

Description. *Carapace* (Figs. 30 and 31). Carapace showing prominent sexual dimorphism; male more elongate, with straighter dorsal margin and less compressed postero-ventral marginal area than in female. Surface covered with distinct reticulations and sieve-type pore canals sparsely distributed. Valves moderate in length, rhomboid in lateral view. Right and left valves showing asymmetry in outline. Both valves slightly tapering backward; greatest height at anterior first third. Dorsal margin very slightly convex. Ventral margin almost straight. Anterior margin broadly rounded. Posterior margin somewhat narrowly rounded, extremity at more than half of height, with slight caudal process. Marginal infold moderately developed. List present along middle of marginal infold in both valves. Vestibula weakly developed in anterior and posterior areas of valves (Fig. 30). Fused zone mostly as wide as infold (Fig. 30). All lateral pore systems sieve-type, with 74 pores per valve. Muscle scars (Fig. 31.9, 12): the smaller one round (formed of 2 frontal scars), the larger one with curved shape, concave anteriorly; 2 mandibular scars of equal dimension; 4 adductor muscle scars in curved sub-vertical row, concave anteriorly, the second scar from bottom smaller than other three, especially in male. Hinge gongylodont with strong crenulations on median element.

Antennula (Fig. 32.1). Five articulated podomeres, length ratios from proximal to distal 20:16:7:14:17, width decreasing in this order. First podomere stout, without seta. Second podomere with 1 medium seta at posterior distal end and setulae along anterior margin. Third podomere with 1 short seta antero-distally. Fourth podomere showing vestigium of segmentation as a ledge with 1 seta, a median seta, and with 1 very long seta postero-distally, 3 setae antero-distally. Fifth podomere slender, with 3 long setae and 1 aesthetasc distally.

Antenna (Fig. 32.2). Four articulated podomeres, length ratios from proximal to distal 30:12:38:3, width decreasing gradually in this order. First podomere stout with very long exopodite (=spinneret) at anterior distal end. Second podomere with 1 long seta postero-distally and a bunch of long setulae along anterior proximal margin. Third podomere very long, with 2 setae on anterior margin, 2 setae and 1 aesthetasc on posterior ledge, 1 short seta at postero-distal end, and setulae along posterior margin. Fourth podomere very short and small with 2 distal claws of sub-equal length.

Mandibula (Fig. 32.3, 3a). Five articulated podomeres. Coxa stout, with teeth on medial edge and 1 medium seta on anterior distal margin. Basis bearing exopodite as bunch of 4 setae (3 long plumose setae and 1 very small reduced seta) and 1 seta at ventral distal end. First podomere of endopodite with 1 annulated seta antero-distally, 2 very long and 2 short setae ventrally. Second podomere of endopodite with 5 annulated setae antero-distally, 2 short setae of unequal length ventrally. Third podomere of endopodite with 4 simple setae, 2 long and 2 short setae.

Maxillula (Fig. 32.4, 4a). Thin branchial plate bearing 16 long plumose setae. Basal podomere bearing a palp and 3 endites; palp with 4 long setulous annulated setae antero-distally, 1 seta ventro-distally, 1 strong claw and 2 stout setae on distal end; 3 endites bearing 6, 5, and 5 setae, respectively; especially the most ventral seta of 3rd endite bearing long setulae arranged in a cluster and terminating in a club-like process.

Fifth limb (Fig. 32.5). Four articulated podomeres, length ratios from proximal to distal 29:24:11:14. First podomere with 2 setulous setae along anterior margin, 2 short setulous setae at anterior distal end, and 1 setulous seta in the middle of posterior margin bearing several long setulae. Second podomere with 1 simple short seta on anterior distal corner, and setulae along anterior margin. Third podomere with short setulae along anterior margin. Fourth podomere bearing 1 long and stout distal claw and setulae along anterior margin.

Sixth limb (Fig. 32.6). Consisting of 4 articulated podomeres, length ratios from proximal to distal 34:30:13:16. First podomere bearing 2 setulose setae along anterior margin, 1 setulose seta at anterior distal end, and 1 long setulose seta with some long setulae at posterior margin. Second podomere with 1 long seta on anterior distal end, and setulae along anterior margin. Third podomere with very short setulae along anterior margin. Fourth podomere with 1 long and stout distal claw and setulae along anterior margin.

Seventh limb (Fig. 32.7). Much larger and longer than fifth and sixth limbs. Consists of 4 articulated podomeres, length ratios from proximal to distal 35:29:14:20. First podomere with 2 setulose setae in middle of anterior margin, 1 short setulose seta at anterior distal end, and 1 setulose seta at first fifth from proximal end of posterior margin. Second podomere with 1 long seta on anterior distal corner, and setulae along anterior margin. Third podomere with very short setulae along anterior margin. Fourth podomere with 1 long, and stout distal claw and setulae along anterior margin.

Male copulatory organ (Fig. 33). Sub-circular shape in general. Basal part relatively large, with a blunt triangular shape. Distal lobe large, and thin with a triangular shape. Clasp apparatus thin and large, overlapping partly distal lobe with distal end extending posteriorly and forming a large tip. Copulatory duct fine, folded inside and short, about one fourth as long as length of capsule.

Brush-shaped organ (Fig. 32.8, 8a). Three-pronged fork shape in general; consisting of pair of branches, with about 23 fine setae on each distal margin.

Dimensions. See Table 15.

Remarks. The carapace outline and appendage morphology of *Loxoconcha santosi* are similar to those of *L. uranouchiensis* Ishizaki, 1968, but the former can be clearly distinguished from the latter by some features of the male copulatory organ (see Okubo 1980), and small differences which are found on the fifth, and sixth limbs and the maxillula. The general shape of the male copulatory organ is significantly different between the two species. The distal lobe of *L. santosi* has a triangular shape, whereas that of *L. uranouchiensis* has a sub quadrangular-like shape, with small process at anterior end. In the species *L. santosi*, there are several long setulae on the plumose seta on the posterior margin of first podomere of fifth and sixth limbs. In the maxillula, the most ventral seta of the 3rd endite of this species bears long setulae arranged in a cluster and terminating in a club-like process.

The carapace outline, appendage morphology, and pore system of *Loxoconcha santosi* resemble those of *L. noharai*. One difference between the two species is found in the general shape and structure of the male copulatory organ. Additionally, the exopodite of the mandible of *L. noharai* consists of a bunch of 4 long plumose setae, while that of *L. santosi* is composed of a bunch of 3 long plumose setae and 1 very small reduced seta. Unlike in *L. noharai*, the seventh limb in *L. santosi* is much larger and longer than the fifth and sixth limbs.

***Loxoconcha sesokoensis* Le & Tsukagoshi, 2014**

(Figs. 34–37)

Type series. All specimens were collected at the northwest coast of Sesoko-jima, Okinawa Islands, southern Japan on 27 May 2000. Holotype: SUM-CO-2167 (soft parts and one right valve of adult male; soft parts were mounted on a slide glass in the “Neo Sigaral” agent and carapace was on a card board with single hole). Paratypes: 5 males (SUM-CO-2168, 2171, 2173, 2174, 2177) and 7 females (SUM-CO-2165, 2166, 2169, 2170, 2172, 2175, 2176); also as for the dissected specimens, soft parts were enveloped on a slide glass in the “Neo Sigaral” as mounting agent and carapace was kept on a cardboard slide with single hole; other specimens, carapaces were preserved on a cardboard slice with single hole.

Etymology. After the type locality, Sesoko-jima Island.

Diagnosis. Carapace sub-rhomboid in lateral view, covered with distinct reticulations and sieve-type pore systems sparsely distributed. Number of pore canals 85 per valve. 4 adductor muscle scars in curved sub-vertical row, concave anteriorly. Valve with a gongylodont hingement with crenulations in the median element. Dorsal and ventral margins nearly parallel to each other, especially in male. On fifth and sixth limbs, plumose seta on the posterior margin of first podomere bearing several long setulae. In the male copulatory organ, distal lobe thin along distal margin and forming a long tip. Clasping apparatus large, thin and overlapping whole distal lobe with distal end forming a tip. Copulatory duct very short, fine and folded.

Description. *Carapace* (Figs. 34 and 35). Carapace showing strong sexual dimorphism; male more elongate and with straighter dorsal margin than female. Carapace surface covered with distinctive reticulations. Valves moderate in length, sub-rhomboid in lateral view. Right and left valves showing asymmetry in outline. Both valves slightly tapering toward posterior;

greatest height at anterior-most fourth. Dorsal margin slightly convex. Ventral margin almost straight. Both margins nearly parallel to each other, especially in male. Anterior margin broadly rounded. Posterior margin somewhat narrowly rounded with slight caudal process. Marginal infold moderately developed. Most of the list present along the middle of the marginal infold in both valves. Vestibula weakly developed, especially in posterior area of valves (Fig. 34). Fused zone mostly as wide as infold (Fig. 34). All lateral pore canals of sieve-type, arranged sparsely with 85 pores per valve. Muscle scars (Fig. 35.9, 12): the smaller one round (from 2 frontal scars), a bigger one in curved shape; 2 mandibular scars; 4 adductor muscle scars in curved sub-vertical row, concave anteriorly. Hingement gongylodont with crenulations in median element except for third and eleventh teeth from posterior terminal tooth.

Antennula (Fig. 36.1). Consisting of 5 articulated podomeres, length ratios from proximal to distal 25:18:8:15:12, width gradually narrowing in this order. First podomere stout without seta. Second podomere with 1 seta at the postero-distal end and setulae along proximal and distal part of the anterior margin. Third podomere with 1 seta antero-distally. Fourth podomere showing vestigium of segmentation as a ledge with 2 setae on both sides, 1 long seta postero-distally, and with 3 setae antero-distally. Fifth podomere slender, with 3 long setae and 1 short aesthetasc distally.

Antenna (Fig. 36.2). Four articulated podomeres, length ratios from proximal to distal 14:7:20:1, width gradually narrowing in this order. First podomere stout bearing very long exopodite (=spinneret) at anterior distal end. Second podomere with 1 long seta postero-distally and bunch of long setulae along part of the anterior proximal margin. Third podomere with 2 setae at middle of anterior setiferous margin, 2 setae at medial suture making a ledge on the posterior margin, and 1 short seta at posterior distal end, and numerous setulae along posterior margin. Fourth podomere with 2 claws distally of sub-equal dimensions.

Mandibula (Fig. 36.3, 3a). Five articulated podomeres. Coxa stout, consisting of teeth on medial edge and 1 long seta on anterior distal margin. Basis consisting of exopodite as a bunch of 4 plumose setae (one of those very short) and 1 seta on opposite distal end. First podomere of endopodite with 1 annulated seta antero-distally, 2 very long and 2 very short setae ventrally. Second podomere of endopodite with 6 annulated setae antero-distally, 2 setae of unequal length at postero-distal corner. Third podomere of endopodite bearing 4 long simple setae at distal end.

Maxillula (Fig. 36.4, 4a). Thin branchial plate with 16 long plumose setae. Basal podomere bearing palp and 3 endites; palp with 4 setulose annulated antero-distal setae, 1 ventral seta, 1 strong claw and 2 stout setae on distal end; 3 endites bearing 5, 6, and 5 setae of unequal length, respectively; especially most ventral seta of 3rd endite bearing long setules arranged in a cluster and terminating in a club-like process.

Fifth limb (Fig. 36.5). Four articulated podomeres, length ratios from proximal to distal 33:25:12:18. First podomere with 2 setulose setae along anterior margin, 2 setulose setae at anterior distal end, and 1 setulose seta with several long setulae in middle of posterior margin. Second podomere with 1 simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with short setulae along anterior margin. Fourth podomere with 1 long, stout distal claw and setulae along anterior margin.

Sixth limb (Fig. 36.6). Four articulated podomeres, length ratios from proximal to distal 18:15:7:10. First podomere with 2 long setulose setae along anterior margin, 1 setulose seta at anterior distal end, and 1 long, branched, setulose seta in middle of posterior margin. Second podomere with 1 long simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with short setulae along anterior margin. Fourth podomere bearing 1 long, stout distal claw and short setulae along anterior margin.

Seventh limb (Fig. 36.7). Four articulated podomeres, length ratios from proximal to distal 26:21:9:14. First podomere consisting of 2 setulose setae along anterior margin, 1 setulose seta at anterior distal end, and 1 setulose seta at proximal end of posterior margin. Second podomere with 1 long simple seta on anterior distal corner, and short setulae along anterior margin. Third podomere with short setulae along anterior margin. Fourth podomere with 1 long, stout distal claw and setulae along anterior margin.

Male copulatory organ (Fig. 37). General shape oval. Basal part relatively large, triangular. Thin distal lobe triangular. Clasp apparatus triangular, thin and large, overlapping whole distal lobe with distal end forming a tip. Copulatory duct very short, fine and folded.

Brush-shaped organ (Fig. 36.8, 8a). Y-shaped in general; consisting of pair of branches, with 16 fine setae on each distal margin.

Dimensions. See Table 15.

Remarks. *Loxoconcha sesokoensis* is the first species of this genus studied inhabiting coral reefs in Japan and adjacent seas. The somewhat oval carapace outline, the shape of the male copulatory organ, and the chaetotaxy of the mandibula and the maxillula of *L. sesokoensis* are clearly different from those of other *Loxoconcha* species living in Japan and adjacent areas as shown by Ishizaki (1968), Okubo (1980), Nakao & Tsukagoshi (2002) and Ozawa (2013).

When comparing *L. sesokoensis* with Ishii et al.'s (2005) results, the distributional pattern of the pore system below the eye tubercle in this species is unique (Fig. 38.3, 4), i.e. neither belonging to Group A (fully marine; phytal, or bottom-dwellers) nor to Group B (brackish, bottom-dweller) and therefore, the pattern of *L. sesokoensis* is named as the Group C. Since Ishii et al. (loc. cit.) do not cover any coral reef *Loxoconcha* species, their grouping obviously cannot be applied to *L. sesokoensis* which inhabits the sediment surface in coral reefs. The present paper thus expands of the knowledge of possible correlations between pore system pattern and habitat in *Loxoconcha* species around Japan.

***Loxoconcha* sp. Y**

(Figs. 39–42)

Type series. All specimens were collected at Bise sand beach, Motobu town, Okinawa Islands, southern Japan, 26°70'00"N, 127°87'89"E on 7 September 2013. Depth of water is about 0.3 m. Holotype: TEM-CO-21 (soft parts and a left valve of adult male; soft parts were enveloped on a slide glass in the “Neo Sigaral” as mounting agent and carapace was on a cardboard slide with single hole). Paratypes: 5 males (TEM-CO-20, 21, 26, 31 and 33) and 7 females (TEM-CO-19, 22, 24, 25, 28, 29 and 32); also as for the dissected specimens, soft parts were mounted on a slide glass in the “Neo Sigaral” agent and carapaces were on a cardboard slide with single hole; other specimens, carapaces were kept on a cardboard slide with single hole.

Diagnosis. Carapace rhomboid in lateral view, covered with distinct reticulations and sieve-type pore systems sparsely distributed. Number of pore systems 73 per valve. Right and left valves showing obvious asymmetry in lateral outline, especially at corner of posterior dorsal margin. In male carapace in lateral view, approximately posterior half relatively poor ornamented. 4 adductor muscle scars isolated, arranged in curved sub-vertical row, concave

anteriorly. Possessing gongylodont hingement with clear crenulations in median element. In male, copulatory organ with very large and thin distal lobe (DI); clasping apparatus (Ca) small, thin and completely overlapping the distal lobe, and copulatory duct (Cd) not clear and very thin.

Description. *Carapace* (Figs. 39 and 40). Carapace rhomboid in lateral view, showing distinct sexual dimorphism; male more elongate and with less compressed than female. Surface covered with distinct reticulations. In male, approximately posterior half of carapace relatively poor ornamented. Right and left valves showing asymmetry in outline, especially at corner of posterior dorsal margin. Both valves slightly tapering backward; greatest height at anterior-most third. Dorsal and ventral margins almost straight. Anterior margin broadly rounded. Posterior margin somewhat narrowly rounded, extremity at around half of height, with clear caudal process, especially in left valve. Marginal infold well developed. List developing along middle of marginal infold in both valves. Very narrow vestibula along anterior and posterior inner margins of valves (Fig. 39). Fused zone almost as wide as marginal infold (Fig. 39). All lateral pore systems of sieve-type and scattered sparsely with 73 pores per valve. Muscle scars (Figs. 39 and 40.9, 12): smaller one of 2 separate frontal scars round and another one with C-shape, opening anteriorly; 2 mandibular scars of equal dimensions with oval shape; 4 adductor muscle scars with equal dimensions arranged in curved sub-vertical row, concave anteriorly. Hinge gongylodont with very clear crenulations in median element.

Antennula (Fig. 41.1). Five articulated podomeres, length ratios from proximal to distal 12:10:4:7:8, width decreasing gradually in this order. First podomere stout without seta. Second podomere with 1 seta at posterior distal end and setulae along anterior proximal and distal margins. Third podomere with 1 seta at anterior distal end. Fourth podomere showing vestigium of segmentation as ledge with 1 seta, and bearing median seta, 1 very long seta at posterior distal end, and 3 setae at anterior-distal end, among them 1 seta very long. Fifth podomere slender, with 3 long setae and 1 aesthetasc at distal end.

Antenna (Fig. 41.2). Four articulated podomeres, length ratios from proximal to distal 11:6:16:2, width decreasing gradually in this order. First podomere stout with long exopodite (=spinneret) at anterior distal end. Second podomere with 1 long seta at posterior distal end and bunch of setulae along anterior proximal margin. Third podomere very long, with 2 setae on one third along anterior proximal margin, 2 setae and 1 aesthetasc on posterior ledge, 1

seta at posterior distal end, and setulae along posterior middle margin and stout setulae along posterior distal margin. Fourth podomere very small and short with 2 terminal claws of sub-equal length.

Mandibula (Fig. 41.3, 3a). Five articulated podomeres. Coxa stout, bearing 9 teeth on medial edge among them, 4 teeth short and large, 5 teeth long and small and 1 seta on anterior margin. Basis bearing exopodite as bunch of 4 plumose setae, and 1 long ventral distal seta. First podomere of endopodite with 1 setulous seta at anterior distal end, 2 very long setae at ventral distal end and 2 short medial setae. Second podomere of endopodite with 4 setulous setae at anterior distal end, 2 setae of unequal length at ventral distal end. Third podomere of endopodite bearing 4 simple setae of unequal dimension, one of them very stout at distal end.

Maxillula (Fig. 41.4, 4a). Thin exopodite with 15 long plumose setae and 1 reflexed setulous seta. Basal podomere consisting of one endopodite and 3 endites: endopodite with 4 setulous annulated setae at anterior distal end, 1 strong claw-like and 2 stout setae on distal end, 1 seta at ventral distal end; 3 endites bearing 6, 6, and 5 setae with long setuleae along margins of distal part, respectively; most ventral seta of 3rd endite stout, bearing long setuleae and lengthening to make in club-like process.

Fifth limb (Fig. 41.5). Four articulated podomeres, length ratios from proximal to distal 15:10:5:7. First podomere carrying 2 setulous setae at anterior margin, 2 short anterior distal end setae with setulae on distal part, and 1 setulous seta at one third from proximal end of posterior margin. Second podomere with 1 simple, short and small seta on anterior distal end, and setulae along anterior margin. Third podomere with very short setulae along anterior margin. Fourth podomere with 1 long, stout terminal claw and setulae along anterior margin.

Sixth limb (Fig. 41.6). Four articulated podomeres, length ratios from proximal to distal 15:13:5:8. First podomere bearing 2 anterior margin- setae with setulae on distal part, 1 short anterior distal end- seta on distal part, and 1 setulous seta at one fourth from proximal end of posterior margin. Second podomere with 1 simple seta on anterior distal corner, and setulae along anterior margin. Third podomere with short setulae along anterior margin. Fourth podomere with 1 long, stout terminal claw and setulae along anterior margin.

Seventh limb (Fig. 41.7). Four articulated podomeres, length ratios from proximal to distal 18:17:6:10. First podomere with 2 setulous setae along anterior margin, 1 setulous seta at anterior distal end, and 1 setulous seta at one fifth from proximal end of posterior margin.

Second podomere with 1 very long simple seta at anterior distal corner, and setulae along anterior margin. Third podomere with short setulae along anterior margin, posterior distal end extending to make small process. Fourth podomere with 1 long and stout terminal claw and setulae along anterior margin.

Brush-shaped organ (Fig. 41.8, 8a). Y-shaped; consisting of pair of branches, with about 21 fine setae on each distal margin.

Male copulatory organ (Fig. 42). Outline sub-circular. Basal capsule relatively large, as a blunt triangle. Thin distal lobe large and triangular. Clasping apparatus thin and small, overlapping completely with distal lobe. Copulatory duct not clear, thin structure and folded inside.

Dimensions. See Table 16.

Remarks. The species *Loxoconcha* sp. Y generally resembles *L. uranouchiensis* Ishizaki, 1968, *L. noharai* Le & Tsukagoshi, 2014 and *L. santosi* Le & Tsukagoshi, 2014 in the characteristics of carapace morphology, but it exhibits a small difference in the approximately posterior half of the carapace in the lateral view of the male. The male copulatory organ of *L. sp. Y* shows clear differences from these species. The distal lobe of *L. yoshidai* is a triangular shape with rounded distal tip (Fig. 43.1), meanwhile of *L. uranouchiensis* is a rectangular shape with pointed distal tip (Fig. 43.2). The clasping apparatus of *L. yoshidai* completely overlaps with the distal lobe, whereas a part of the clasping apparatus of *L. santosi* and *L. noharai* does so with the distal lobe, while the remaining parts of the clasping apparatus of the other two species protrude outside of the margin of the distal lobe (Fig. 43.3, 4).

The pore pattern below the eye tubercle of species *Loxoconcha* sp. Y is unique, as a few examined specimens show an intermediate form between Groups B and C (i. e., belonging to neither Group C nor Group B). Indeed intra-specific variation of the pore pattern is observed in multiple individuals in this new species (Fig. 21). The pore patterns of a total of 13 valves were examined here. Nine of the valves belong to the Group C (Fig. 21.1, 4) and only two valves to the Group B (Fig. 21.2, 5) and two valves to an intermediate form (Fig. 21.3, 9). Of course, all of the examined specimens were classified based on the male copulatory organ or other species-specific characters. These discoveries strongly suggest that the Groups B and C of the genus *Loxoconcha* are closely related to each other.

Acknowledgments

First of all, I would like to express my deepest gratitude and sincere thanks to my supervisor, Prof. Akira Tsukagoshi, for his continuous support to my Ph.D study and research, for his guidance, encouragement, enthusiasm and helpful suggestions. I would like to extend my sincere thanks to Prof. Yoshimi Suzuki, Prof. Beatriz E. Casareto and the staff of ELSU project (Shizuoka University) who supported my study. I greatly appreciate Prof. Takahiro Kamiya (Kanazawa University) and Dr. Tohru Ishii (Kanazawa University) for valuable advices. I also thank Dr. Shinnosuke Yamada, Dr. Hayato Tanaka and the members of the Ostracod Research Team of Shizuoka University for helpful comments and assistance. My sincere thanks are extended to the staff members of Tropical Biosphere Research Center Sesoko Station (University of Ryukyus) and Dr. Ryuta Yoshida (University of Ryukyus) who provided me specimens and various facilities during my field trips. Thanks also go to the Research Institute for Marine Fisheries, Provincial People's Committees of Quang Ninh, Khanh Hoa and Kien Giang for their help during my field trips in Vietnam. I also thank all my ELSU (2012–2015) classmates and Vietnamese friends for their help during my stay in Shizuoka. Finally, I want to express my special gratitude to my great family, my parents, my daughters and my wife for their never-ending love and moral support. This study was partly funded by the Japan Society for the Promotion of Science, the Grant-in-Aid for Scientific Research (No. 04740443 and 23370042).

