



<http://dx.doi.org/10.11646/zootaxa.3796.1.7>

<http://zoobank.org/urn:lsid:zoobank.org:pub:100761B6-225E-48AF-97F4-8E3824348915>

Three new species of the genus *Loxoconcha* (Crustacea, Ostracoda, Podocopida) from the Okinawa Islands, southern Japan

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Abstract

Three new species of Ostracoda, *Loxoconcha noharai* sp. nov., *L. santosi* sp. nov. and *L. sesokoensis* sp. nov., are described from the Okinawa Islands, southern Japan. The two species *Loxoconcha noharai* sp. nov. and *L. santosi* sp. nov. live in estuaries, whereas the species *L. sesokoensis* sp. nov. lives in coral reefs. These species can be easily distinguished from other previously described *Loxoconcha* species by their morphological differences, mainly in the male copulatory organ, and distribution pattern of their pore systems. In addition, *L. sesokoensis* sp. nov. is suggested to be phylogenetically apart from any other *Loxoconcha* species which have been reported so far from Japan and the adjacent seas.

Key words: taxonomy, soft parts morphology, brackish-water, estuary, coral reef

Introduction

The genus *Loxoconcha* Sars, 1866 is one of the most diverse Recent ostracod taxa. Species of this genus are distributed in low to middle latitude areas of marine and brackish waters, and up to more than 150 living and 350 fossil species have been identified in the world (Kempf 1986a, 1986b). Since a part of these species was later assigned to other genera, e.g. *Palmoconcha*, *Sagmatocythere* and *Loxocorniculum*, the effective species number of *Loxoconcha* must be smaller. More than twenty living and four fossil species have been described so far from Japan (Ishii *et al.* 2005; Ozawa & Ishii 2008).

As for the phylogenetical view of this genus, there are four remarkable papers. Firstly, Kamiya (1988) described two main modes of life in *Loxoconcha* species, i.e., phytal and bottom-dwelling, and suggested that these modes reflect the differences of adaption to each microhabitat. He showed the distinct differences in carapace morphologies between species of the two life modes. The phytal species were round in lateral view and rugby-ball shaped in posterior view, whereas the sand bottom species were elongate rectangular in lateral view and triangular in posterior view. Secondly, Kamiya (1989) interpreted the difference in the distributional patterns of pore-systems in the adults of the phytal species *L. japonica* and the bottom-dwelling species *L. uranouchiensis*, especially in the ventral area as the result of adaptation to their respective microhabitats. Thirdly, on the basis of carapace morphology, Tanaka & Ikeya (2002) divided the genus *Loxoconcha* from East Asia into five species groups. The migration and speciation patterns of four species of the *L. japonica* species group were presented. Fourthly, Ishii *et al.* (2005) studied 17 species of *Loxoconcha* around Japan, and concluded that they were divided into two groups according to the distribution pattern of the pore systems located below the eye tubercle. The Group A is more diverse, but has fewer pore systems in the ventral area than Group B, and tends to inhabit normal marine environments, while the Group B inhabits brackish water. They also showed that the density of pore-systems on the ventral area of *Loxoconcha* species was not determined by the adaptation to habitat, but by phylogeny.

Since the 1970s, various 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 & Yabu, 1983). Nohara & Tsukishima (1980) investigated the ostracod distribution in coral reefs of Komesu and southeast

Sesoko-jima. They showed the structure of species composition for each traverse and each location. Tabuki & Nohara (1988) studied the ecology of intertidal and subtidal ostracods living in the moat of a coral reef off Sesoko Island, and their preliminary results on the species composition of ostracods and its seasonal changes were discussed.

The previous studies were based on carapace morphology of the investigated ostracods, without descriptions of soft parts. However it is difficult to identify the species accurately without information on the soft parts, especially the characteristics of the male copulatory organ. Thus, in this study, the diagnostic and complete descriptive characters of three new species from Okinawa Island, southern Japan, are illustrated. This work will not only contribute to the understanding of the local ostracod fauna, but will allow for a much more accurate comparison with the faunas of adjacent areas.

Material and methods

Superficial sediments were collected from the uppermost 5 mm of the active layer of the study areas (Fig. 1C–E). Sampling was carried out