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

Species name	Sampling location	Habitat	Salinity	Group
<i>Loxoconcha</i>				
<i>japonica</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
<i>L. shanhaiensis</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
<i>L. lilljeborgii</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
<i>L. tumulosa</i>	Okinawa Islands, southern Japan	Phytal	n	A
<i>L. sp. 1</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
<i>L. sp. 7</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
	Sesoko Island, Okinawa Islands, southern Japan and			
<i>L. kosugii</i>	Kisarazu city, Chiba Pref., central Japan	Bottom	b-n	B
<i>L. noharai</i>	Ohura estuary, Okinawa Islands, southern Japan	Bottom	b	B
<i>L. santosi</i>	Ada, Okinawa Islands, southern Japan	Bottom	b	B
<i>L. sp. 3</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	C
<i>L. sp. 13</i>	Sesoko Island, Okinawa Islands, southern Japan	-	-	C
	Bise beach, Motobu town, Okinawa Islands, southern			
<i>L. sp. Y</i>	Japan	Bottom	n	C
<i>L. sesokoensis</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	C
<i>L. sp. 6</i>	Ikei, Okinawa Islands, southern Japan	-	-	-
<i>L. sp. 8</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	n	A
<i>L. sp. 9</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	-	A
<i>L. sp. 10</i>	Sesoko Island, Okinawa Islands, southern Japan	Phytal	-	A
<i>L. sp. 14</i>	Iriomote Island, Okinawa Islands, southern Japan	-	-	A
<i>L. sp. 15</i>	Ohura estuary, Okinawa Islands, southern Japan	-	-	A
<i>L. sp. 16</i>	Sosu, Okinawa Islands, southern Japan	-	-	A
<i>L. sp. 17</i>	Ikei, Okinawa Islands, southern Japan	-	-	A
<i>L. mutsuensis</i>	Miyazaki, Miyazaki Pref., southern Japan	Phytal	n	A
<i>L. harimensis</i>	Miura city, Kanagawa Pref., central Japan	Bottom	n	A
<i>L. tosaensis</i>	Miura city, Kanagawa Pref., central Japan	Bottom	n	A
<i>L. modesta</i>	Miura city, Kanagawa Pref., central Japan	Bottom	n	A
<i>L. pulchra</i>	Kisarazu city, Chiba Pref., central Japan	Bottom	b	B
<i>L.</i>				
<i>uranouchiensis</i>	Miura, Kanagawa Pref., central Japan	Bottom	b-n	B

Species name	Sampling location	Habitat	Salinity	Group
<i>L. sp. 4</i>	Miura, Kanagawa Pref., central Japan	Bottom	b-n	B
<i>L. sp. 5</i>	Obitsu river estuary, Chiba Pref., central Japan	Bottom	b	B
<i>L. sp. 30</i>	Uranouchi Bay, Kochi Pref., southern Japan	-	-	A
<i>L. sp. 11</i>	Soi Sim island, Ha Long Bay, Ha Long city, Quang Ninh Pro., northern Vietnam	Bottom	n	C
<i>L. sp. 18</i>	Ba Trai Dao island, Cat Ba Island, Hai Phong city, northern Vietnam	Phytal	n	A
<i>L. sp. 19</i>	Ba Trai Dao island, Cat Ba Island, Hai Phong city, northern Vietnam	-	-	A
<i>L. sp. 20</i>	Sung Sot cave, Ha Long Bay, Ha Long city, Quang Ninh Pro., northern Vietnam	-	-	A
<i>L. sp. 21</i>	Sung Sot cave, Ha Long Bay, Ha Long city, Quang Ninh Pro., northern Vietnam	-	-	A
<i>L. sp. 22</i>	Ba Trai Dao island, Cat Ba Island, Hai Phong city, northern Vietnam	Bottom	-	B
<i>L. ocellata</i>	Thien Cung cave, Ha Long Bay, Ha Long city, Quang Ninh Pro., northern Vietnam	Bottom	b-n	B
<i>L. vietnamensis</i>	Van Don island, Quang Ninh Pro., northern Vietnam	Bottom	n	C
<i>L. sp. 12</i>	Dam Ngoai island, Phu Quoc MPA, Phu Quoc Island, Kien Giang Pro., southern Vietnam	Phytal	n	A
<i>L. sp. 23</i>	Bai Thom beach, Phu Quoc Island, Kien Giang Pro., southern Vietnam	-	n	-
<i>L. sp. 24</i>	Saraku resort, Nha Trang city, central Vietnam	-	n	-
<i>L. sp. 25</i>	Saraku resort, Nha Trang city, central Vietnam	-	n	A
<i>L. sp. 26</i>	Saraku resort, Nha Trang city, central Vietnam	Bottom	n	B
<i>L. sp. 27</i>	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	Phytal	n	A
<i>L. sp. 28</i>	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	-	n	-
<i>L. sp. 29</i>	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	Phytal	n	A
<i>L. elliptica</i>	England	Bottom	n-b	A
<i>L. rhomboidea</i>	England	Phytal	n	A
<i>L. dampierensis</i>	Australia	-	n	-

Species name	Sampling location	Habitat	Salinity	Group
<i>Xestoleberis</i>				
<i>hanaii</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	A
<i>X. sesokoensis</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	A
<i>X. ryukyuensis</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	A
<i>X. planuventer</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	A
<i>X. ikeya</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	A
<i>X. sp. 1</i>	Midland Island, Okinawa Islands, southern Japan	-	n	A
<i>X. sp. 2</i>	Sesoko Island, Okinawa Islands, southern Japan	-	n	A
<i>X. sp. 3</i>	Midland Island, Okinawa Islands, southern Japan	-	n	A
<i>X. sp. 4</i>	Sesoko Island, Okinawa Islands, southern Japan	-	n	A
<i>X. sp. 5</i>	Sesoko Island, Okinawa Islands, southern Japan	-	n	A
<i>X. sp. 6</i>	Sesoko Island, Okinawa Islands, southern Japan	-	n	A
<i>X. kuroshio</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	B
<i>X. magnoculus</i>	Sesoko Island, Okinawa Islands, southern Japan	Bottom	n	B
	Sung Sot cave, Ha Long Bay, Ha Long city, Quang Ninh			
<i>X. sp. 7</i>	Pro., northern Vietnam	Bottom	n	A
	Ba Trai Dao island, Cat Ba Island, Hai Phong city,			
<i>X. sp. 9</i>	northern Vietnam	-	n	A
	Vung Tau, Long Chau island, Cat Ba island, Hai Phong			
<i>X. sp. 10</i>	city, northern Vietnam	-	n	A
	Soi Sim island, Ha Long Bay, Ha Long city, Quang Ninh			
<i>X. sp. 11</i>	Pro., northern Vietnam	-	n	A
	Ba Trai Dao island, Cat Ba Island, Hai Phong city,			
<i>X. sp. 12</i>	northern Vietnam	-	n	A
	Dam Ngoai island, Phu Quoc MPA, Phu Quoc Island,			
<i>X. sp. 8</i>	Kien Giang Pro., southern Vietnam	Bottom	n	A
	Bai Thom beach, Phu Quoc Island, Kien Giang Province,			
<i>X. sp. 13</i>	southern Vietnam	-	n	A
	Dam Trong island, Phu Quoc MPA, Phu Quoc Island,			
<i>X. sp. 14</i>	Kien Giang Pro., southern Vietnam	-	n	A
	Dam Trong island, Phu Quoc MPA, Phu Quoc Island,			
<i>X. sp. 15</i>	Kien Giang Pro., southern Vietnam	-	n	B
<i>X. sp. 16</i>	Saraku resort, Nha Trang city, central Vietnam	-	n	A
<i>X. sp. 17</i>	Hon Mun island, Nha Trang Bay MPA, Nha Trang city,	-	n	B

Species name	Sampling location	Habitat	Salinity	Group
	central Vietnam			
X. sp. 18	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	-	n	A
X. sp. 19	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	-	n	A
X. sp. 20	Hon Mun island, Nha Trang Bay MPA, Nha Trang city, central Vietnam	-	n	A

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

TABLE 2. List of species from the Okinawa Island, Okinawa Prefecture, southern Japan.

No	Family name	Species name	No	Family name	Species name
					<i>Loxocorniculum</i> sp.
1	Bairdiidae	Bairdiid sp. A	70		B
					<i>Loxocorniculum</i> sp.
2		Bairdiid sp. B	71		C
					<i>Loxoconcha</i>
3		Bairdiid sp. C	72		<i>uranouchiensis</i>
					<i>Loxoconcha</i> sp. 1
4		Bairdiid sp. D	73		<i>Loxoconcha</i> sp. 1
5		Bairdiid sp. E	74		<i>Loxoconcha kosugii</i>
6		Bairdiid sp. F	75		<i>Loxoconcha</i> sp. 3
7		Bairdiid sp. G	76		<i>Loxoconcha</i> sp. 13
8		Bairdiid sp. H	77		<i>Loxoconcha</i> sp. 7
9		Bairdiid sp. I	78		<i>Loxoconcha</i> sp. 14
10		Bairdiid sp. J	79		<i>Loxoconcha</i> sp. 15
11		Bairdiid sp. K	80		<i>Loxoconcha</i> sp. 16
12		<i>Neonesidea</i> sp.	81		<i>Loxoconcha</i> sp. 9
13		<i>Triebelina</i> sp.	82		<i>Loxoconcha</i> sp. 10
14	Bythocyprididae	<i>Anchistrocheles</i> sp.	83		<i>Loxoconcha</i> sp. Y
15	Bythocytheridae	<i>Bythoceratina</i> sp.	84		<i>Loxoconcha</i> sp. 8
16		<i>Sclerochilus</i> sp.	85		<i>Loxoconcha</i> sp. 6
17	Candonidae	<i>Paracypris</i> sp.	86		<i>Loxoconcha</i> sp. 17
18	Cobanocytheridae	<i>Cobanocythere</i> sp.	87		<i>Pseudoconcha</i> sp.
19		<i>Paracobanocythere</i> sp.	88	Macrocyprididae	<i>Macrocyprina</i> sp.
20	Cushmaniidae	<i>Pontocythere</i> sp.	89	Paracytherideidae	<i>Paracytheridea</i> sp.
		<i>Cytherelloidea</i>			<i>Paradoxostoma</i> sp.
21	Cytherellidae	<i>asatoensis</i>	90		H
22		<i>Cytherelloidea hanaii</i>	91	Paradoxostomatidae	<i>Cytherois</i> sp.
		<i>Cytherelloidea</i>			
23		<i>senkakuensis</i>	92		<i>Paracytherois</i> sp.
					<i>Paradoxostoma</i>
24		<i>Cytherelloidea</i> sp.	93		<i>affine</i>
		<i>Cythere</i>			<i>Paradoxostoma</i> cf.
25	Cytheridae	<i>omotenipponica</i>	94		<i>gibberum</i>
					<i>Paradoxostoma</i>
26		<i>Schizocythere</i> sp.	95		<i>lunatum</i>

No	Family name	Species name	No	Family name	Species name
					<i>Paradoxostoma</i> sp.
27		<i>Spinileberis</i> sp.	96		A
		<i>Perissocytheridea</i>			<i>Paradoxostoma</i> sp.
28	Cytherideidae	<i>inabai</i>	97		B
					<i>Paradoxostoma</i> sp.
29	Cytheroidea	<i>Cytheroidea</i> sp.	98		C
					<i>Paradoxostoma</i> sp.
30	Cytheromatidae	<i>Microloxoconcha</i> sp.	99		D
					<i>Paradoxostoma</i> sp.
31		<i>Paracytheroma</i> sp.	100		E
					<i>Paradoxostoma</i> sp.
32	Cytheruridae	<i>Cytheropteron</i> sp.	101		F
					<i>Paradoxostoma</i> sp.
33		<i>Cytherura</i> sp.	102		G
34		<i>Eucytherura</i> sp.	103	Pectocytheridae	<i>Keijia</i> sp.
35		<i>Hemicytherura</i> sp.	104		<i>Mckenzieartia</i> sp.
		<i>Semicytherura</i>			
36		<i>miurensis</i>	105		<i>Morkhovenia</i> sp.
37		<i>Semicytherura</i> sp.	106		<i>Parakeijia</i> sp.
38	Eucytheridae	<i>Eucythere</i> sp.	107		<i>Pectocythere</i> sp.
39	Hemicytheridae	<i>Aurila</i> sp. A	108	Polycopidae	<i>Polycope</i> sp.
40		<i>Aurila</i> sp. B	109		<i>Polycopidae</i> sp.
41		<i>Caudites</i> sp.	110		<i>Parapolycope</i> sp. 6
42		<i>Coquimba</i> sp.	111		<i>Parapolycope</i> sp. 9
					<i>Pontocypridoidea</i>
43		<i>Cornucoquimba</i> sp.	112	Pontocyprididae	sp.
44		<i>Finmarchinella</i> sp.	113		<i>Pontocypris</i> sp.
					<i>Propontocypris</i>
45		<i>Hermanites</i> sp.	114		(<i>Ekpontocypris</i>) sp.
46		<i>Mutilus</i> sp.	115		<i>Propontocypris</i> sp.
47		<i>Procythereis</i> sp.	116	Pussellidae	<i>Pussella</i> sp.
					<i>Neomonoceratina</i>
48		<i>Radimella</i> sp.	117	Schizocytheridae	sp.
					<i>Australimoosella</i>
49		<i>Robustaurila</i> sp.	118	Trachyleberididae	sp.
50		<i>Tenedocythere</i> sp.	119		<i>Basslerites</i> sp.

No	Family name	Species name	No	Family name	Species name
		<i>Tenedocythere</i>			
51		<i>transoceanica</i>	120		<i>Moosella</i> sp.
52	Krithidae	<i>Parakrithella</i> sp.	121		<i>Trachyleberis</i> sp.
53	Leptocytheridae	<i>Callistocythere</i> sp. A	122		<i>Wichmannella</i> sp.
54		<i>Callistocythere</i> sp. B	123	Xestoleberididae	<i>Microxestoleberis</i> sp.
55		<i>Callistocythere</i> sp. C	124		<i>Ornatoleberis</i> sp.
56		<i>Cluthia</i> sp.	125		<i>Xestoleberis hanaii</i>
57		<i>Ishizakiella</i> sp.	126		<i>Xestoleberis ikeya</i>
58		<i>Leptocythere</i> sp.	127		<i>Xestoleberis kuroshio</i>
59		<i>Neocytheromorpha</i> sp.	128		<i>Xestoleberis magnoculus</i>
60		<i>Tanella</i> sp.	129		<i>Xestoleberis planuventer</i>
61	Limnocytheridae	<i>Paracythereis</i> sp.	130		<i>Xestoleberis ryukyuensis</i>
62	Loxoconchidae	<i>Loxoconcha japonica</i>	131		<i>Xestoleberis sesokoensis</i>
63		<i>Loxoconcha lilljeborgii</i>	132		<i>Xestoleberis</i> sp. 1
64		<i>Loxoconcha noharai</i>	133		<i>Xestoleberis</i> sp. 2
65		<i>Loxoconcha santosi</i>	134		<i>Xestoleberis</i> sp. 3
66		<i>Loxoconcha sesokoensis</i>	135		<i>Xestoleberis</i> sp. 4
67		<i>Loxoconcha shanghaiensis</i>	136		<i>Xestoleberis</i> sp. 5
68		<i>Loxoconcha tumulosa</i>	137		<i>Xestoleberis</i> sp. 6
69		<i>Loxocorniculum</i> sp. A	138		<i>Isocythereis</i> sp.
			139		<i>Propontocytheris</i> sp.

TABLE 3. Sorensen values between the Okinawa Island and other areas, and number of species of the genera *Loxoconcha* and *Xestoleberis*.

Locations	Sorensen values		Number of species	
	Species level	Genus level	<i>Loxoconcha</i>	<i>Xestoleberis</i>
Otsuchi bay, Pacific Coast of northeastern, Japan ¹	10.5	35.7	4	4
The Tsushima warm current, Japan ²	12.0	31.0	11	9
Hamana-ko Bay, Pacific Coast of Japan ³	10.5	31.3	5	4
Hiuchi-nada Bay, Seto Inland sea of Japan ⁴	18.2	36.9	13	2
Southwestern Okhotsk Sea off Shiretoko Peninsula, Japan ⁵	5.3	28.2	5	3
Northeastern Japan Sea off Okushiri Island, Japan ⁵	10.0	36.6	5	5
Malacca straits, Malaysia ⁶	5.3	28.6	4	4
The shelf seas off China ⁷	15.8	18.8	6	2
Coast of Vietnam ^{8&14}	6.3	24.7	20	14
New South Wales, southeast Australia ⁹	0	21.5	10	8
Darwin and northwestern, Australia ¹⁰	0	31.1	4	5
Coast of Australia ^{9, 10&16}	0	26.8	33	37
Coast of the Philippines ^{11&14}	5.9	20.9	22	16
Coast of Indonesia ^{12&15} (reef of Bali and coast of Java sea)	4.8	33.3	7	5
Amami Island, Kagoshima Prefecture, Japan*	50.1	No data	18	No data

¹ Ikeya et al. (1992), ² Tanaka (2008), ³ Ikeya & Hanai (1982), ⁴ Yamane (1998), ⁵ Ozawa & Tsukawaki (2008), ⁶ Whatley & Zhao (1987, 1988), ⁷ Zhao & Wang (1988), ⁸ Tanaka et al. (2009), ⁹ Yassini & Jones (1995), ¹⁰ Howe & Kckenzie (1989), ¹¹ Key (1954), ¹² Whatley & Watson (1988), ¹³ Nakao & Tsukagoshi (2002), ¹⁴ This study, ¹⁵ Dewi (1993), ¹⁶ Deckker & Jones (1978) and * only species of the genus *Loxoconcha* were estimated in this study

TABLE 4. Dimension of some hinge elements of left valves of 24 species of the genus *Loxoconcha*.

Species name	Group	Habitat	Carapace length (μm)	Anterior tooth (μm)	Posterior socket (μm)	Posterior tooth (μm)	Sex	<i>N</i>
<i>L. japonica</i>	A	P, n	586	22.7	25.2	19.9	M	2
<i>L. shanghaiensis</i>	A	P, n	547	19.4	23.4	18.3	M	2
<i>L. lilljeborgii</i>	A	P, n	536	24.7	25.1	25.5	F	1
<i>L. tumulosa</i>	A	P, n	533	23.2	ND	25.9	F	1
<i>L. sp. 1</i>	A	P, n	496	19.4	23.4	17.9	M	2
<i>L. sp. 7</i>	A	P, n	482	20.8	22.3	20.8	-	1
<i>L. mutsuensis</i>	A	P, n	694	24.4	26.9	26.2	M	3
<i>L. harimensis</i>	A	B, n	532	18.5	21.1	21.9	-	2
<i>L. tosaensis</i>	A	B, n	646	21.8	34.4	22.7	M	2
<i>L. modesta</i>	A	B, n	624	25.2	28.5	25.7	M	2
<i>L. sp. 8</i>	A	P, n	514	20.0	24.0	22.0	F	1
<i>L. sp. 12</i>	A	P, n	553	18.1	23.1	24.5	M	2
<i>Average</i>			561.9	21.5	25.2	22.6		
<i>L. noharai</i>	B	B, b	535	19.5	24.6	11.0	M	4
<i>L. santosi</i>	B	B, b	487	15.3	22.5	9.4	M	4
<i>L. pulchra</i>	B	B, b	576	23.4	24.0	11.7	M	3
<i>L. kosugii</i>	B	B, b+n	691	22.9	31.1	13.9	M	3
<i>L. uranouchiensis</i>	B	B, b+n	534	20.8	26.7	13.4	M	2
<i>L. sp. 5</i>	B	B, b	461	25.8	15.2	16.7	F	1
<i>L. ocellata</i>	B	B, b+n	624	15.8	21.2	13.2	M	1
<i>L. sp. 4</i>	B	B, b	532	14.3	29.4	15.7	F	2
<i>Average</i>			555.0	19.7	24.3	13.1		
<i>L. sp. Y</i>	C	B, n	465	17.8	26.7	11.2	M	5
<i>L. sp. 3</i>	C	B, n	472	ND	23.3	11.7	M	2
<i>L. sesokoensis</i>	C	B, n	486	11.3	20.8	9.3	M	4
<i>L. vietnamensis</i>	C	B, n	502	18.1	23.6	13.7	M	3
<i>Average</i>			481.3	15.7	23.6	11.5		

Abbreviations: B, Bottom dwelling species; P, Phytal species; b, brackish water; n, normal marine water; F, Female; M, Male; -, No data.

TABLE 5. Results of t-Test on dimension of some hinge elements of the left valves of 24 species of the genus *Loxoconcha*.

Hinge element	Compared pair	Mean of length (μm)	t Critical		
			t Stat	two-tail	Conclusion
Anterior tooth	Groups A and B	21.5 and 19.7	1.08	2.23	No difference
	Groups A and C	21.5 and 15.7	2.48	4.30	No difference
	Groups B and C	19.7 and 15.7	1.49	2.78	No difference
Posterior socket	Groups A and B	25.2 and 24.3	0.42	2.18	No difference
	Groups A and C	25.2 and 23.6	0.99	2.31	No difference
	Groups B and C	24.3 and 23.6	0.35	2.23	No difference
Posterior tooth	Groups A and B	22.6 and 13.1	7.84	2.11	<i>Difference</i>
	Groups A and C	22.6 and 11.5	8.93	2.26	<i>Difference</i>
	Groups B and C	13.1 and 11.5	1.33	2.31	No difference
	<i>L. japonica</i> and <i>L.</i>	22.3 and 11.3	6.47	2.45	<i>Difference</i>
	<i>uranouchiensis</i> groups				

t Stat < -t Critical two-tail or t Stat > t Critical two-tail: Difference

-t Critical two-tail < t Stat < t Critical two-tail: No difference

TABLE 6. Number of tooth of median element of hingement of the species of the genus *Loxoconcha*.

Species name	Group	Habitat	Number of tooth of median element	<i>N</i>
<i>Loxoconcha</i> sp. 1	A	Phytal, n	39–40	2
<i>L. japonica</i>	A	Phytal, n	39–49	4
<i>L. lilljeborgii</i>	A	Phytal, n	24	2
<i>L. tumulosa</i>	A	Phytal, n	29–35	3
<i>L. tosaensis</i>	A	Bottom, n	47–51	4
<i>L. modesta</i>	A	Bottom, n	48	1
<i>L. shanghaiensis</i>	A	Phytal, n	33–38	3
<i>L.</i> sp. 12	A	Phytal, n	33–34	4
<i>L. noharai</i>	B	Bottom, b	46–51	4
<i>L. santosi</i>	B	Bottom, b	47–58	4
<i>L.</i> sp. Y	C	Bottom, n	35–49	3
<i>L. sesokoensis</i>	C	Bottom, n	37–49	4

Abbreviations: b, brackish water; n, normal marine water.

TABLE 7. Characters of muscle scars of 23 species of the genus *Loxoconcha*.

Species name	Group	Number of adductor scars	Shapes of frontal scar
<i>Loxoconcha shanghaiensis</i>	A	4	Bean or oval shape
<i>Loxoconcha</i> sp. 1	A	4	C-shape
<i>L. japonica</i>	A	4	Bean or oval shape
<i>L.</i> sp. 9	A	4	Bean or oval shape
<i>L.</i> sp. 10	A	4	Bean or oval shape
<i>L.</i> sp. 30	A	4	C-shape
<i>L. mutsuensis</i>	A	4	C-shape
<i>L. modesta</i>	A	4	C-shape
<i>L. tosaensis</i>	A	4	C-shape
<i>L. harimensis</i>	A	4	C-shape
<i>L.</i> sp. 8	A	4	Bean or oval shape
<i>L.</i> sp. 12	A	4	C-shape
<i>L. pulchra</i>	B	4–5	C-shape
<i>L. kosugii</i>	B	4	C-shape and Y-shape
<i>L. uranouchiensis</i>	B	4	C-shape
<i>L. noharai</i>	B	4	C-shape
<i>L. santosi</i>	B	4	C-shape
<i>L.</i> sp. 5	B	4	C-shape
<i>L.</i> sp. 4	B	4	C-shape
<i>L.</i> sp. 26	B	4	C-shape
<i>L. sesokoensis</i>	C	4	C-shape
<i>L.</i> sp. Y	C	4	C-shape
<i>L.</i> sp. 3	C	4	C-shape

TABLE 8. Dimensions of carapaces of instars of *Loxoconcha noharai* Le & Tsukagoshi, 2014.

Instar	Sex	Height (μm)		Length (μm)			
		Mean	Range	<i>N</i>	Mean	Range	<i>N</i>
A-7		70.8	68–72	4	116.5	105–122	4
A-6		94.3	93–96	4	137.5	135–142	4
A-5		104.0	102–106	4	172.3	171–174	4
A-4		120.0	118–124	4	201.0	196–206	4
A-3		148.5	139–154	12	246.2	231–254	12
A-2		183.3	178–189	4	307.3	296–320	4
A-1	Female	230.0	225–235	7	380.0	372–394	7
	Male	237.8	232–240	6	405.3	400–410	6
Adult	Female	284.6	271–294	8	462.3	436–483	8
	Male	281.0	271–290	8	513.0	502–529	8

TABLE 9. Number of the setae of three endites, the outer 1st podomere of the endopodite and exopodite on the maxillula, and 2nd podomere of endopodite on mandible of 19 species of the genus *Loxoconcha*.

Species name	Group	Habitat	Carapace length (μm)	Maxillula				Outer 1st podomere of the endopodite	Exopodite	Mandible 2nd podomere of endopodite	N
				First endite	Second endite	Third endite	Total three endites				
<i>L. shanhaiensis</i>	A	Phytal, n	547	5	4	5	14	4	16	6	-
<i>L. mutsuensis</i>	A	Phytal, n	694	3	4	3	10	5	16	5	3
<i>L. japonica</i>	A	Phytal, n	586	4	5	4	13	3	17	6	-
<i>L. rhomboidea</i>	A	Phytal, n	590	4	4	3	11	4	15	ND	-
<i>L. harimensis</i>	A	Bottom, n	532	5	4	4	13	3	16	5	-
<i>L. elliptica</i>	A	Bottom, n+b	660	5	4	4	13	4	17	ND	-
<i>L. sp. 12</i>	A	Phytal, n	553	5	5	4	14	4	17	5	3
<i>Average</i>				4.4	4.3	3.9	12.6	3.9	16.3	5.4	
<i>L. pulchra</i>	B	Bottom, b	576	6	7	4	17	4	16	6	-
<i>L. kosugii</i>	B	Bottom, b+n	691	5	6	6	17	4	17	6	4
<i>L. noharai</i>	B	Bottom, b	535	6	6	4	16	4	16	5	8
<i>L. santosi</i>	B	Bottom, b	487	6	5	5	16	4	16	5	7
<i>L. uranouchiensis</i>	B	Bottom, b+n	534	5	6	5	16	4	16	6	2
<i>L. sp. 11</i>	B	Bottom, n	480	6	6	5	17	4	16	ND	2
<i>Average</i>				5.7	6.0	4.8	16.5	4.0	16.2	5.6	

Species name	Group	Habitat	Carapace length (μm)	Maxillula							Mandible	N
				First endite	Second endite	Third endite	Total three endites	Outer 1st podomere of the endopodite	Exopodite	2nd podomere of endopodite		
<i>L. sp. Y</i>	C	Bottom, n	465	6	6	5	17	4	16	5		7
<i>L. sp. 3</i>	C	Bottom, n	472	6	6	6	18	ND	16	ND		1
<i>L. sesokoensis</i>	C	Bottom, n	486	5	6	5	16	4	17	6		5
<i>L. vietnamensis</i>	C	Bottom, n	502	5	6	5	16	4	16	ND		3
<i>Average</i>				5.5	6.0	5.3	16.8	4.0	16.3	5.5		
<i>L. bizenensis</i>	ND	Bottom, n	560	6	4	5	15	4	ND	5		-
<i>L. dampierensis</i>	ND	n	ND	5	6	6	17	3	ND	ND		-

Abbreviations: ND, no data; -, data is taken from the literatures, i. e., *L. shanhaiensis* after Tanaka & Ikeya (2002); *L. japonica* after Smith & Kamiya (2003); *L. rhomboidea* and *L. elliptica* after Athersuch et al. (1989); *L. harimensis* and *L. bizenensis* after Okubo (1980) and *L. pulchra* after Nakao & Tsukagoshi (2002); *L. dampierensis* from Hartmann & Hartmann (1978). Habitat: b, brackish water; n, normal marine water.

TABLE 10. Results of t-Test on number of the setae of three endites and of exopodite on the maxillula of 19 species of the genus *Loxoconcha*.

Part of maxillula	Compared pair	Mean of number of setae	t Stat	t Critical two-tail	Conclusion
Three endites	Groups A and B	12.6 and 16.5	-6.40	2.31	<i>Difference</i>
	Groups A and C	12.6 and 16.8	-5.61	2.26	<i>Difference</i>
	Groups B and C	16.5 and 16.8	-0.47	2.78	No difference
	Phytal and bottom species	12.4 and 16.5	-4.77	2.57	<i>Difference</i>
Exopodite	Groups A and B	16.3 and 16.2	0.36	2.26	No difference
	Groups A and C	16.3 and 16.3	0.09	2.26	No difference
	Groups B and C	16.2 and 16.3	-0.28	2.45	No difference

t Stat < -t Critical two-tail or t Stat > t Critical two-tail: Difference

-t Critical two-tail < t Stat < t Critical two-tail: No difference

TABLE 11. Number of setae of three endites, the 1st podomere of maxillular endopodite, exopodite of the maxillula and the 3rd podomere of mandibular endopodite of 22 species of the genus *Xestoleberis*.

Species	Group	Three endites	1st podomere of maxillular endopodite	Exopodite of the maxillula	3rd podomere of mandibular endopodite	<i>N</i>	Source
<i>X. hanaii</i>	A	13	4	17	4	4	(1)
<i>X. sp. 1</i>	A	13	4	16	4	3	(1)
<i>X. sp. 2</i>	A	-	-	-	4	2	(1)
<i>X. sp. 5</i>	A	12	4	-	-	4	(1)
<i>X. sp. 6</i>	A	-	4	-	4	1	(1)
<i>X. sp. 7</i>	A	14	5	16	4	2	(1)
<i>X. sp. 8</i>	A	13	4	16	4	3	(1)
<i>X. sp. 20</i>	A	14	4	17–18	4	3	(1)
<i>X. magutiensis</i>	A	12	4	13	4	1	(2)+(1)
<i>X. kamiya</i>	A	11	4	15	4	1	(2)+(1)
<i>X. ikeya</i>	A	11	4	17	4		(3)
<i>X. planuventer</i>	A	-	3	17	4		(3)
<i>X. ryukyuensis</i>	A	14	4	17	4		(3)+(1)
<i>X. sesokoensis</i>	A	12	4	17	4		(3)+(1)
<i>X. setouchiensis</i>	A	11	4	16	4		(4)
<i>X. kuroshio</i>	B	11	4	17	6	3	(3)+(1)
<i>X. magnoculus</i>	B	13	4	17	6	3	(3)+(1)
<i>X. notoensis</i>	C	-	2	16	2		(3)
<i>X. sagamiensis</i>	C	14	2	16–17	2		(3)
<i>X. ishizakii</i>	C	-	2	-	2		(3)
<i>X. iturupica</i>	C	-	2	-	2		(3)
<i>X. inabai</i>	-	14	5	16	3		(5)

Sources: (1) This study; (2) Hirosaki (2013BS); (3) Sato & Kamiya (2007); (4) Okubo (1979); (5) Okubo (1985). -, No data. In mandible: 3rd podomere of endopodite of *Xestoleberis* species is equivalent to the 2nd of *Loxoconcha* species.

TABLE 12. Geographical distribution of three groups of the genera *Loxoconcha* and *Xestoleberis*, and number of species of two genera.

Genus	Pore group	Geologic age	Japanese Island Arc	Amami Island	Okinawa Islands	Vietnam	Philippines	Australia
<i>Loxoconcha</i>	A	Old	x	x	x	x	x	x
	B	Median	x	x	x	x	?	?
	C	Young	-	x	x	x	x	x
	Number of species		26	18	22	20	22	33
<i>Xestoleberis</i>	A	Old	x (*)	x (**)	x (**)	x (**)	x (**)	x (**)
	B	Old	-	x	x	x	x	x
	C	Young	x	-	-	-	-	-
	Number of species		13	ND	13	14	16	37

(x) Present; (-) No present; (*) Rare; (**) Common; (ND) No data.

TABLE 13. The development of number of setae on the maxillula of *Loxoconcha noharai*, *L. japonica*, *Uncinocythere occidentalis*, *Limnocythere inopinata*, *Eucypris virens*, *Neonesidea oligodentata* and *Keijcyoidea infralittoralis*.

Order	Superfamily	Species	Parts of the maxillula	Molt instar (A-1, A-2, etc., in descending order of size)								
				A-8	A-7	A-6	A-5	A-4	A-3	A-2	A-1	Adult
Podocopida	Cytheroidea	<i>L. noharai</i> ¹	Endopodite			0	2	2	3	3	3	3
			First endite			1	3	3	3	6	6	6
			Second endite		Anlage	2	2	2	3	6	6	6
			Third endite			2	2	3	3	4	4	4
			Exopodite			6	9	11	13	15	16	16
			Outer 1st podomere of endopodite			0	1	2	2	3	4	4
			Inner 1st podomere of endopodite			0	1	1	1	1	1	1
			<i>Total</i>			11	20	24	28	38	40	40
		<i>L. sesokoensis</i> ¹			(N=2)	(N=5)	(N=3)	(N=4)	(N=5)	(N=4)	(N=6)	(N=2)
			Endopodite		Anlage	0	2	2	3	3	3	3
			First endite			1	3	3	3	5	5	5
			Second endite			2	2	3	3	6	6	6
			Third endite			2	2	2	3	5	5	5
			Exopodite			6	9	11	13	14	15	16
			Outer 1st podomere of endopodite			0	1	2	2	3	4	4

Order	Superfamily	Species	Parts of the maxillula	Molt instar (A-1, A-2, etc., in descending order of size)								
				A-8	A-7	A-6	A-5	A-4	A-3	A-2	A-1	Adult
		<i>L. japonica</i> ²	Inner 1st podomere of endopodite			0	1	1	1	1	1	1
			<i>Total</i>			<i>11</i>	<i>20</i>	<i>24</i>	<i>28</i>	<i>37</i>	<i>39</i>	<i>40</i>
					(N=2)	(N=3)	(N=8)	(N=4)	(N=3)	(N=5)	(N=3)	(N=2)
			Endopodite			0	2	2	3	3	3	3
			First endite			1	3	3	3	4	4	4
			Second endite		Anlage	2	2	2	3	5	5	5
			Third endite			2	2	2	3	4	4	4
			Exopodite			6	9	11	11	14	15	17
			Outer 1st podomere of endopodite			0	1	2	2	2	3	3
			Inner 1st podomere of endopodite			0	1	1	1	1	1	1
			<i>Total</i>			<i>11</i>	<i>20</i>	<i>23</i>	<i>26</i>	<i>33</i>	<i>35</i>	<i>37</i>
			Endopodite		Anlage		2	2	2	2	2	2
			First endite				0	0	1	2	2	2
			Second endite				0	0	0	0	0	0
			<i>Uncinocythere occidentalis</i> ³	Third endite				0	0	0	0	0
Exopodite					1	8	11	13	17	21		
Outer 1st podomere of endopodite					0	0	0	0	0	0		

Order	Superfamily	Species	Parts of the maxillula	Molt instar (A-1, A-2, etc., in descending order of size)								
				A-8	A-7	A-6	A-5	A-4	A-3	A-2	A-1	Adult
Cypridoidea	<i>Eucypris virens</i> ⁴		Inner 1st podomere of endopodite				0	0	0	0	0	0
			<i>Total</i>				3	10	14	17	21	25
			Endopodite			1	3	4	5	5	6	6
			First endite		Anlage	1	2	5	7	8	10	12
			Second endite			2	4	4	7	7	8	8
			Third endite			4	5	5	7	12	13	13
			Exopodite			4	4	9	15	18	24	26
			Outer 1st podomere of endopodite			0	1	2	2	4	5	6
			Inner 1st podomere of endopodite			0	0	0	0	0	0	0
			<i>Total</i>			12	19	29	43	54	66	71
	Bairdioidea	<i>Neonesidea oligodentata</i> ⁵	Endopodite			1	2	2	2	2	2	2
			First endite		Anlage	1	3	3	4	4	5	5
			Second endite			3	3	3	4	6	6	7
			Third endite			4	4	5	6	7	8	9
			Exopodite			6	10	14	20	23	27	30
			Outer 1st podomere of endopodite			0	1	1	1	2	3	3
			Inner 1st podomere of			0	0	1	1	1	1	1

Order	Superfamily	Species	Parts of the maxillula	Molt instar (A-1, A-2, etc., in descending order of size)								
				A-8	A-7	A-6	A-5	A-4	A-3	A-2	A-1	Adult
			endopodite									
			<i>Total</i>			15	23	29	38	45	52	57
			Endopodite	Numerous setulae						30-		
				along posterior	Numerous setulae along posterior margin and one hirsute at posterior distal area	0	2	25	29	36	42	>42
			First endite	margin and 1 long,		2	2	7				
			Second endite	curved, smooth		2	2	7				
			Third endite	seta with widened		2	2	3				
			Exopodite	protruding from		15	18	20	25	28	31	>31
			Outer 1st podomere of endopodite	middle of posterior margin								
			Inner 1st podomere of endopodite									

1) This study, 2) after Smith & Kamiya (2003), 3) after Smith & Kamiya (2005), 4) after Smith & Martens (2000) and Smith et al. (2005), 5) after Smith & Kamiya (2002), 6) after Tsukagoshi et al. (2006) and Okada et al. (2008).

TABLE 14. Summary of maxillulan ontogeny of *Loxoconcha noharai*, *L. sesokoensis*, *L. japonica*, *Uncinocythere occidentalis*, *Limnocythere inopinata*, *Eucypris virens*, *Neonesidea oligodentata* and *Keijcyoidea infralittoralis*.

Instar	Taxon	Podocopida						Platycopida	
		Cytheroidea					Cypridoidea	Bairdiodea	Cytherelloidea
		<i>Loxoconcha</i>	<i>Loxoconcha</i>	<i>Loxoconcha</i>	<i>Uncinocythere</i>	<i>Limnocythere</i>	<i>Eucypris</i>	<i>Neonesidea</i>	<i>Keijcyoidea</i>
		<i>noharai</i>	<i>sesokoensis</i>	<i>japonica</i>	<i>occidentalis</i>	<i>inopinata</i>	<i>virens</i>	<i>oligodentata</i>	<i>infralittoralis</i>
A-8								⊙	
A-7	○	○	○		○	○	○	⊙	
A-6	●	●	●	○	●	●	●	●	
A-5	●	●	●	●	●	●	●	●	
A-4	●	●	●	●	●	●	●	●	
A-3	●	●	●	●	●	●	●	●	
A-2	●	●	●	●	●	●	●	●	
A-1	●	●	●	●	●	●	●	●	
Adult	●	●	●	●	●	●	●	●	

● Fully formed (Maxillula resembling that of the adult, but the number of setae is not complete) ⊙ Intermediate form ○ Anlage

The information on *L. japonica* is taken from Smith & Kamiya (2003), *U. occidentalis* taken from Smith & Kamiya (2005), *E. virens* taken from Smith & Martens (2000), *N. oligodentata* taken from Smith & Kamiya (2002), *L. inopinata* taken from Scheerer-Ostermeyer (1940), *K. infralittoralis* taken from Tsukagoshi et al. (2006) and Okada et al. (2008).

TABLE 15. Dimensions of the valves of *Loxoconcha noharai* Le & Tsukagoshi, 2014; *L. santosi* Le & Tsukagoshi, 2014 and *L. sesokoensis* Le & Tsukagoshi, 2014.

Species name	Sex	Valve	Height (mm)			Length (mm)		
			Mean	Range	<i>N</i>	Mean	Range	<i>N</i>
<i>Loxoconcha noharai</i>	F	LV	0.28	0.27–0.29	3	0.45	0.43–0.47	3
		RV	0.28	0.28–0.29	3	0.46	0.44–0.47	3
	M	LV	0.28	0.28	3	0.51	0.50–0.51	3
		RV	0.28	0.27–0.29	3	0.51	0.50–0.51	3
<i>L. santosi</i>	F	LV	0.28	0.25–0.29	4	0.44	0.43–0.45	4
		RV	0.28	0.26–0.30	2	0.44	0.43–0.46	2
	M	LV	0.28	0.28	2	0.52	0.52–0.53	2
		RV	0.29	0.29	2	0.53	0.52–0.53	2
<i>L. sesokoensis</i>	F	LV	0.25	0.24–0.26	3	0.40	0.40–0.41	3
		RV	0.25	0.25	3	0.41	0.40–0.41	3
	M	LV	0.25	0.25–0.26	2	0.48	0.47–0.48	2
		RV	0.25	0.25–0.26	2	0.47	0.45–0.48	2

Abbreviations: F, Female; M, Male; LV, left valve; RV, right valve.

TABLE 16. Dimensions of the valves of *Loxoconcha* sp. Y.

Sex	Valve	Height (μm)			Length (μm)		
		Mean	Range	<i>N</i>	Mean	Range	<i>N</i>
Female	Left valve	244	229–257	4	418	409–432	4
	Right valve	241	236–244	4	419	418–420	4
Male	Left valve	242	240–244	5	471	465–482	5
	Right valve	241	238–242	5	473	467–486	5

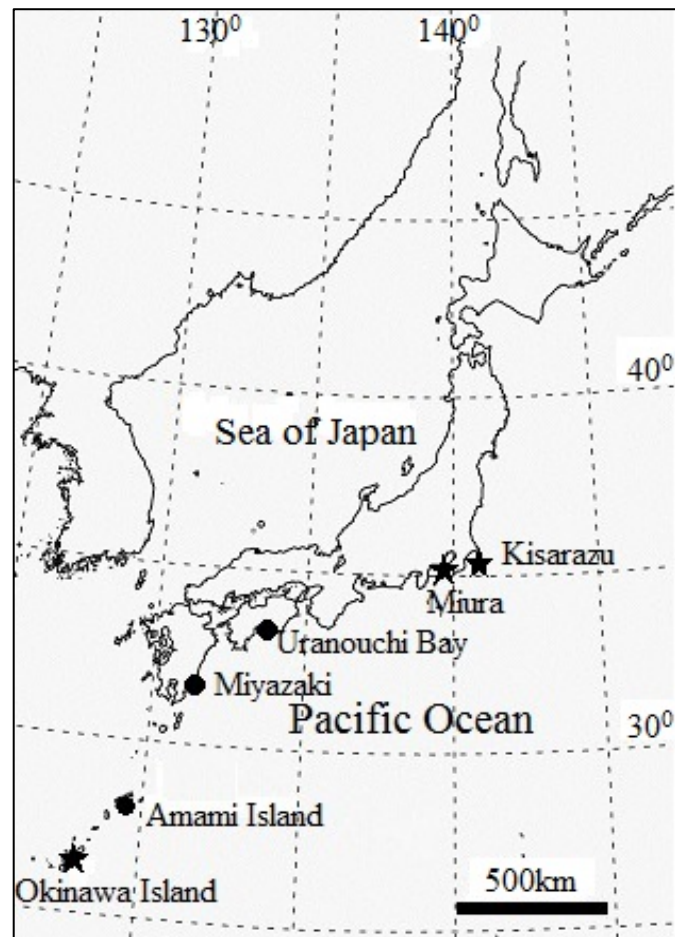


FIGURE 1. Study sites in Japan. Details of occurrence are shown in Table 1. Star shapes (Sampling and using ready specimens), solid circles (Only using ready specimens).

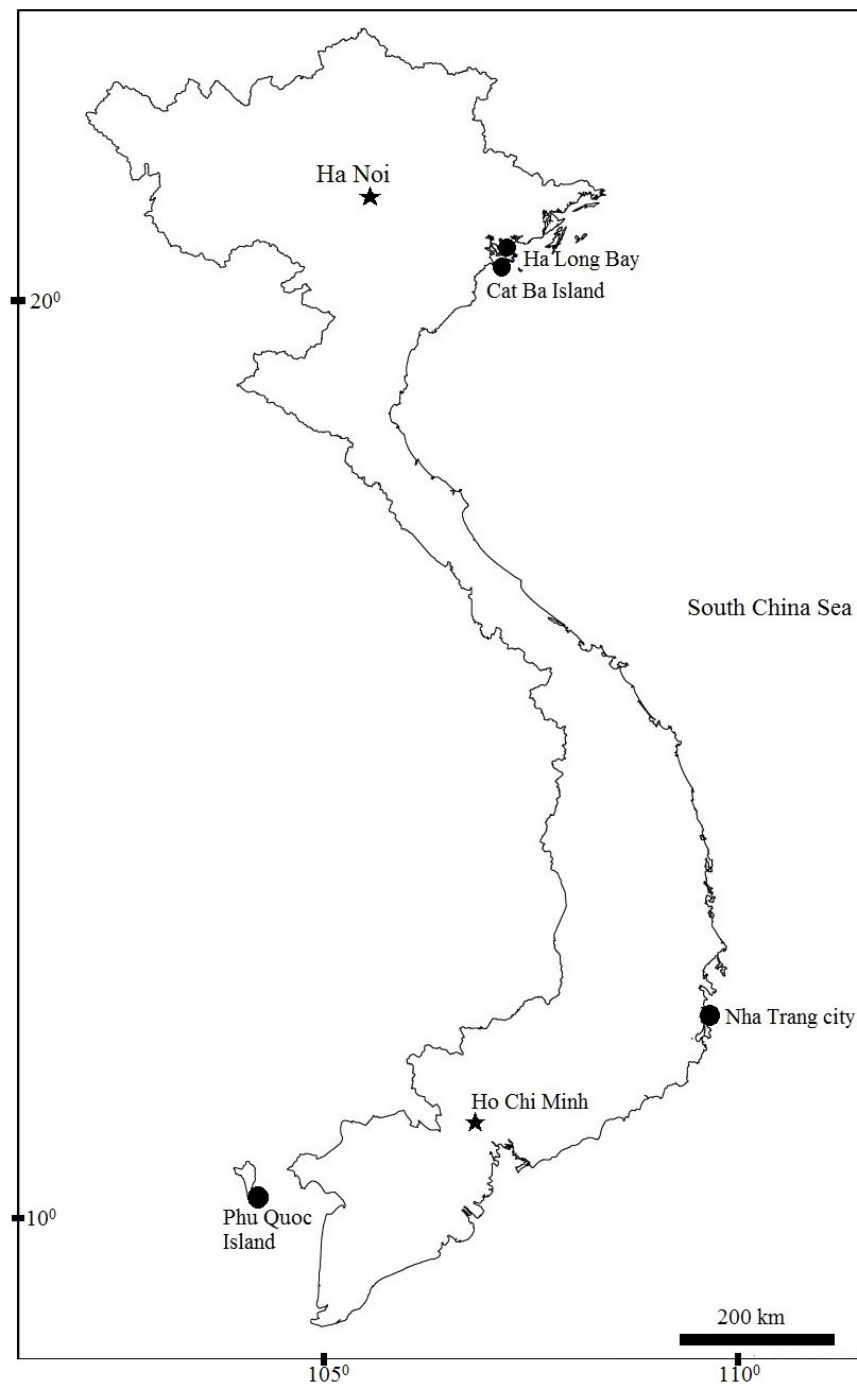


FIGURE 2. Sampling sites in Vietnam with solid circles. Details of occurrence are shown in Table 1.

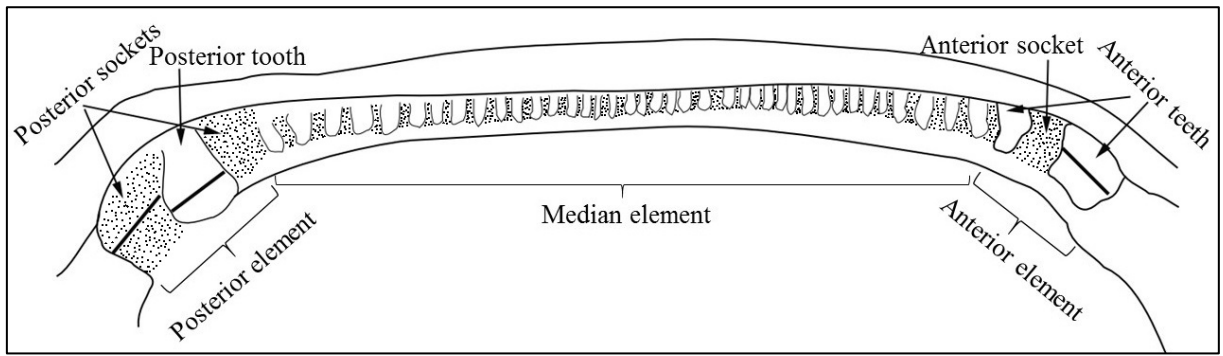


FIGURE 3. Scheme of hinge structure of left valve of female in *Loxoconcha* sp. 8.

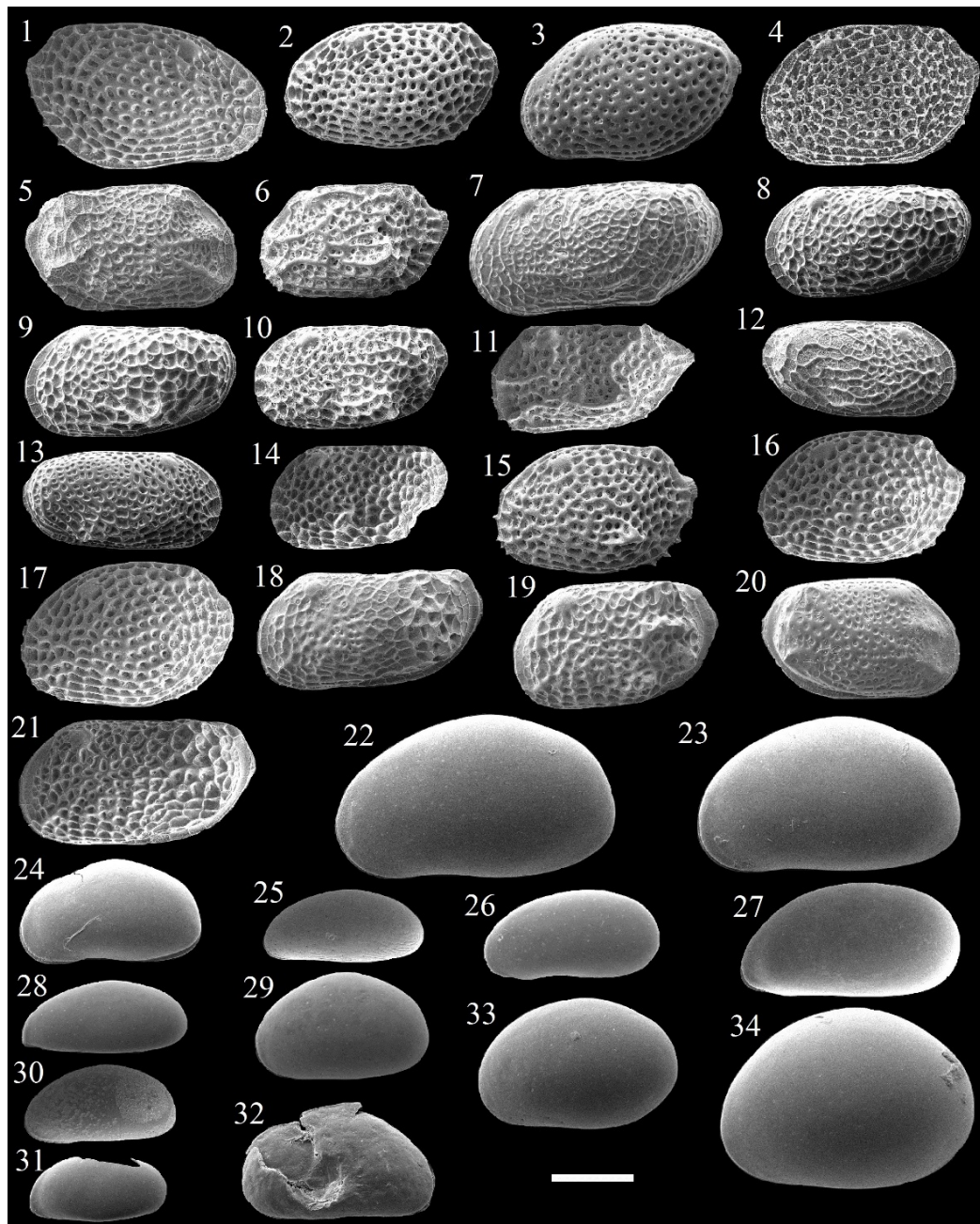


FIGURE 4. External view of examined ostracod carapaces from Okinawa Island, southern Japan. 1, *Loxoconcha japonica* (male, RV); 2, *L. shanghaiensis* (male, LV); 3, *L. lilljeborgii* (male, LV); 4, *L. tumulosa* (male, LV; after Tanaka & Ikeya, 2002); 5, *L. sp. 1* (female, RV); 6, *L. sp. 7* (LV); 7, *L. kosugii* (male, LV); 8, *L. noharai* (male, LV); 9, *L. santosi* (male, LV); 10, *L. sp. 3* (male, LV); 11, *L. sp. 13* (LV); 12, *L. sp. Y* (male, RV); 13, *L. sesokoensis* (male, RV); 14, *L. sp. 6* (LV); 15, *L. sp. 8* (LV); 16, *L. sp. 9* (LV); 17, *L. sp. 10* (LV); 18, *L. sp. 14* (LV); 19, *L. sp. 15* (LV); 20, *L. sp. 16* (RV); 21, *L. sp. 17* (LV); 22, *Xestoleberis hanaii* (male, LV); 23, *X. sesokoensis* (male, LV); 24, *X. ryukyuensis* (male, LV); 25, *X. planuventer* (female, LV); 26, *X. ikeya* (LV); 27, *X. sp. 1* (female, LV); 28, *X. sp. 2* (female, LV); 29, *X. sp. 3* (LV); 30, *X. sp. 4* (LV); 31, *X. sp. 5* (female, LV); 32, *X. sp. 6* (male, RV); 33, *X. kuroshio* (male, LV); 34, *X. magnoculus* (female, LV). Scale: 200 μ m. Abbreviations: LV, left valve; RV, right valve.

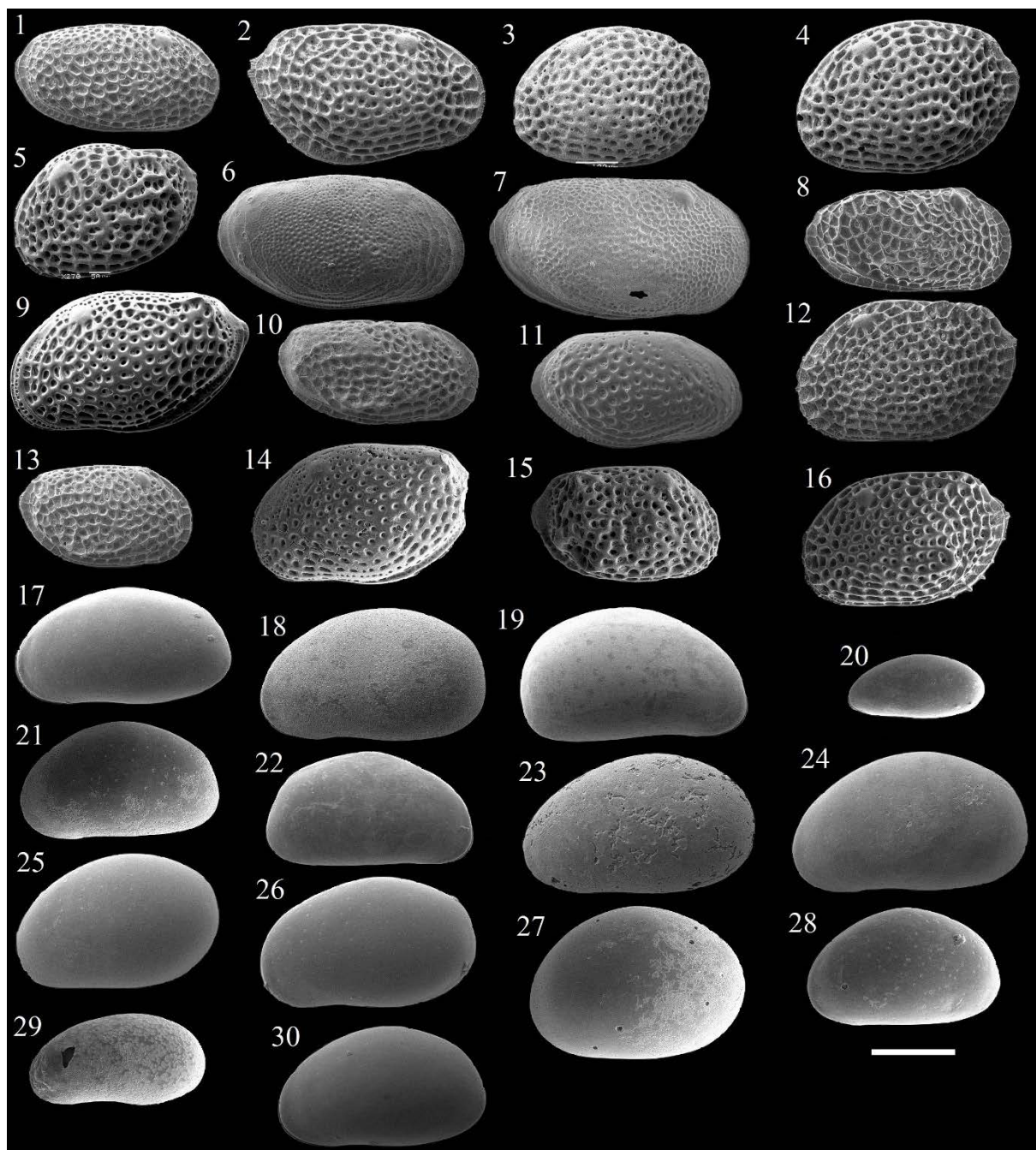


FIGURE 5. External view of examined ostracod carapaces from Vietnam. 1, *Loxoconcha* sp. 11 (male, RV); 2, *L.* sp. 18 (male, RV); 3, *L.* sp. 19 (LV); 4, *L.* sp. 20 (LV); 5, *L.* sp. 21 (LV); 6, *L.* sp. 22 (male, RV); 7, *L. ocellata* (male, RV; after Tanaka et al., 2009); 8, *L. vietnamensis* (male, RV); 9, *L.* sp. 12 (male, RV); 10, *L.* sp. 23 (RV); 11, *L.* sp. 24 (LV); 12, *L.* sp. 25 (LV); 13, *L.* sp. 26 (female, RV); 14, *L. lilljeborgii?* (LV); 15, *L.* sp. 28 (RV); 16, *L.* sp. 29 (LV); 17, *Xestoleberis* sp. 7 (male, LV); 18, *X.* sp. 9 (LV); 19, *X.* sp. 10 (RV); 20, *X.* sp. 11 (LV); 21, *X.* sp. 12 (LV); 22, *X.* sp. 8 (male, RV); 23, *X.* sp. 13 (LV); 24, *X.* sp. 14 (LV); 25, *X.* sp. 15 (LV); 26, *X.* sp. 16 (LV); 27, *X.* sp. 17 (LV); 28, *X.* sp. 18 (LV); 29, *X.* sp. 19 (LV); 30, *X.* sp. 20 (male, LV). Scale: 200 μ m. Abbreviations: LV, left valve; RV, right valve.

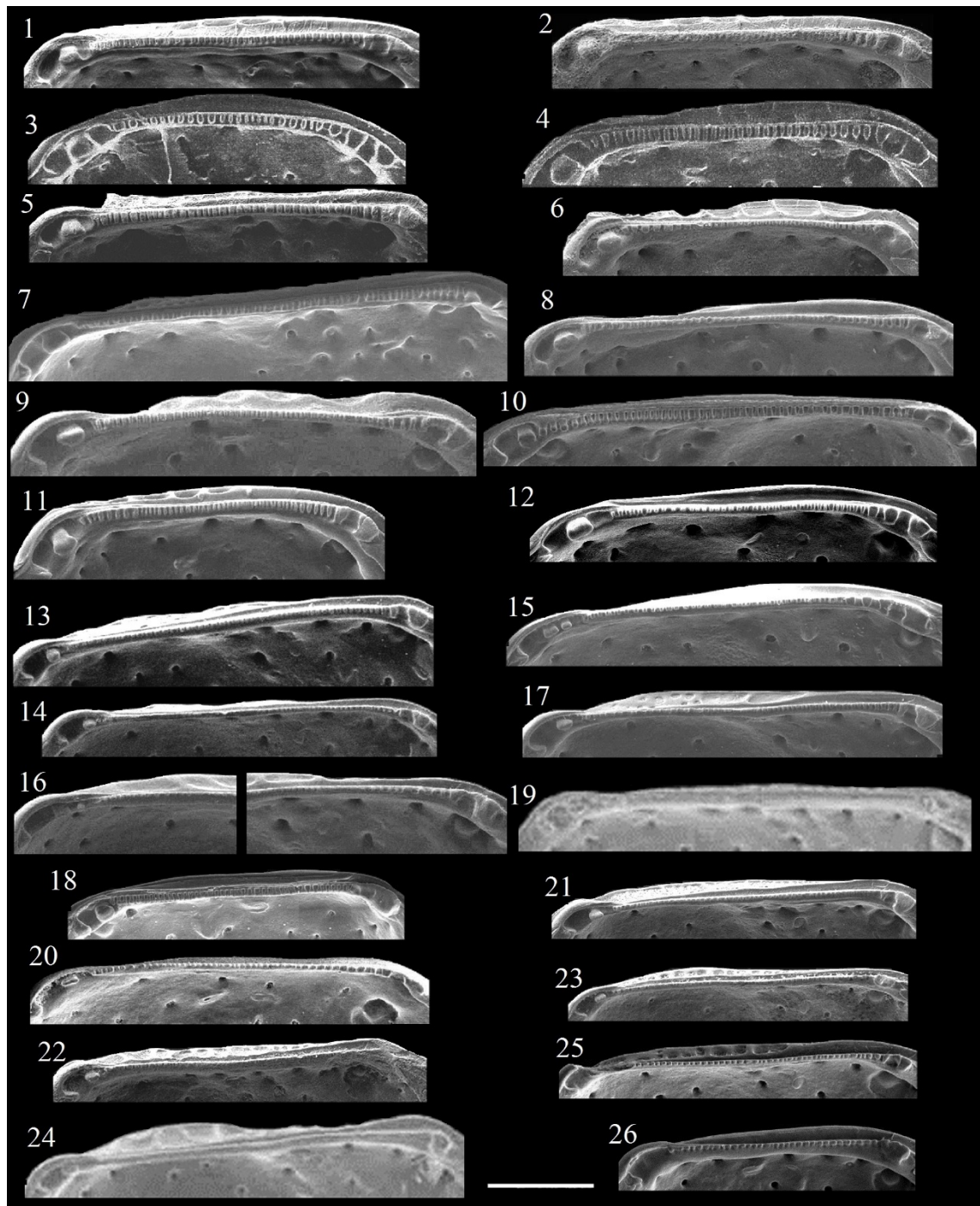


FIGURE 6. Internal view of hingement of 25 species in the genus *Loxoconcha*. 1, *L. japonica* (male, LV); 2, *L. shanhaiensis* (male, LV); 3, *L. lilljeborgii* (female, LV; after Tanaka & Ikeya, 2002); 4, *L. tumulosa* (female, LV; after Tanaka & Ikeya, 2002); 5, *L. sp. 1* (male, LV); 6, *L. sp. 7* (LV); 7, *L. mutsuensis* (male, LV); 8, *L. harimensis* (LV); 9, *L. tosaensis* (male, LV); 10, *L. modesta* (male, RV); 11, *L. sp. 8* (female, LV); 12, *L. sp. 12* (male, LV); 13, *L. noharai* (male, LV); 14, *L. santosi* (male, LV); 15, *L. pulchra* (male, LV); 16, *L. kosugii* (male, LV); 17, *L. uranouchiensis* (male, LV); 18, *L. sp. 5* (female, LV); 19, *L. ocellata* (male, LV; after Tanaka et al., 2009); 20, *L. sp. 4* (LV); 21, *L. sp. Y* (male, LV); 22, *L. sp. 3* (male, LV); 23, *L. sesokoensis* (male, LV); 24, *L. vietnamensis* (male, LV); 25, *L. sp. 26* (male, LV); 26, *L. sp. 26* (female, LV). Scale: 100 μ m. Abbreviations: LV, left valve; RV, right valve.

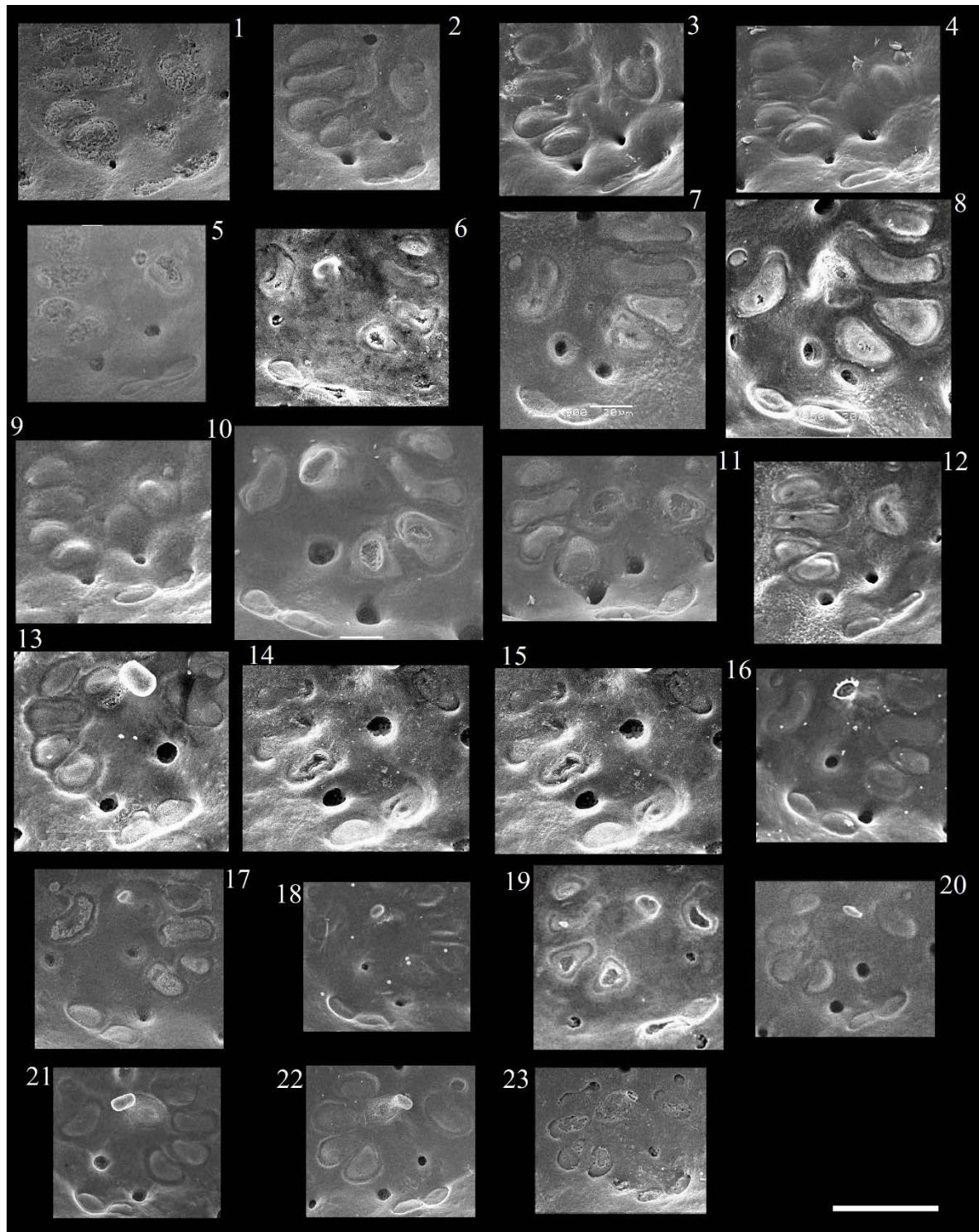


FIGURE 7. Muscle scars of 23 species of the genus *Loxoconcha*. 1, *L. shanghaiensis* (male, LV); 2, *L. sp. 1* (male, LV); 3, *L. japonica* (male, LV); 4, *L. sp. 9* (LV); 5, *L. sp. 10* (LV); 6, *L. sp. 30* (RV); 7, *L. mutsuensis* (male, RV); 8, *L. modesta* (male, RV); 9, *L. tosaensis* (male, RV); 10, *L. harimensis* (LV); 11, *L. sp. 8* (female, LV); 12, *L. sp. 12* (male, LV); 13, *L. pulchra* (male, LV); 14, *L. kosugii* (male, LV); 15, *L. uranouchiensis* (male, LV); 16, *L. noharai* (male, RV); 17, *L. santosi* (male, RV); 18, *L. sp. 5* (female, RV); 19, *L. sp. 4* (LV); 20, *L. sp. 26* (male, LV); 21, *L. sesokoensis* (male, RV); 22, *L. sp. Y* (male, LV); 23, *L. sp. 3* (male, LV). Scale: 100 μ m. Abbreviations: LV, left valve; RV, right valve.

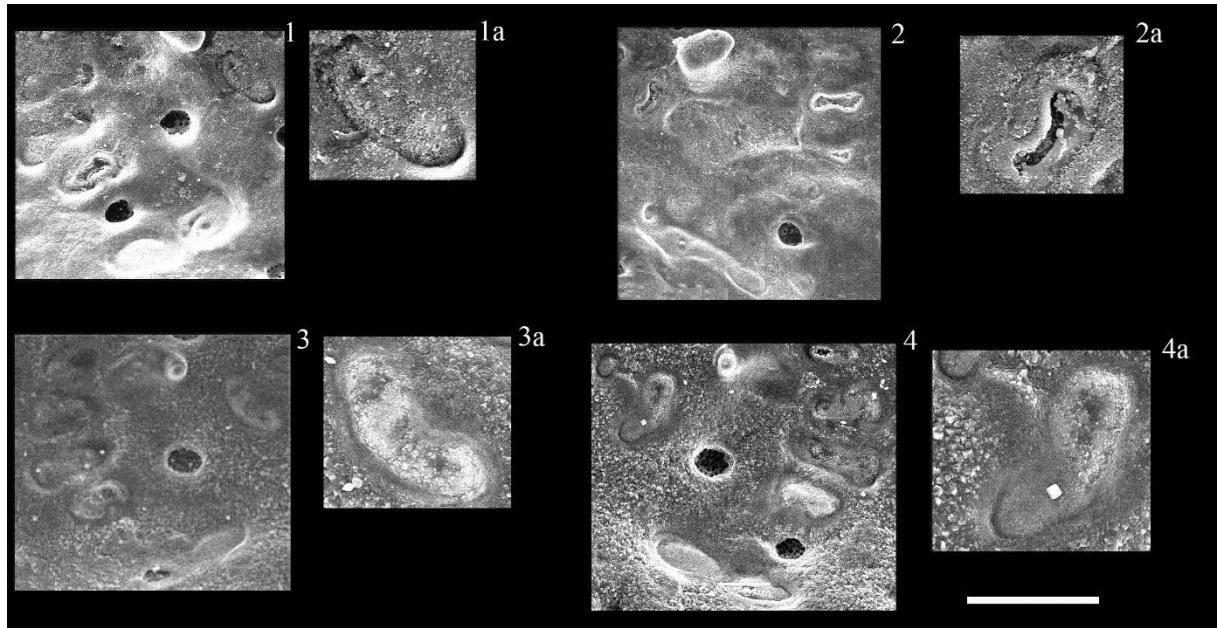


FIGURE 8. Muscle scars of *Loxoconcha kosugii*. 1, male, left valve; 2, male, right valve; 3, female, left valve; 4, female, right valve. 1a–4a, frontal muscle scar of 1–4, respectively. Scale: 50 μm for 1–4; 20 μm for 1a–4a.

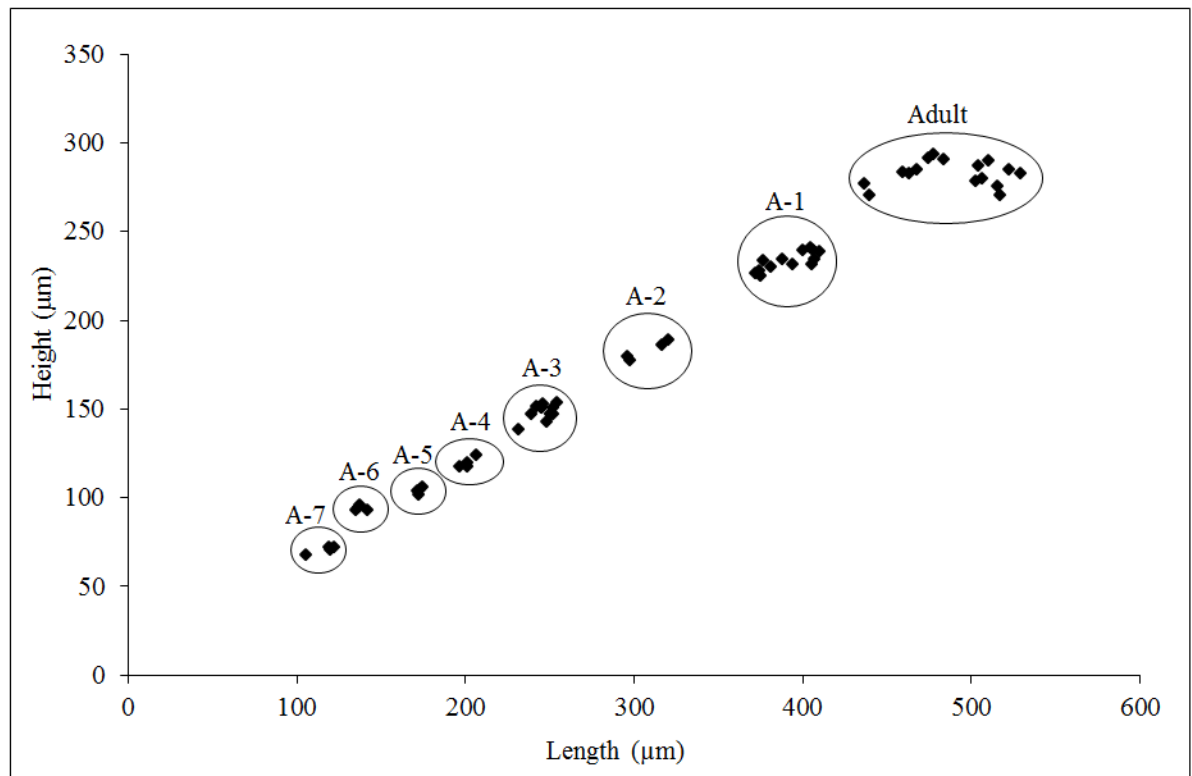


FIGURE 9. Carapace size of eight instars of *Loxoconcha noharai*.

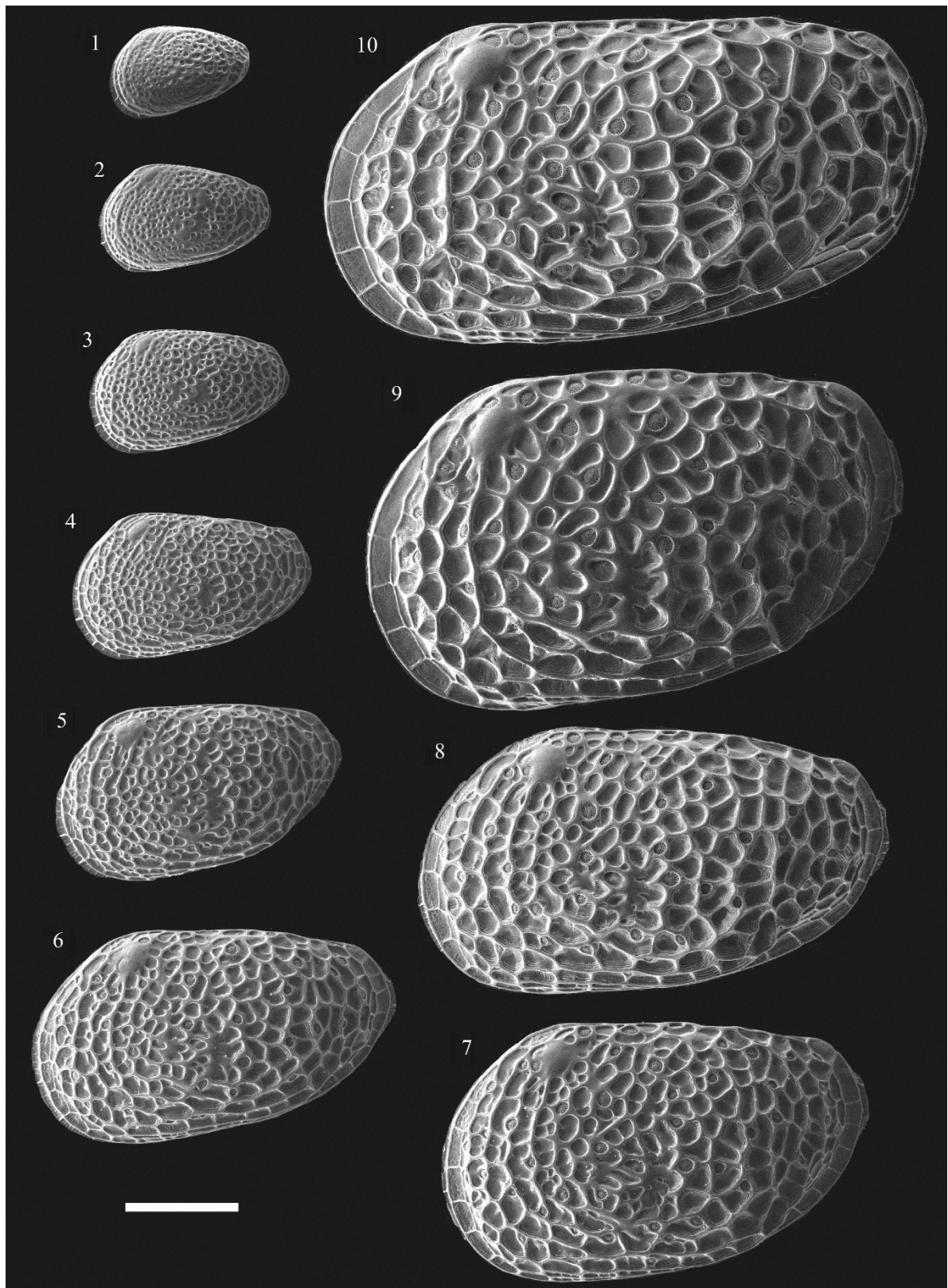


FIGURE 10. Left valve in external lateral view of *Loxoconcha noharai*. 1, A-7 (SUM-CO-01, paratype); 2, A-6 (SUM-CO-02, paratype); 3, A-5 (SUM-CO-03, paratype); 4, A-4 (SUM-CO-04, paratype); 5, A-3 (SUM-CO-05, paratype); 6, A-2 (SUM-CO-06, paratype); 7, female of A-1 (SUM-CO-07, paratype); 8, male of A-1 (SUM-CO-08, paratype); 9, female of adult (SUM-CO-09, paratype); 10, male of adult (SUM-CO-10, paratype). Scale: 100 μ m.

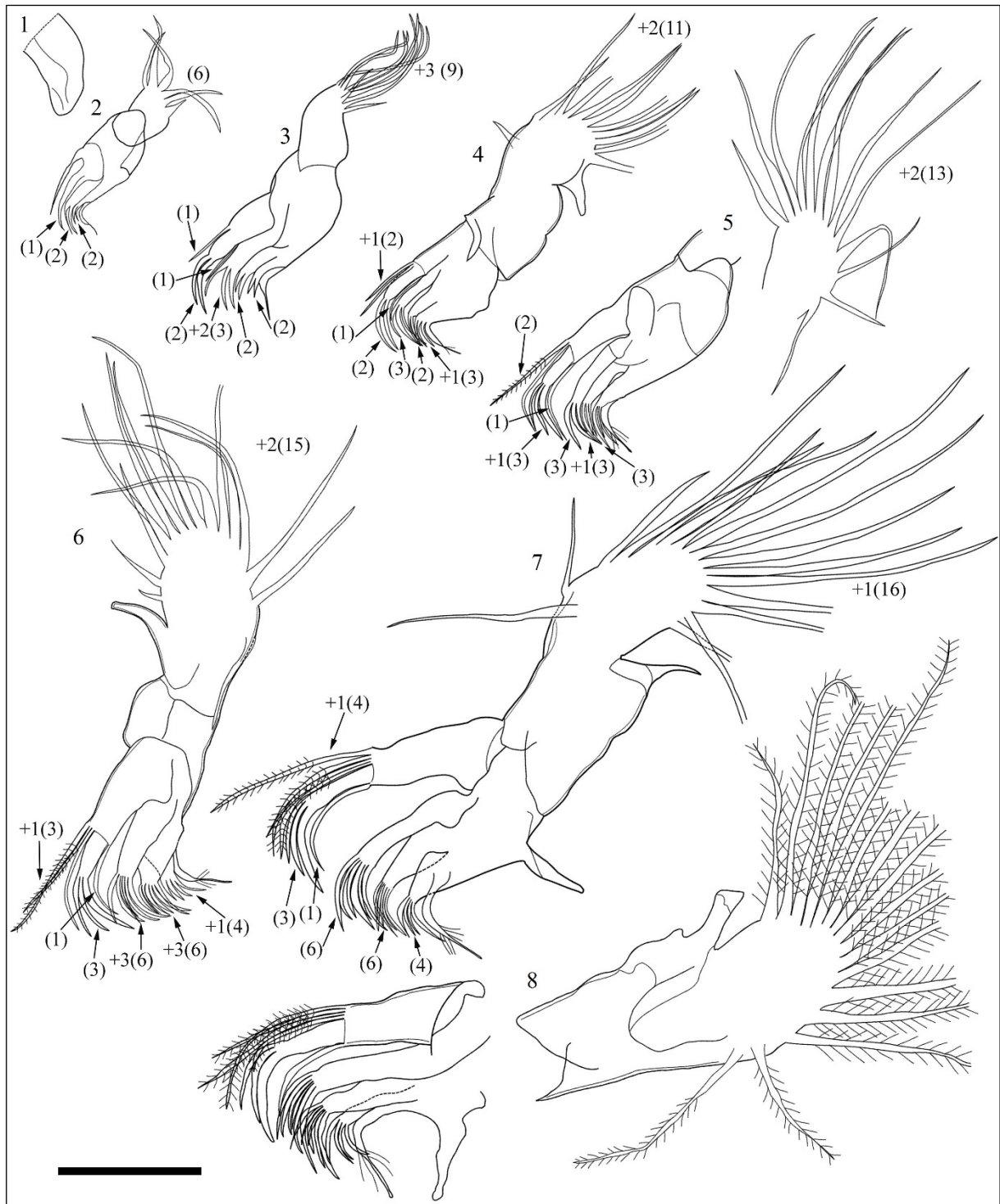


FIGURE 11. Morphology of maxillula of *Loxoconcha noharai* in each instar. 1, A-7 (SUM-CO-11, paratype); 2, A-6 (SUM-CO-12, paratype); 3, A-5 (SUM-CO-13, paratype); 4, A-4 (SUM-CO-14, paratype); 5, A-3 (SUM-CO-15, paratype); 6, A-2 (SUM-CO-16, paratype); 7, A-1 (SUM-CO-17, paratype); 8, adult (SUM-CO-18, paratype). Bracketed figures indicate the number of setae and figures outside of brackets indicate the additional setae comparing with prior instar. Scale: 50 μ m.

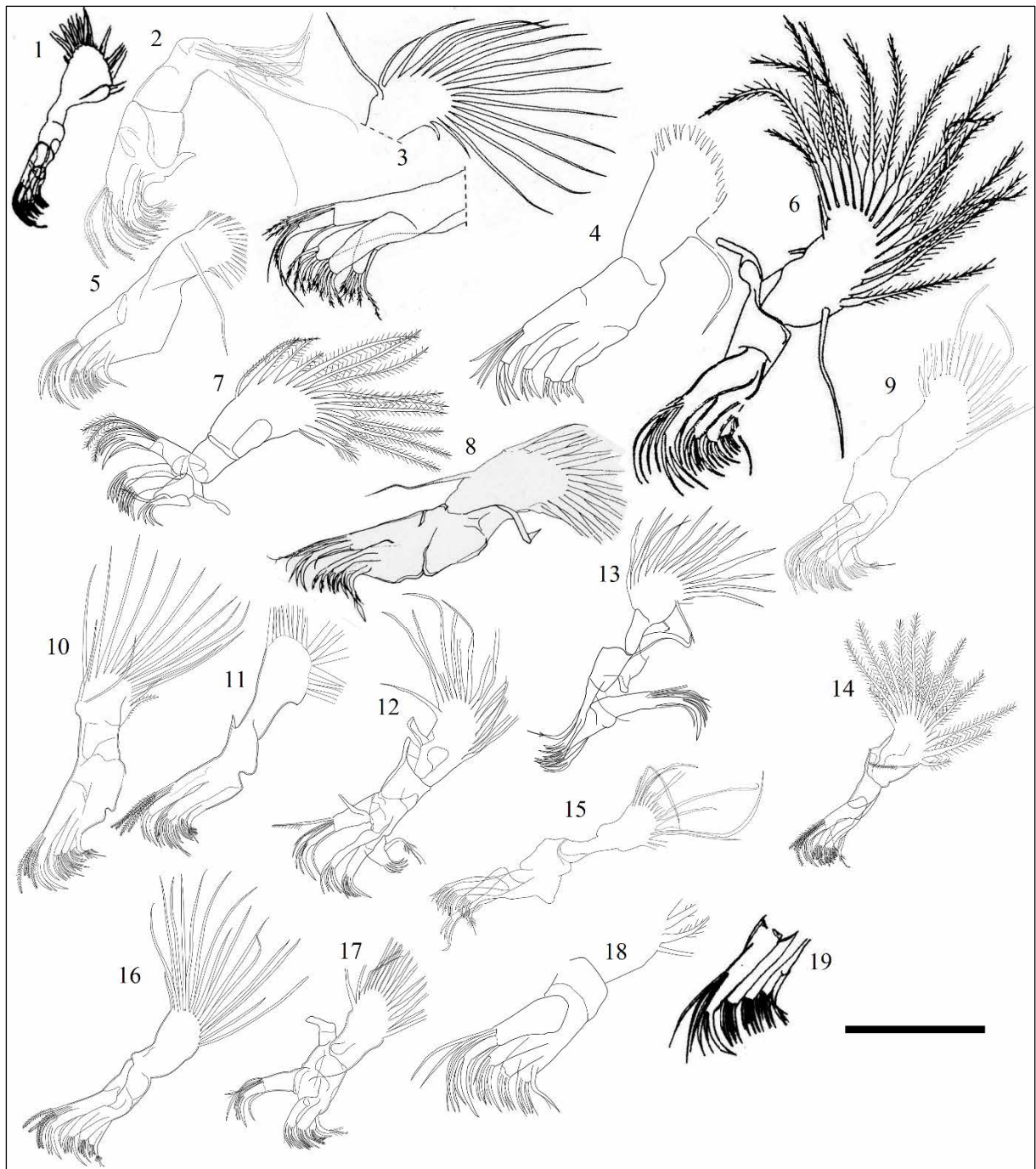


FIGURE 12. Morphology of maxillula in 19 species of the genus *Loxoconcha*. 1, *L. shanhaiensis* (male, after Tanaka & Ikeya, 2002); 2, *L. mutsuensis* (male); 3, *L. japonica* (male, after Smith & Kamiya, 2003); 4, *L. rhomboidea* (adopted from Athersuch et al., 1989); 5, *L. harimensis* (adopted from Okubo, 1980); 6, *L. elliptica* (after from Athersuch et al., 1989); 7, *L. sp. 12* (male); 8, *L. pulchra* (male, after Nakao & Tsukagoshi, 2005); 9, *L. kosugii* (male); 10, *L. noharai* (male); 11, *L. santosi* (male); 12, *L. uranouchiensis* (male); 13, *L. sp. 11* (male); 14, *L. sp. Y* (male); 15, *L. sp. 3* (male); 16, *L. sesokoensis* (male); 17, *L. vietnamensis* (male); 18, *L. bizenensis* (adopted from Okubo, 1980); 19, *L. dampierensis* (after Hartmann & Hartmann, 1978). Scale: 100 μ m.

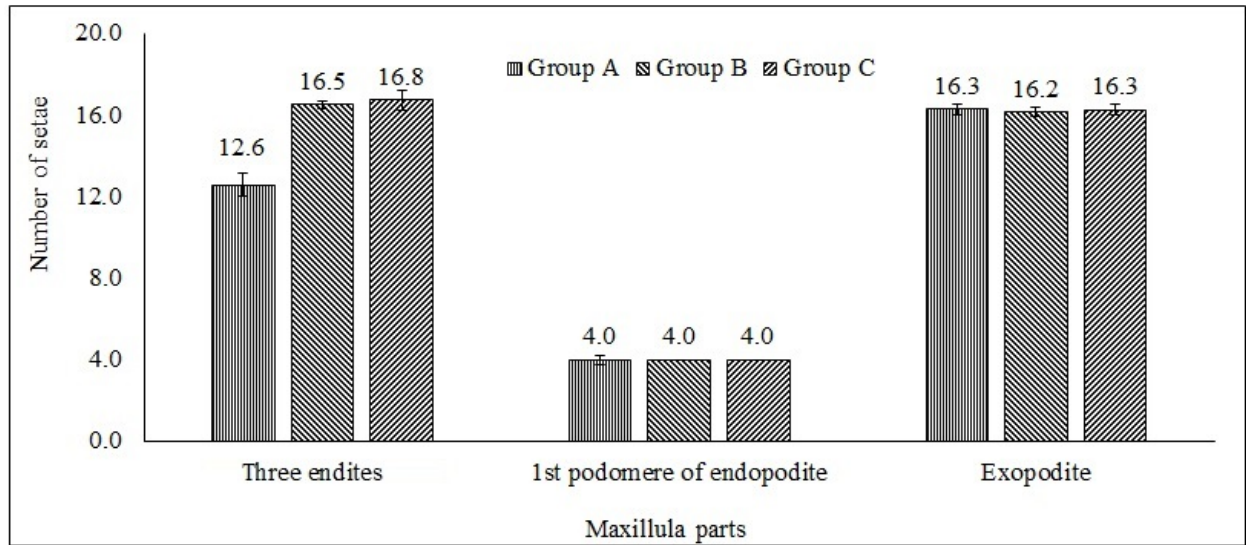


FIGURE 13. Comparison of average number of setae of three endites, the 1st podomere of the endopodite and exopodite on adult maxillula among three groups of the genus *Loxoconcha*.

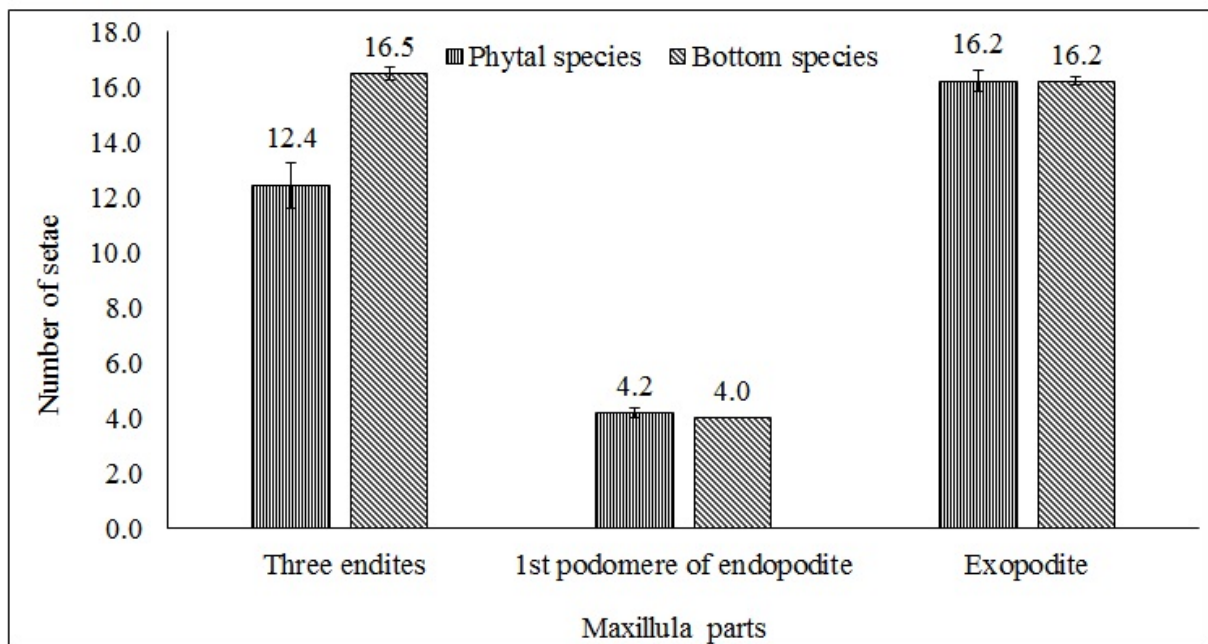


FIGURE 14. Comparison of the average number of setae of three endites, the 1st podomere of the endopodite and exopodite on adult maxillula between the two habitats of the genus *Loxoconcha*.

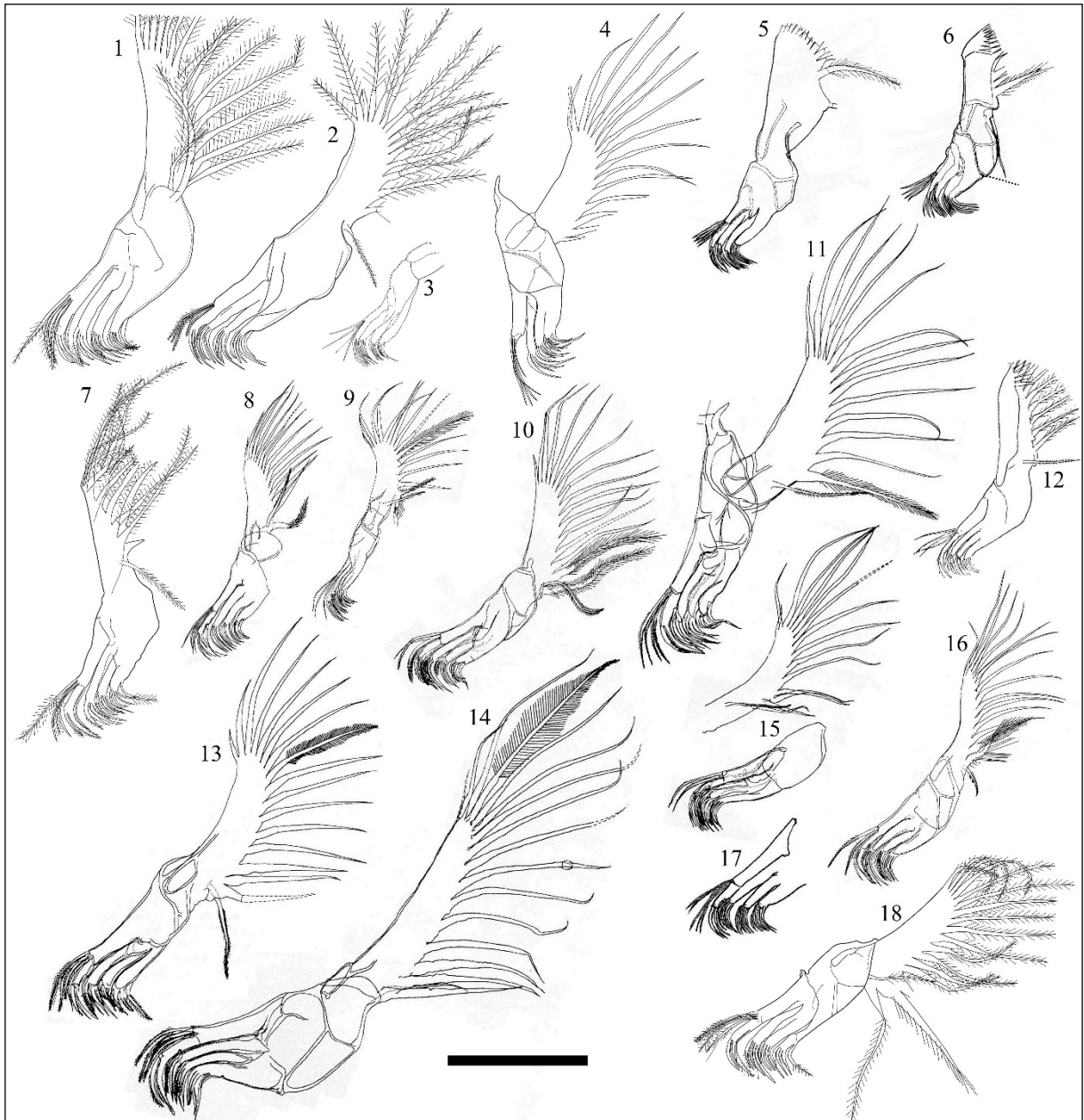


FIGURE 15. Adult maxillula in 18 species of the genus *Xestoleberis*. 1, *X. hanaii* (male); 2, *X. sp. 1* (female); 3, *X. sp. 5* (male); 4, *X. sp. 7* (male); 5, *X. maguitiensis*; 6, *X. kamiya*; 7, *X. sp. 8* (male); 8, *X. ikeya* (male); 9, *X. planuventer* (male); 10, *X. ryukyuensis* (male); 11, *X. sesokoensis* (male); 12, *X. setouchiensis* (male); 13, *X. kuroshio*; 14, *X. magnoculus* (male); 15, *X. notoensis* (male); 16, *X. sagamiensis* (male); 17, *X. inabai* (male); 18, *X. sp. 20* (male). 8–11, 13–16, after Sato & Kamiya (2007); 12, after Okubo (1979); 17, after Okubo (1985). Scale: 100 μ m.



FIGURE 16. Adult mandible in 18 species of the genus *Xestoleberis*. 1, *X. hanaii* (male); 2, *X. sp. 1* (female); 3, *X. sp. 6* (male); 4, *X. sp. 7* (male); 5, *X. magutiensis*; 6, *X. kamiya*; 7, *X. sp. 8* (male); 8, *X. ikeya* (male); 9, *X. planuventer* (male); 10, *X. ryukyuensis* (male); 11, *X. sesokoensis* (male); 12, *X. setouchiensis* (male); 13, *X. kuroshio*; 14, *X. magnoculus* (male); 15, *X. notoensis* (male); 16, *X. sagamiensis* (male); 17, *X. inabai* (male); 18, *X. sp. 20* (male). 8–11, 13–16, after Sato & Kamiya (2007); 12, after Okubo (1979); 17, after Okubo (1985). Scale: 100 μ m.

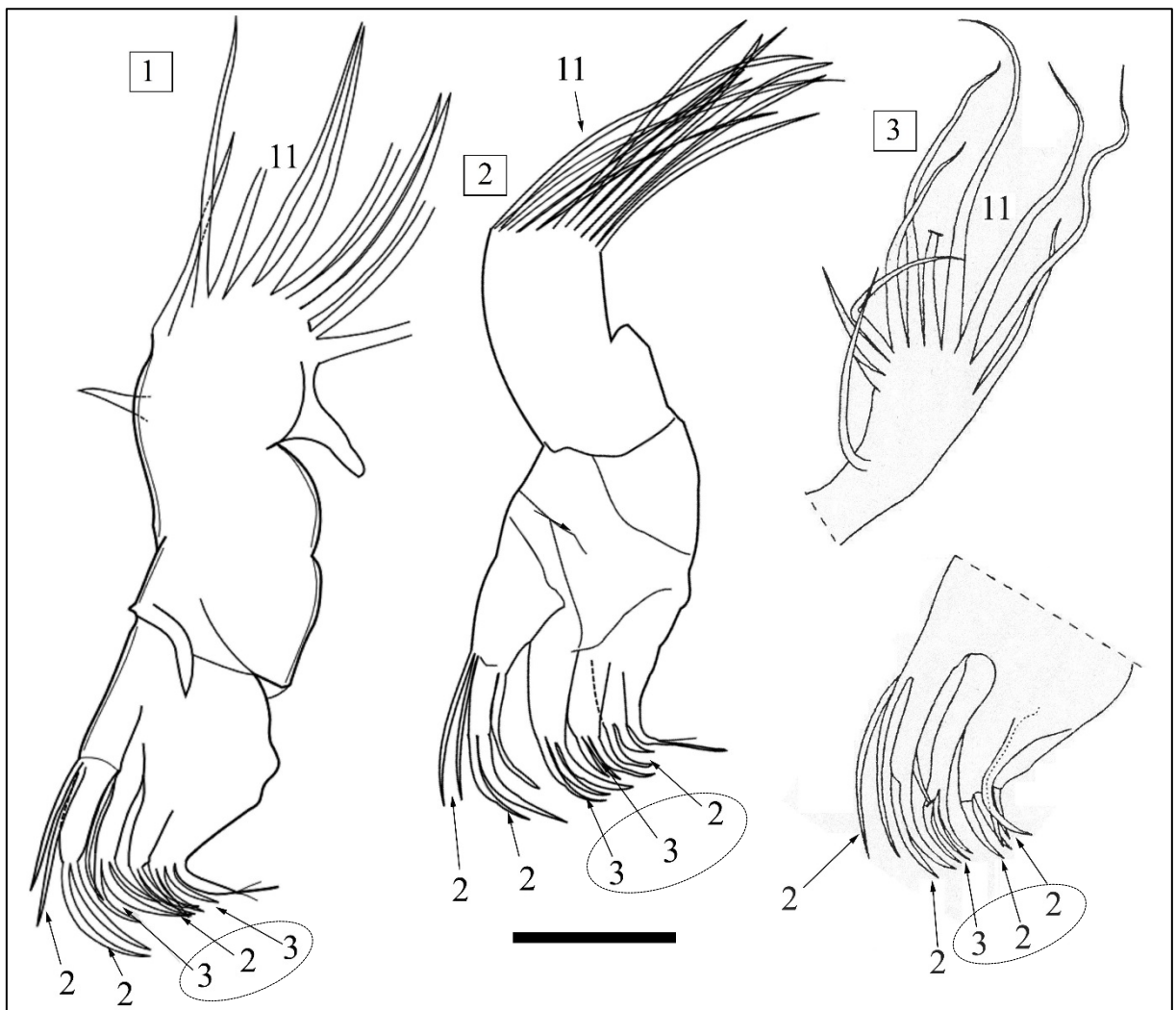


FIGURE 17. Maxillula in instar A-4 showing difference in the number of setae of three endites among three species: 1, *Loxoconcha noharai*; 2, *L. sesokoensis*; 3, *L. japonica* (after Smith & Kamiya, 2003). Scale: 25 μ m.

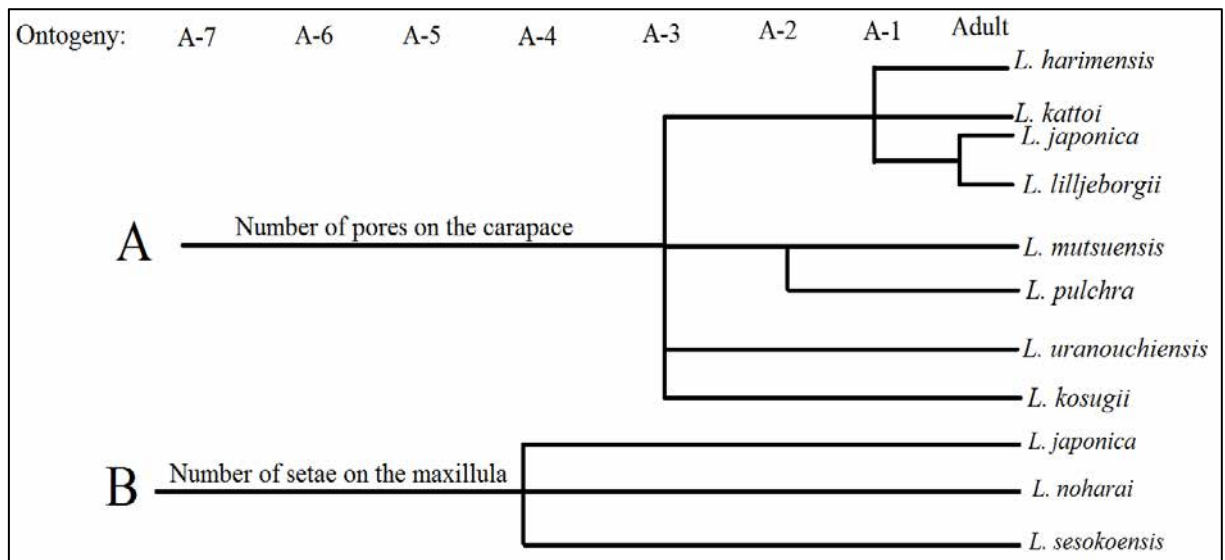


FIGURE 18. Phylogenetic relationship among three groups of the genus *Loxoconcha*. A, from the number of pores on the carapace (adapted from Ishii et al., 2005); B, from the number of setae on the maxillula (data of *L. japonica* is taken from Smith & Kamiya, 2003).

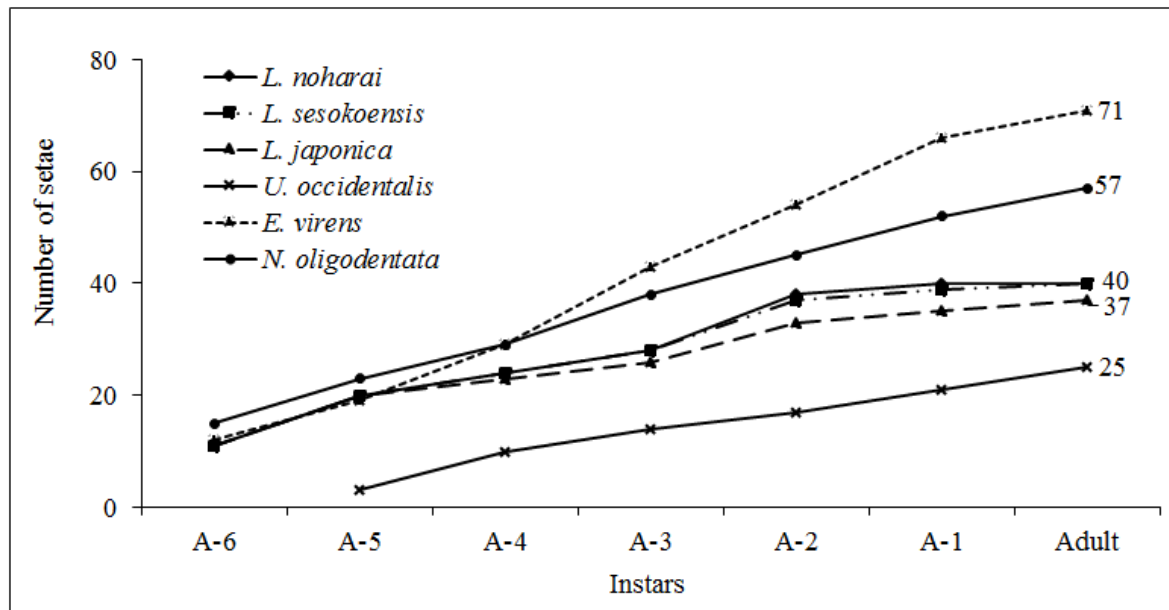


FIGURE 19. Total number of setae on maxillula in *Loxoconcha noharai*, *L. japonica*, *Ucinocythere occidentalis*, *Eucypris virens* and *Neonesidea oligodentata* through ontogenetic stages. Data on *L. japonica* is adopted from Smith & Kamiya (2003), *U. occidentalis* adopted from Smith & Kamiya (2005), *E. virens* adopted from Smith & Martens (2000) and Smith et al. (2005), and *N. oligodentata* adopted from Smith & Kamiya (2002).

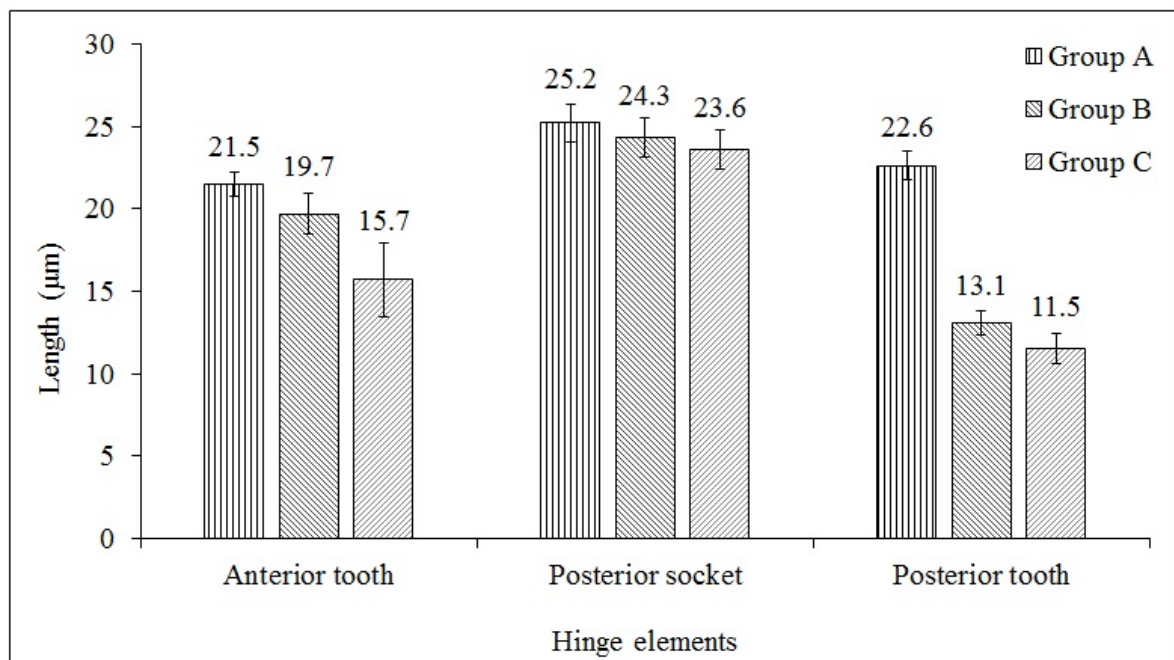


FIGURE 20. Comparison of length of hinge elements of left valve among three groups of the genus *Loxoconcha*.

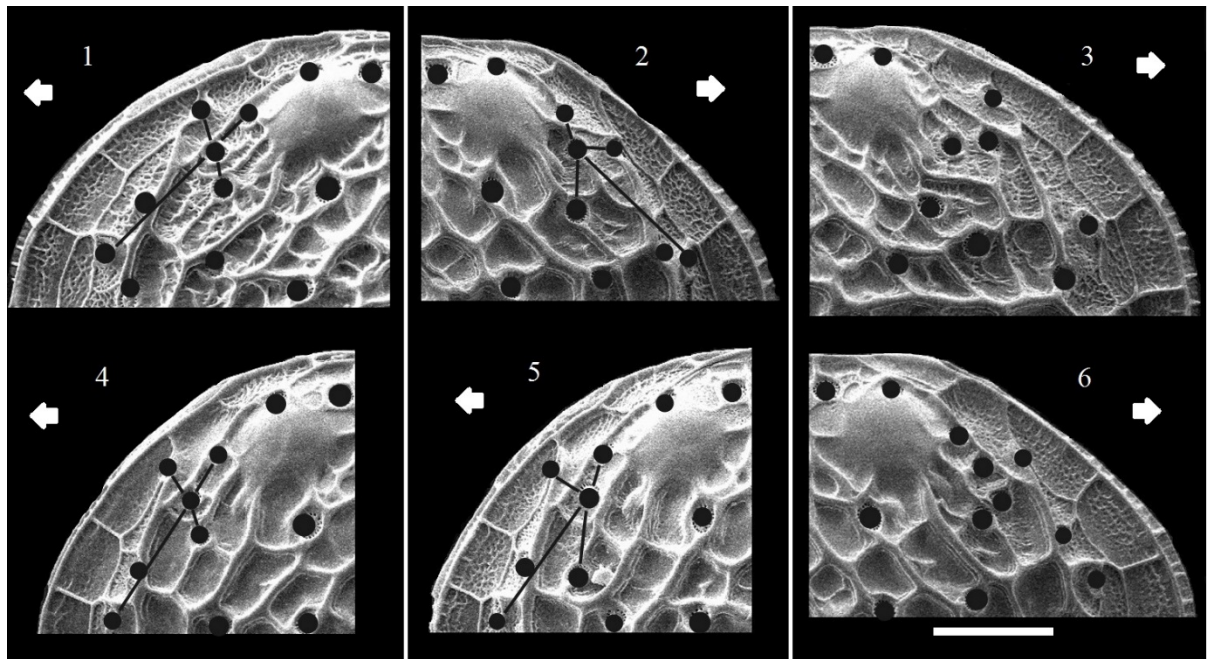


FIGURE 21. Intraspecific variation of patterns of pore systems below eye tubercle in *Loxoconcha* sp. Y. 1, male left valve (TEM-CO-31, paratype); 2, female right valve (TEM-CO-24, paratype); 3, male right valve (TEM-CO-31, paratype); 4, female left valve (TEM-CO-32, paratype); 5, female left valve (TEM-CO-24, paratype); 6, male right valve (TEM-CO-33, paratype). Scale: 50 μ m.

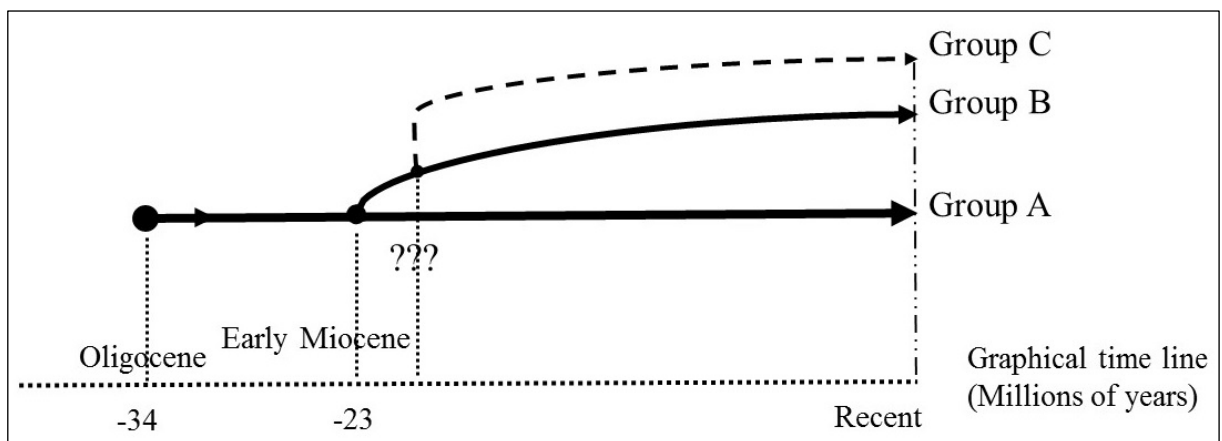


FIGURE 22. Evolutionary relationship of three groups of the genus *Loxoconcha*.

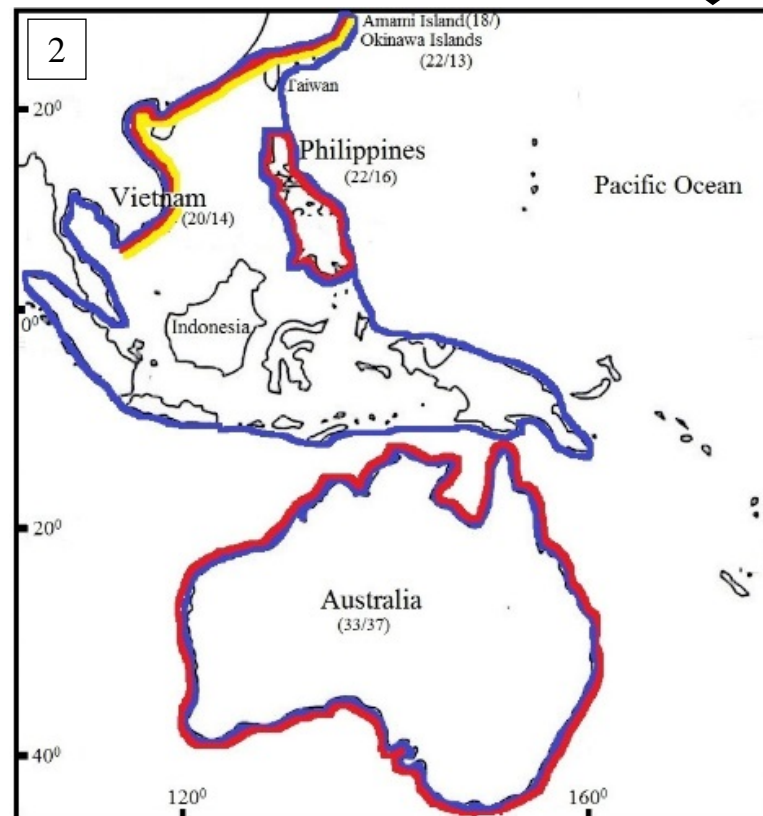
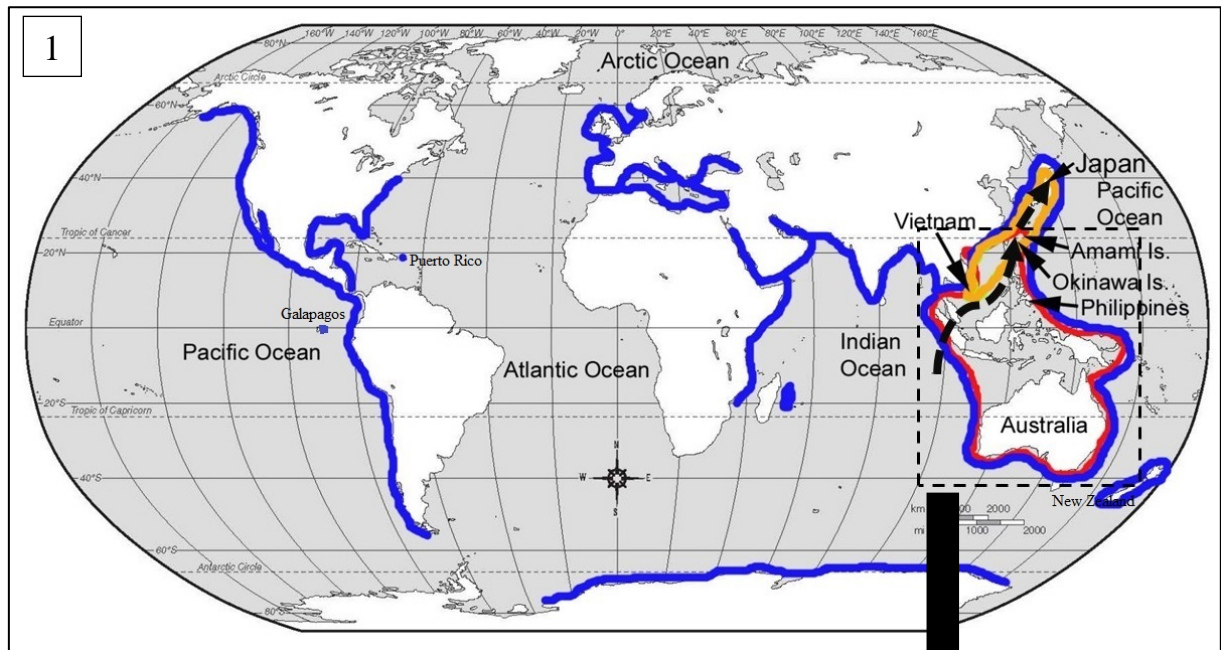


FIGURE 23. Geographical distribution of three groups and suggested migratory route of the genus *Loxoconcha*. Group A, blue colour; Group B, yellow colour; Group C, red colour; migratory route, black dot arrows.

1, in the World.

2, within the “hot-spot” of *Loxoconcha* biodiversity, bracketed figures indicate the number of species of *Loxoconcha* (numerator) and of *Xestoleberis* (denominator).

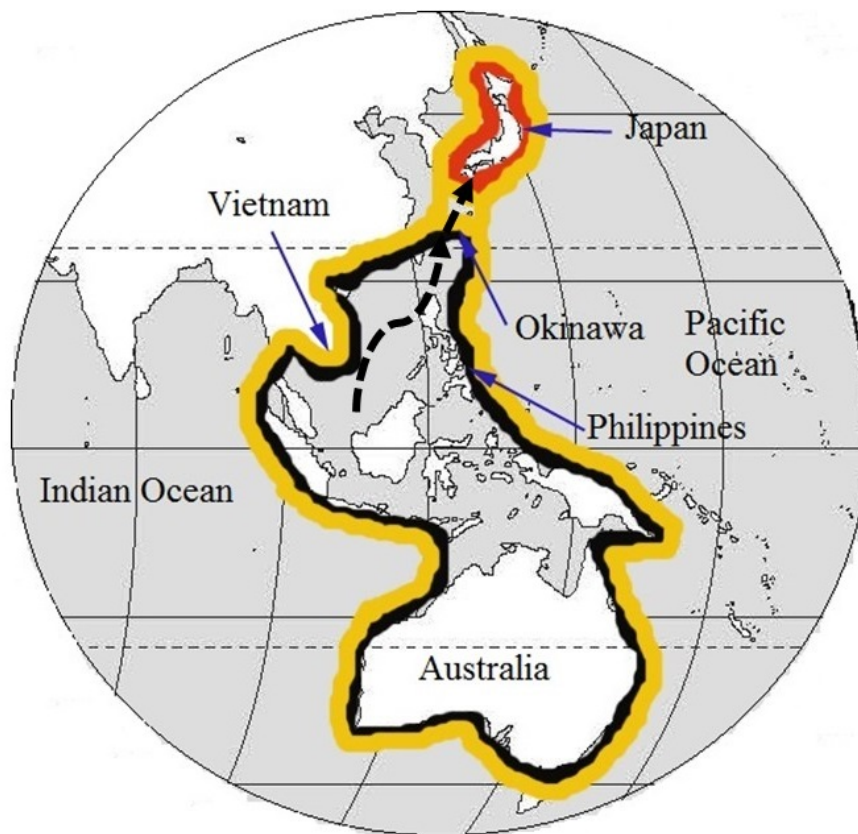


FIGURE 24. Geographical distribution of three groups and suggested migratory route of the genus *Xestoleberis*. Group A, yellow colour; Group B, red colour; Group C, black colour; migratory route, black dot arrows.

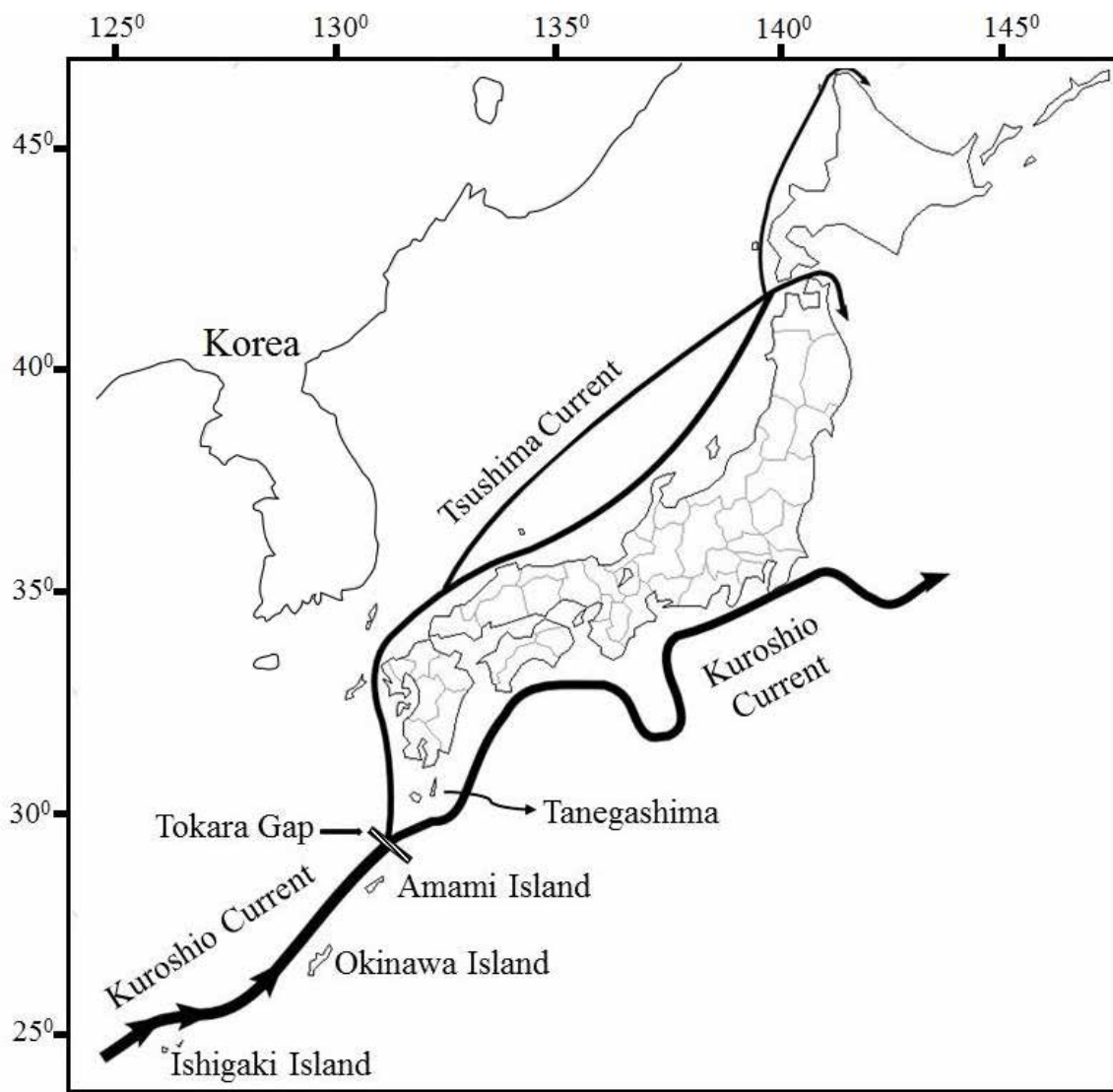


FIGURE 25. Map of ocean current around Japanese Archipelago showing with Kuroshio Current and Tokara gap. Compiled from Oba et al. (1991), Ogoh & Ohmiya (2005), Sato & Kamiya (2007) and Tanaka (2012).

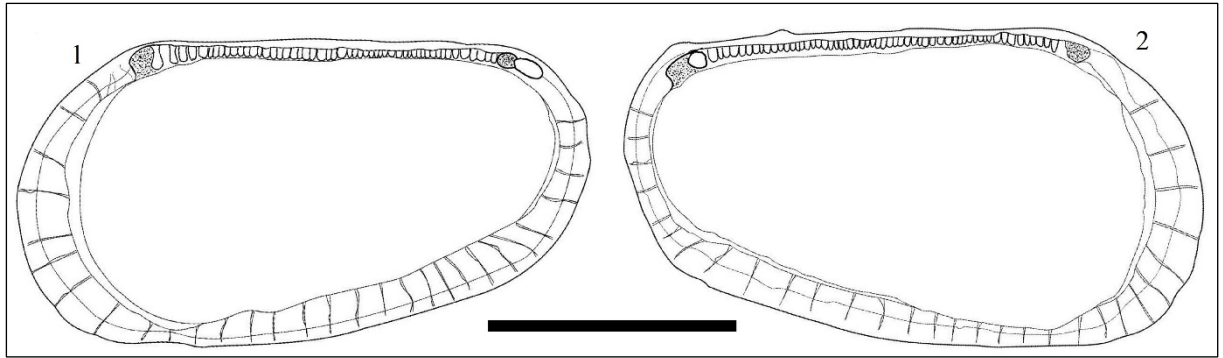


FIGURE 26. Carapace of *Loxoconcha noharai* Le & Tsukagoshi, 2014. 1, male right valve in internal lateral view (SUM-CO-2135, paratype); 2, male left valve in internal lateral view (SUM-CO-2136, paratype). Scale: 200 μ m.

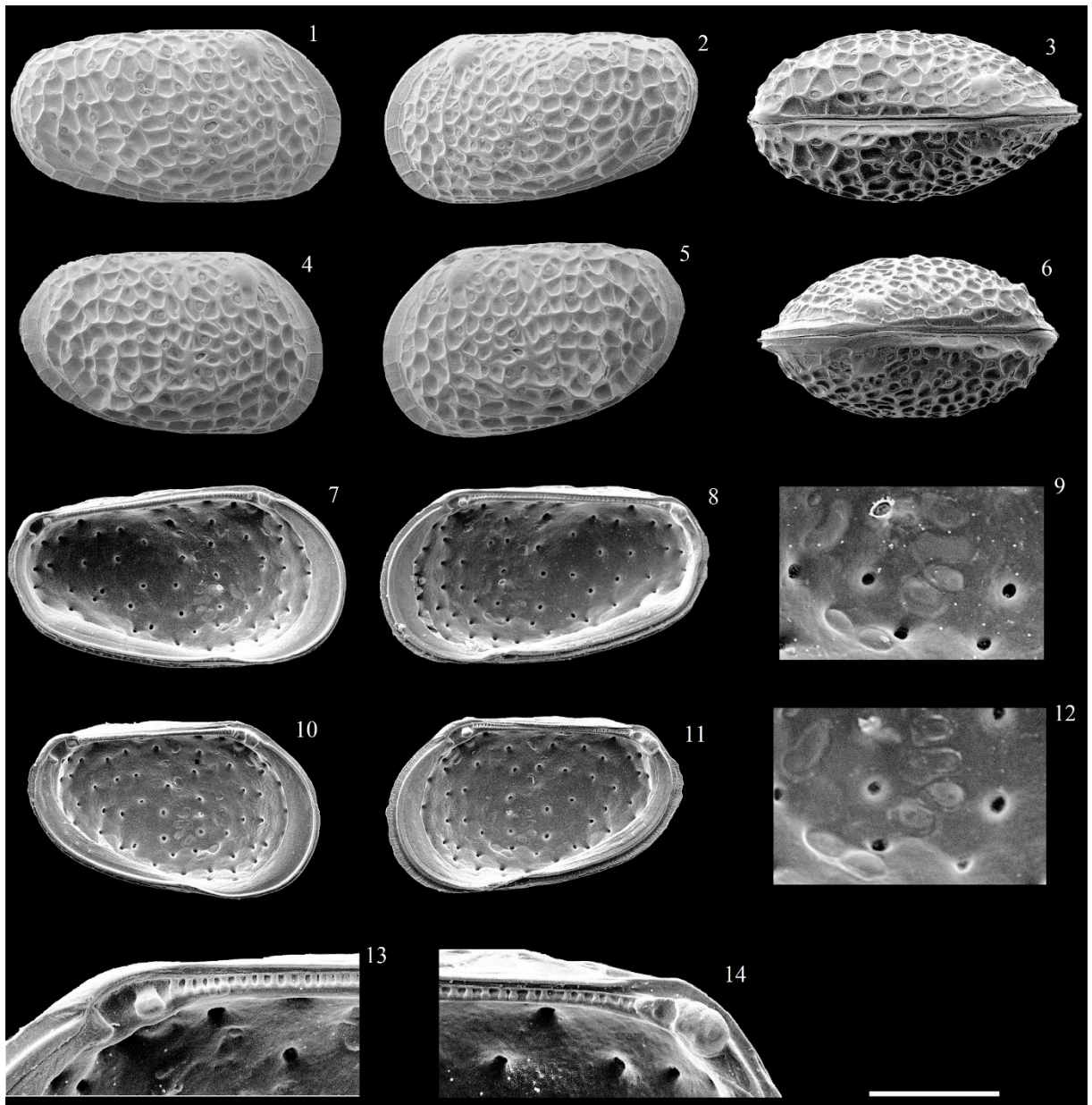


FIGURE 27. Carapace of *Loxoconcha noharai* Le & Tsukagoshi, 2014. 1, male right valve in external lateral view (SUM-CO-2137, holotype); 2, male left valve in external lateral view (SUM-CO-2138, paratype); 3, male carapace in dorsal view (SUM-CO-2139, paratype); 4, female right valve in external lateral view (SUM-CO-2140, paratype); 5, female left valve in external lateral view (SUM-CO-2141, paratype); 6, female carapace in dorsal view (SUM-CO-2142, paratype); 7, male left valve in internal lateral view (SUM-CO-2143, paratype); 8, male right valve in internal lateral view (SUM-CO-2144, paratype); 9, muscle scars of male right valve (SUM-CO-2144, paratype); 10, female left valve in internal lateral view (SUM-CO-2145, paratype); 11, female right valve in internal lateral view (SUM-CO-2146, paratype); 12, muscle scars of female right valve (SUM-CO-2146, paratype); 13 and 14, anterior and posterior elements of hingement on male right valve (SUM-CO-2144, paratype). Scale: 200 μ m for 1–8, 10, 11, 60 μ m for 9, 12–14.

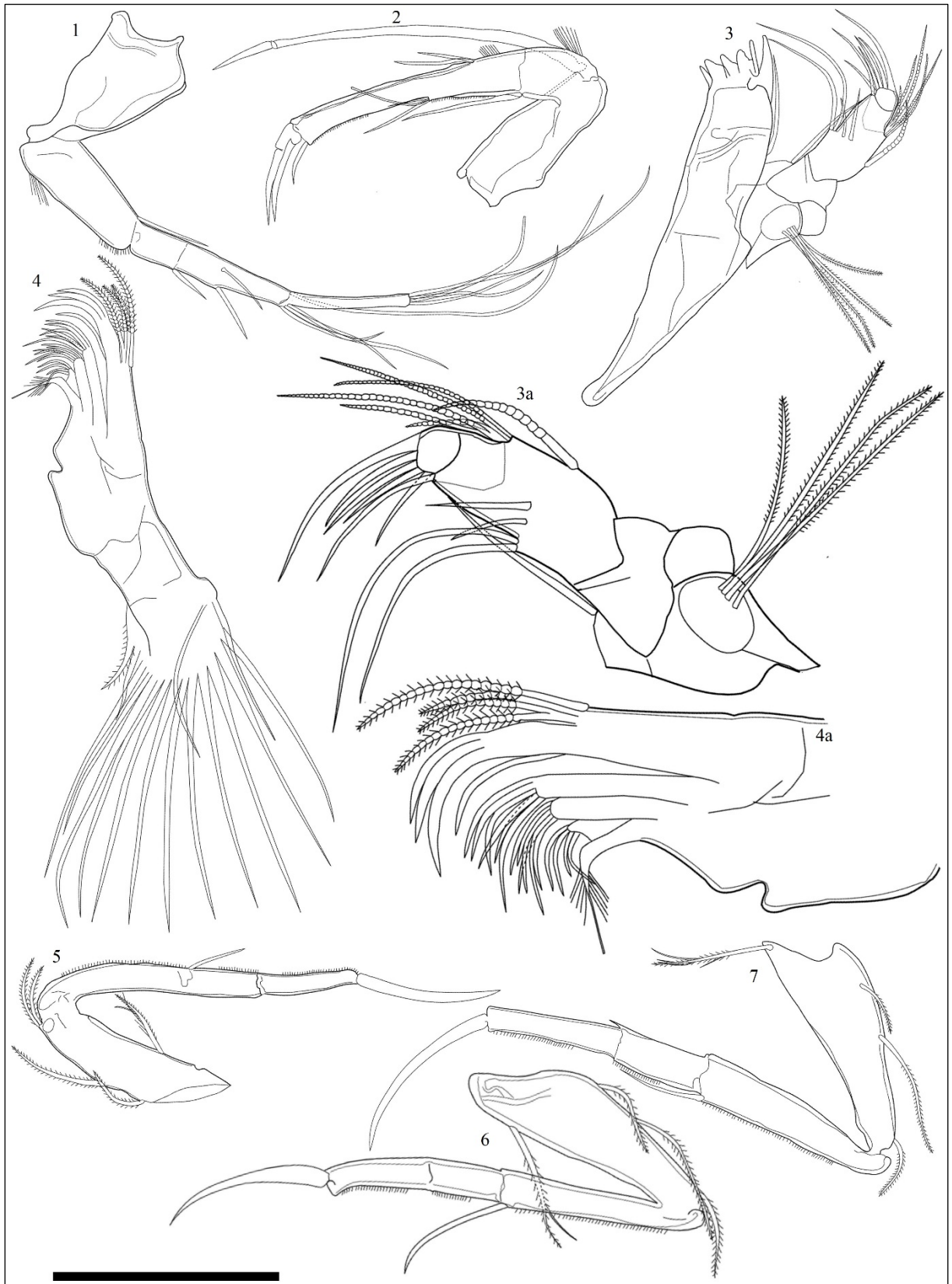


FIGURE 28. *Loxoconcha noharai* Le & Tsukagoshi, 2014. 1, 3, 6, male (SUM-CO-2137, holotype); 2, 5, 7, male (SUM-CO-2147, paratype); 4, male (SUM-CO-2148, paratype). 1, antennula; 2, antenna; 3, mandibula; 4, maxillula; 5, fifth limb; 6, sixth limb; 7, seventh limb; 3a, 4a, enlarged details of 3 and 4, respectively. Scale: 100 μ m for 1–7, 50 μ m for 3a and 4a.

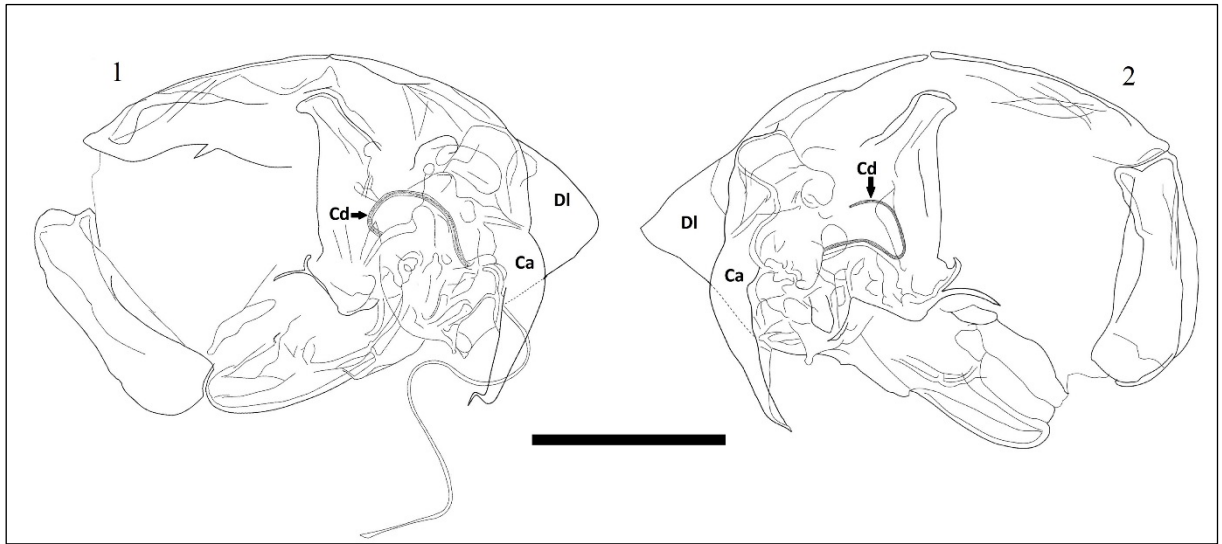


FIGURE 29. *Loxoconcha noharai* Le & Tsukagoshi, 2014, male holotype (SUM-CO-2137). 1, right copulatory organ; 2, left copulatory organ. Abbreviations: Ca, clasping apparatus; Cd, copulatory duct; DI, distal lobe. Scale: 100 μ m.

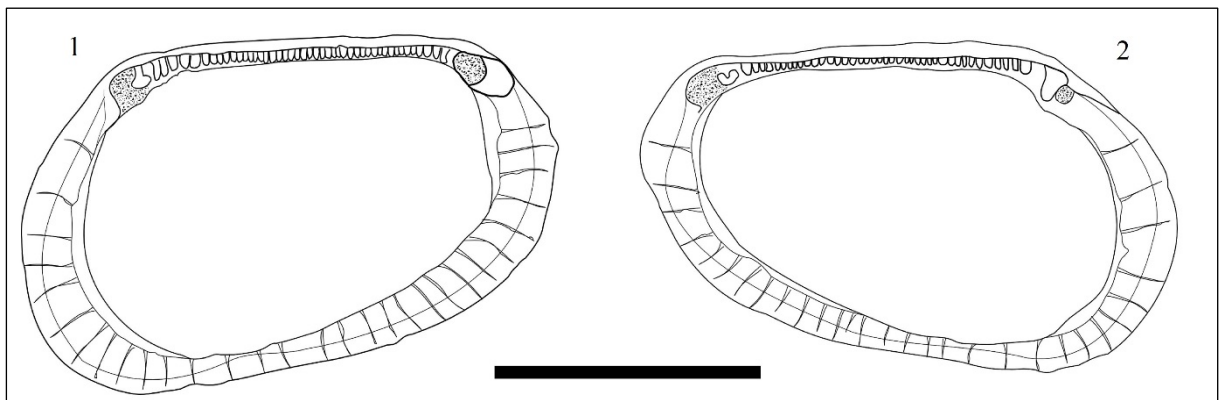


FIGURE 30. Carapace of *Loxoconcha santosi* Le & Tsukagoshi, 2014. 1, female right valve in internal lateral view (SUM-CO-2150, paratype); 2, female left valve in internal lateral view (SUM-CO-2150, paratype). Scale: 200 μ m.

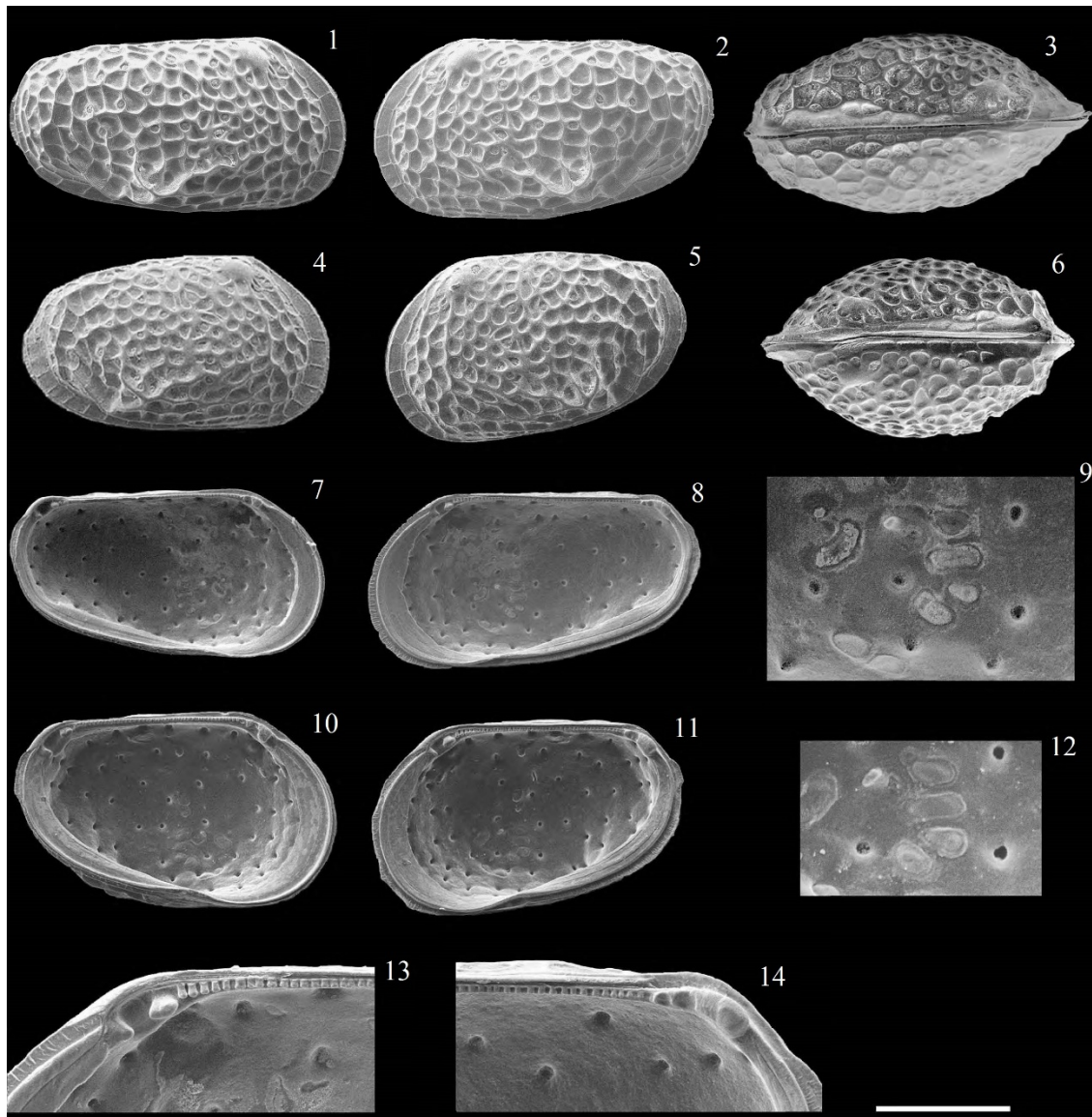


FIGURE 31. Carapace morphology of *Loxoconcha santosi* Le & Tsukagoshi, 2014. 1, male right valve in external lateral view (SUM-CO-2151, holotype); 2, male left valve in external lateral view (SUM-CO-2151, holotype); 3, male carapace in dorsal view (SUM-CO-2152, paratype); 4, female right valve in external lateral view (SUM-CO-2153, paratype); 5, female left valve in external lateral view (SUM-CO-2154, paratype); 6, female carapace in dorsal view (SUM-CO-2155, paratype); 7, male left valve in internal lateral view (SUM-CO-2156, paratype); 8, male right valve in internal lateral view (SUM-CO-2157, paratype); 9, muscle scars of male right valve (SUM-CO-2157, paratype); 10, female left valve in internal lateral view (SUM-CO-2158, paratype); 11, female right valve in internal lateral view (SUM-CO-2159, paratype); 12, muscle scars of female right valve (SUM-CO-2159, paratype); 13 and 14, anterior and posterior elements of hingement on male right valve in internal lateral view (SUM-CO-2157, paratype). Scale: 200 μ m for 1–8, 10, 11, 60 μ m for 9, 12–14.



FIGURE 32. *Loxoconcha santosi* Le & Tsukagoshi, 2014. 1, 2, 5, 6, male (SUM-CO-2160, paratype); 3, 8, male (SUM-CO-2161, paratype); 4, 7, male (SUM-CO-2162, paratype). 1, antennula; 2, antenna; 3, mandibula; 4, maxillula; 5, fifth limb; 6, sixth limb; 7, seventh limb; 8, brush-shaped organ. 3a, 4a, 8a, enlarged details of 3, 4, 8, respectively. Scale: 100 μ m for 1–8, 50 μ m for 3a, 4a, 8a.

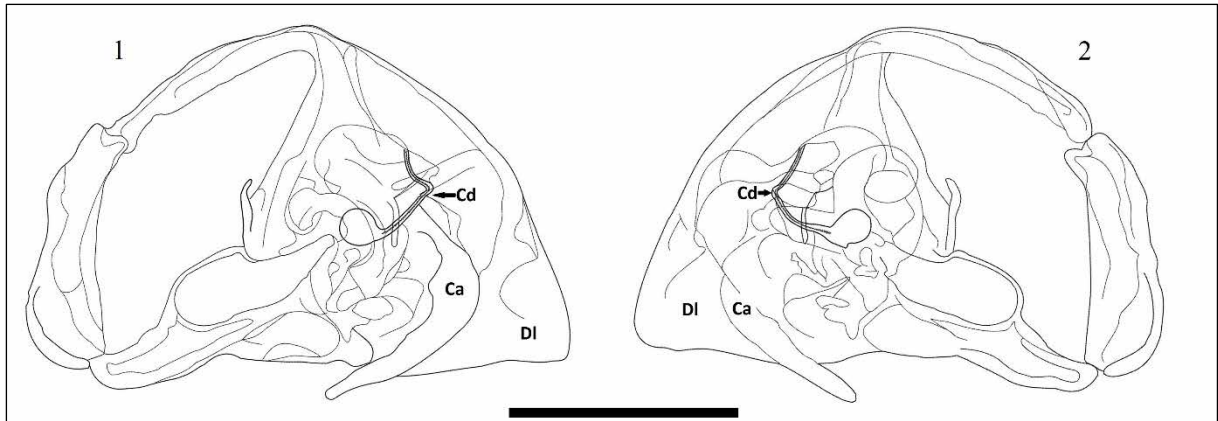


FIGURE 33. *Loxoconcha santosi* Le & Tsukagoshi, 2014., male holotype (SUM-CO-2151). 1, right copulatory organ; 2, left copulatory organ. Abbreviations: Ca, clasping apparatus; Cd, copulatory duct; Dl, distal lobe. Scale: 100 μ m.

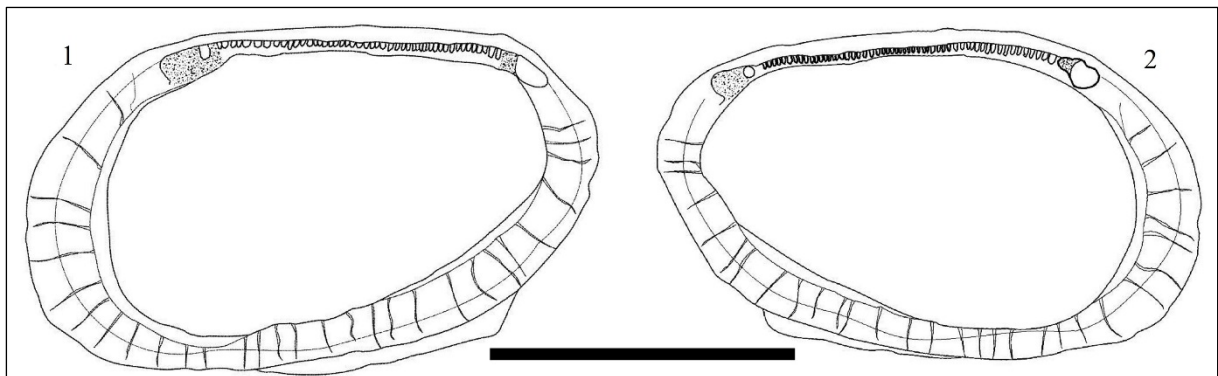


FIGURE 34. Carapace of *Loxoconcha sesokoensis* Le & Tsukagoshi, 2014. 1, female right valve in internal lateral view (SUM-CO-2165, paratype); 2, female left valve in internal lateral view (SUM-CO-2166, paratype). Scale: 200 μ m.

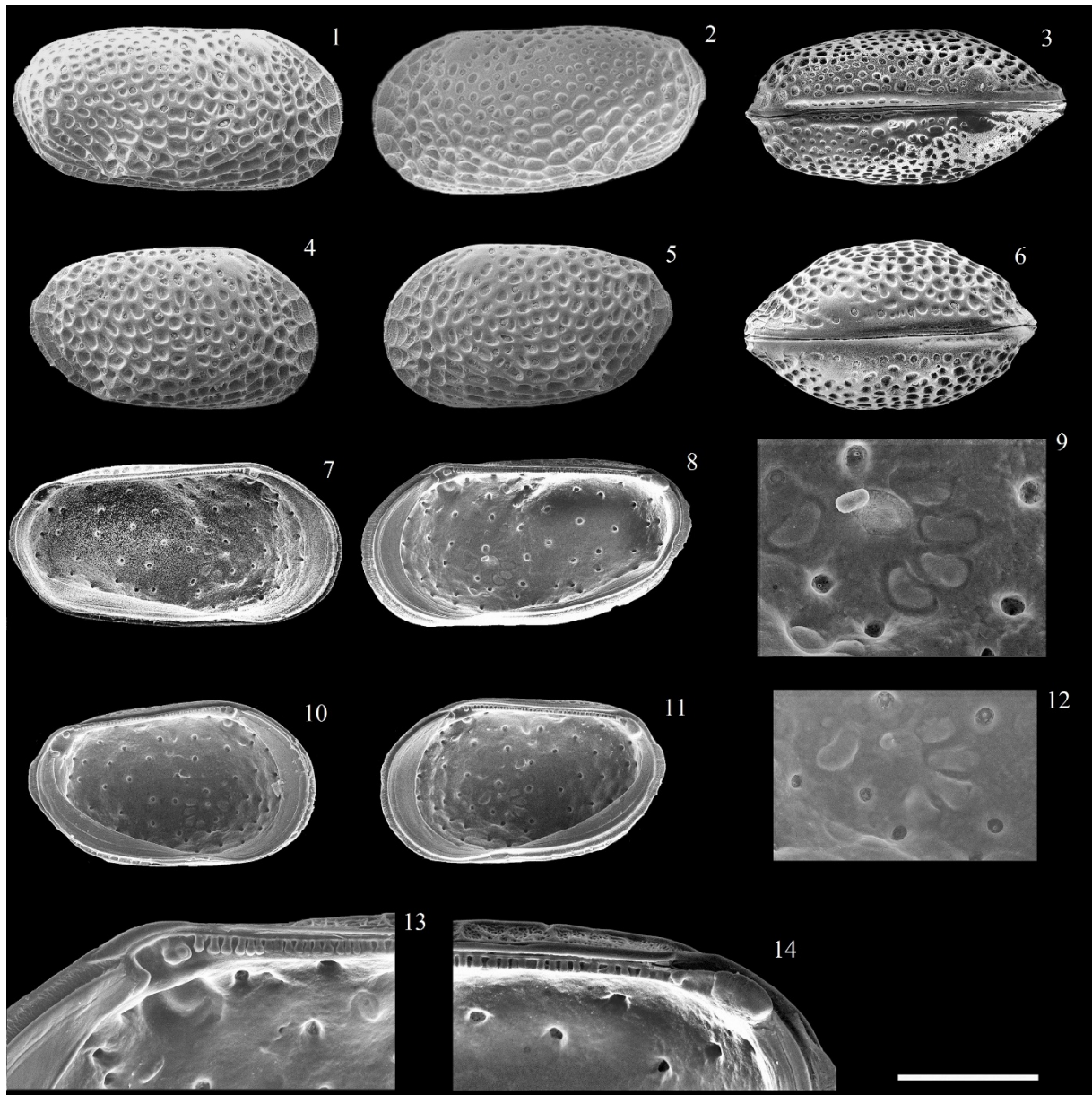


FIGURE 35. Carapace morphology of *Loxoconcha sesokoensis* Le & Tsukagoshi, 2014. 1, male right valve in external lateral view (SUM-CO-2167, holotype); 2, male left valve in external lateral view (SUM-CO-2168, paratype); 3, male carapace in dorsal view (SUM-CO-2169, paratype); 4, female right valve in external lateral view (SUM-CO-2170, paratype); 5, female left valve in external lateral view (SUM-CO-2171, paratype); 6, female carapace in dorsal view (SUM-CO-2172, paratype); 7, male left valve in internal lateral view (SUM-CO-2173, paratype); 8, male right valve in internal lateral view (SUM-CO-2174, paratype); 9, muscle scars of male right valve (SUM-CO-2174, paratype); 10, female left valve in internal lateral view (SUM-CO-2175, paratype); 11, female right valve in internal lateral view (SUM-CO-2176, paratype); 12, muscle scars of female right valve (SUM-CO-2176, paratype); 13 and 14, anterior and posterior elements of hingement on male right valve (SUM-CO-2174, paratype). Scale: 200 μ m for 1–8, 10, 11, 60 μ m for 9, 12–14.



FIGURE 36. *Loxoconcha sesokoensis* Le & Tsukagoshi, 2014. 1, 3, 4, male (SUM-CO-2177, paratype); 2, 5–8, male (SUM-CO-2167, holotype). 1, antennula; 2, antenna; 3, mandibula; 4, maxillula; 5, fifth limb; 6, sixth limb; 7, seventh limb; 8, brush-shaped organ. 3a, 4a, 8a, enlarged details of 3, 4, 8, respectively. Scale: 100 μm for 1–8, 50 μm for 3a, 4a, 8a.

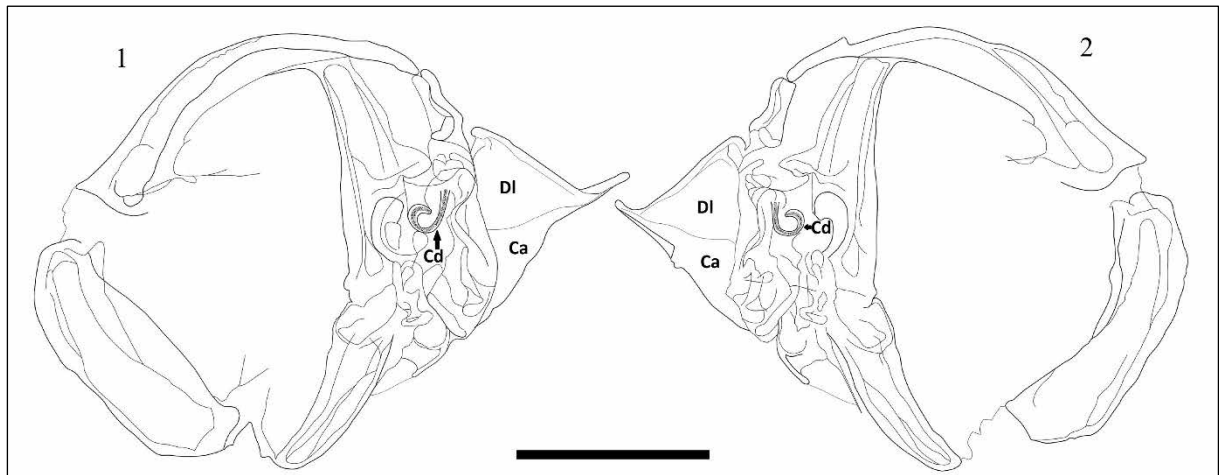


FIGURE 37. *Loxoconcha sesokoensis* Le & Tsukagoshi, 2014., holotype, male (SUM-CO-2167). 1, right copulatory organ; 2, left copulatory organ. Abbreviations: Ca, clasper; Cd, copulatory duct; DI, distal lobe. Scale: 100 μ m.

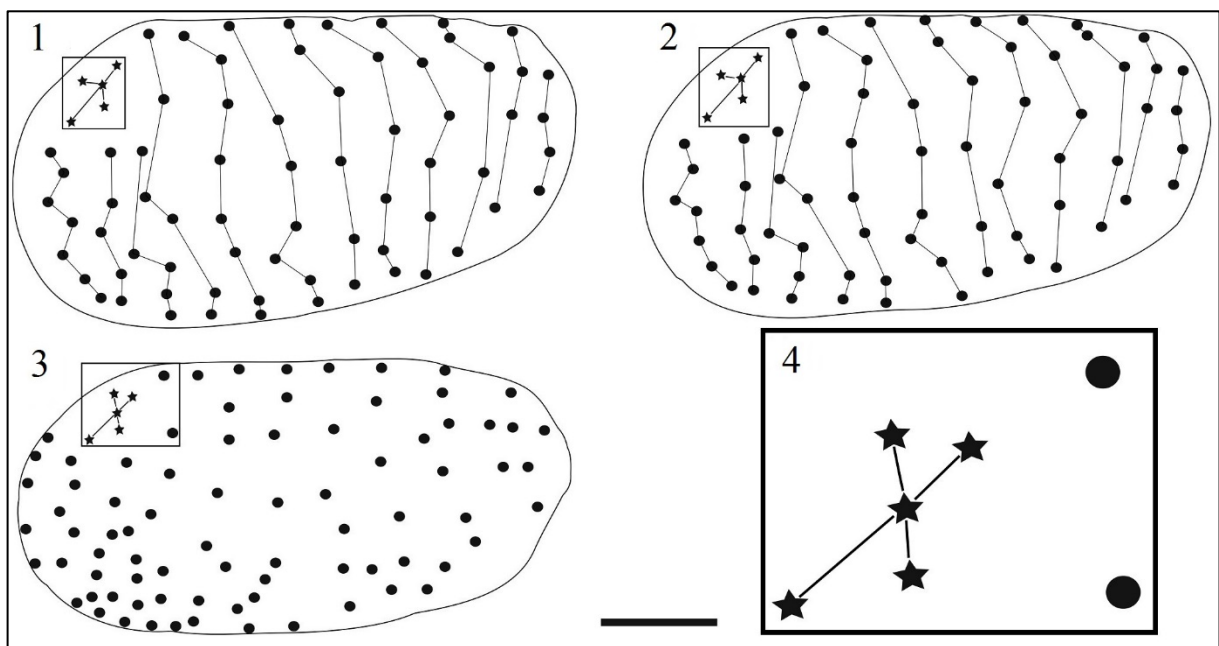


FIGURE 38. Distributional pattern of pore systems. 1, pattern B of male left valve of *Loxoconcha noharai* Le & Tsukagoshi, 2014 (SUM-CO-2138, paratype); 2, pattern B of male left valve of *L. santosi* Le & Tsukagoshi, 2014 (SUM-CO-2163, paratype); 3, pattern C of male left valve of *L. sesokoensis* Le & Tsukagoshi, 2014 (SUM-CO-2168, paratype); 4, enlarged detail of 3. Scale: 100 μ m for 1–3, 25 μ m for 4.

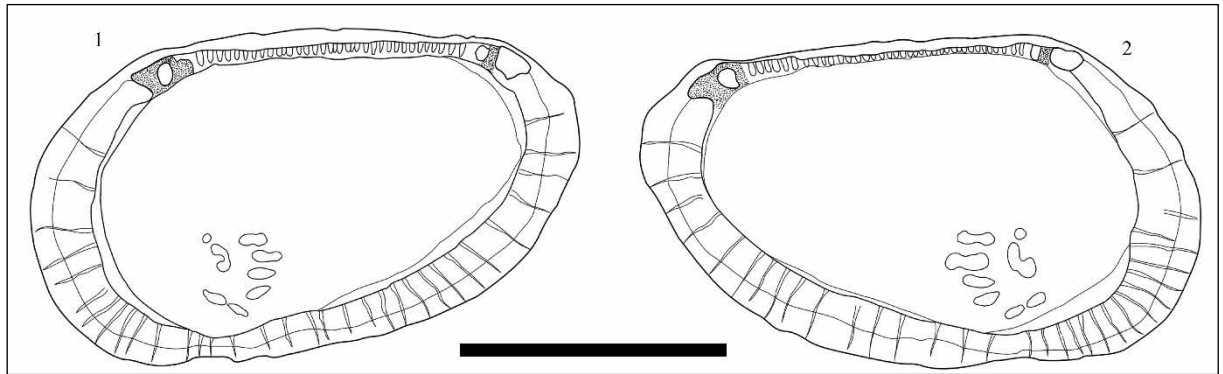


FIGURE 39. Carapace of *Loxoconcha* sp. Y. 1, female right valve internal lateral view (TEM-CO-19, paratype); 2, female left valve internal lateral view (TEM-CO-19, paratype). Scale: 200 μ m.

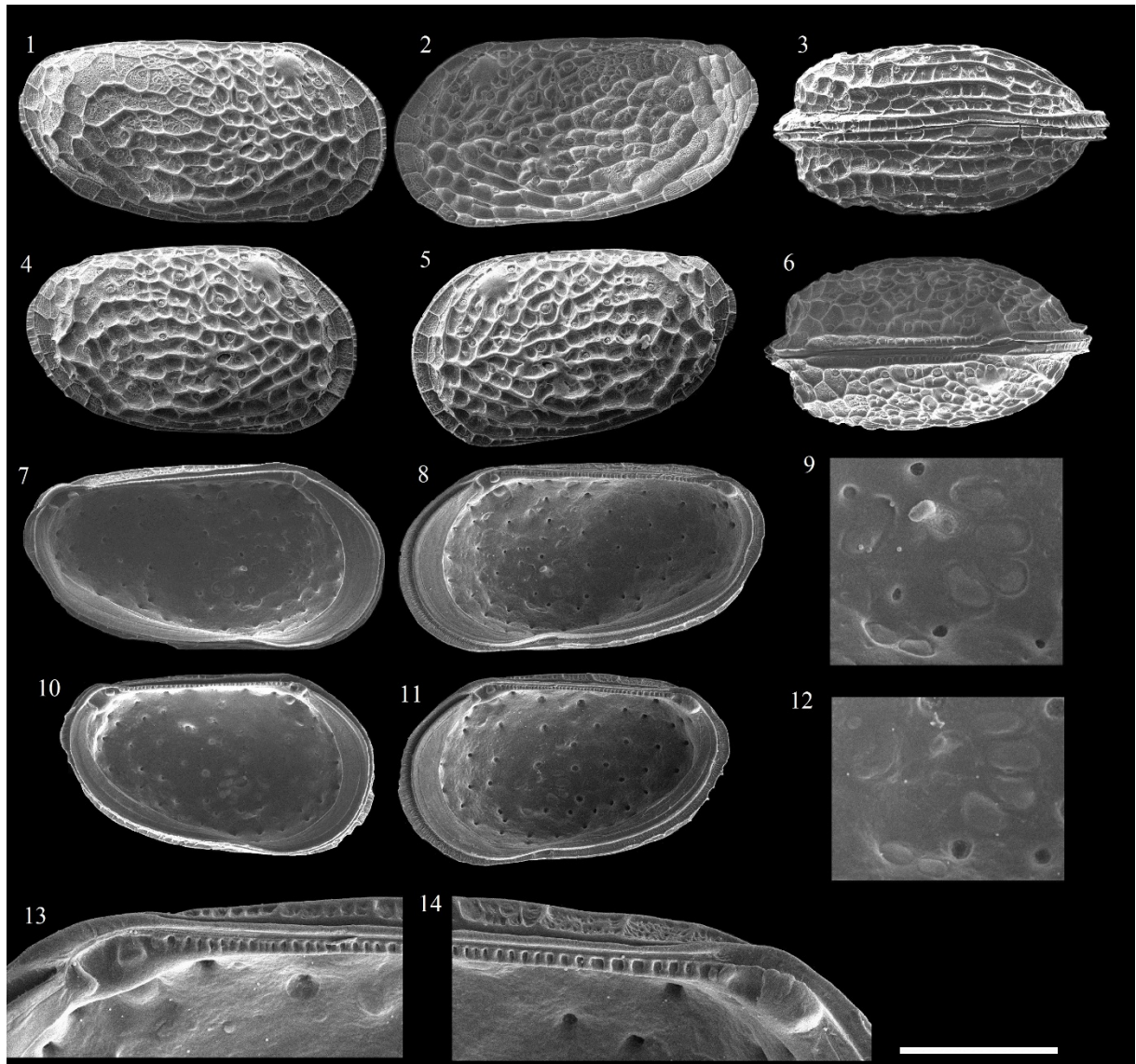


FIGURE 40. Carapace morphology of *Loxoconcha* sp. Y. 1, male right valve in external lateral view (TEM-CO-20, paratype); 2, male left valve in external lateral view (TEM-CO-21, holotype); 3, female carapace in ventral view (TEM-CO-22, paratype); 4, female right valve in external lateral view (TEM-CO-24, paratype); 5, female left valve in external lateral view (TEM-CO-24, paratype); 6, female carapace in dorsal view (TEM-CO-25, paratype); 7, male left valve in internal lateral view (TEM-CO-26, paratype); 8, male right valve in internal lateral view (SUM-CO-26, paratype); 9, muscle scars of male right valve (TEM-CO-26, paratype); 10, female left valve in internal lateral view (TEM-CO-28, paratype); 11, female right valve in internal lateral view (TEM-CO-29, paratype); 12, muscle scars of female right valve (TEM-CO-29, paratype); 13 and 14. anterior and posterior elements of hingement on male right valve in internal lateral view (TEM-CO-26, paratype). Scale: 200 μ m for 1–8, 10, 11; 60 μ m for 9, 12–14.



FIGURE 41. *Loxoconcha* sp. Y. 1, 2, 5–7. male (TEM-CO-21, holotype); 3. male (TEM-CO-20, paratype); 4, 8. male (TEM-CO-26, paratype). 1, antennula; 2, antenna; 3, mandibula; 4, maxillula; 5, fifth limb; 6, sixth limb; 7, seventh limb; 8, brush-shaped organ. 3a, 4a, 8a, enlarged details of 3, 4, 8, respectively. Scale: 100 μ m for 1–8; 50 μ m for 3a, 4a, 8a.

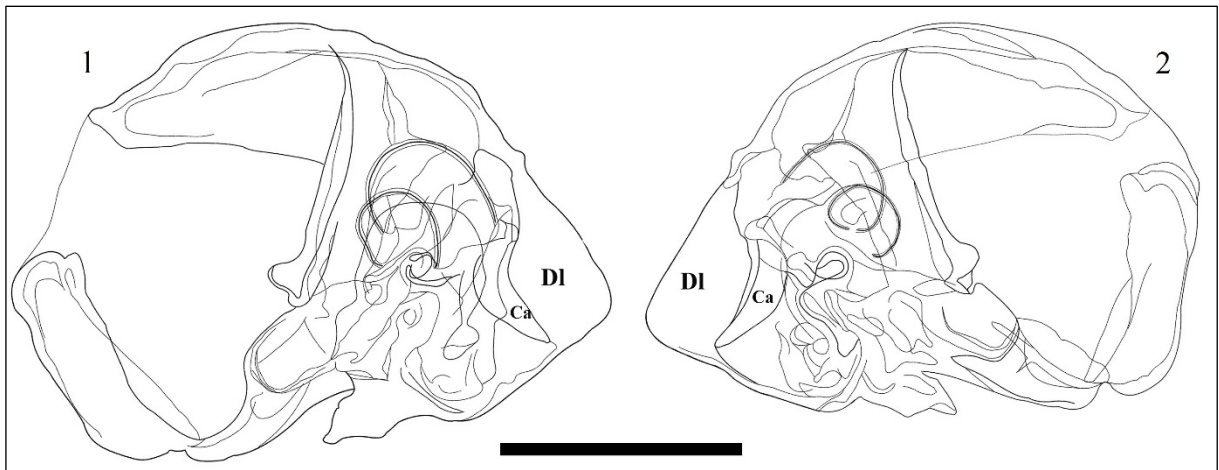


FIGURE 42. Copulatory organ of *Loxoconcha* sp. Y, male holotype (TEM-CO-21). Abbreviations: Ca, clasper; Dl, distal lobe. Scale: 100 μ m.

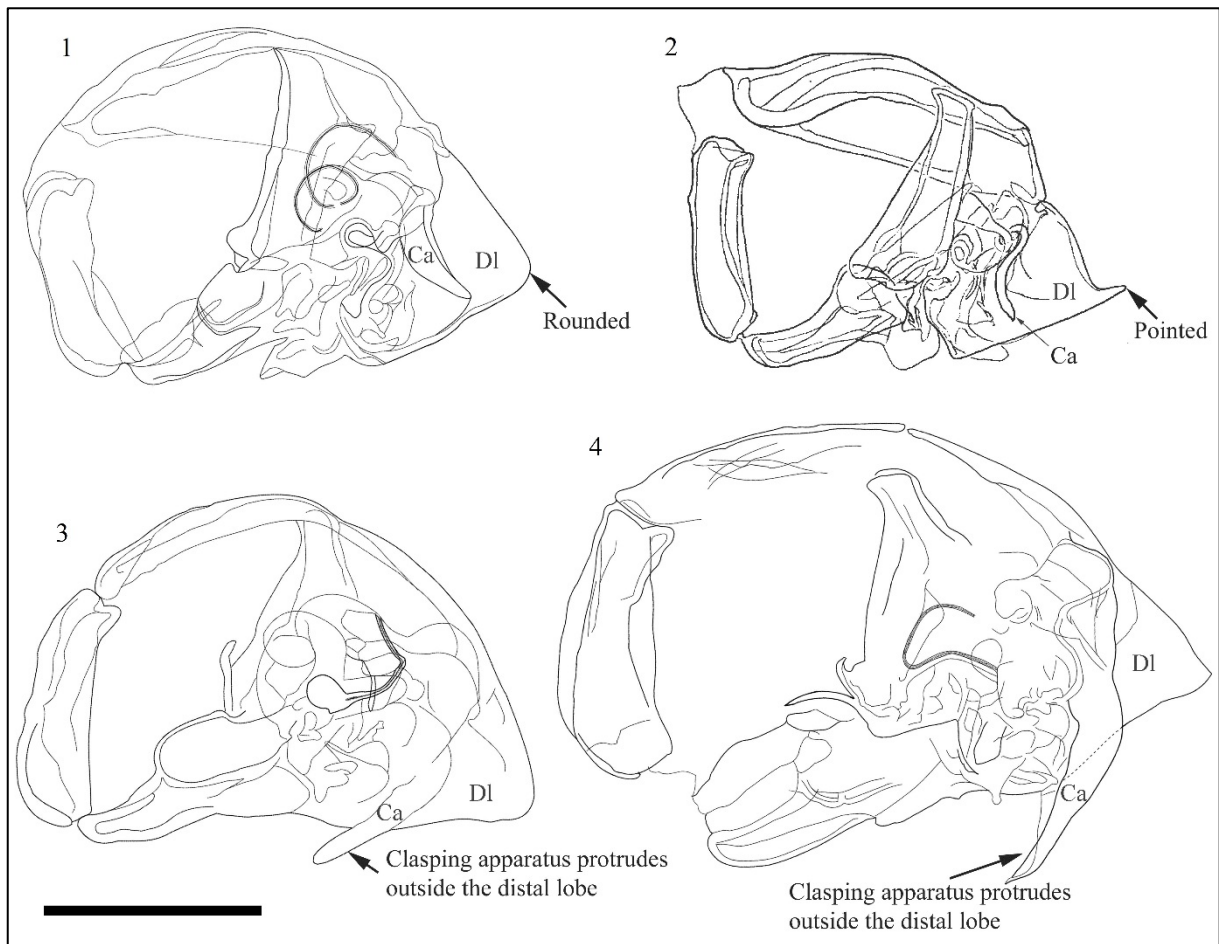


FIGURE 43. Comparison of the copulatory organ among four species of *Loxoconcha*. 1, *L.* sp. Y (TEM-CO-21); 2, *L. uranouchiensis* (after Okubo, 1980); 3, *L. santosi* (after Le & Tsukagoshi, 2014); 4, *L. noharai* (after Le & Tsukagoshi, 2014). Scale: 100 μ m.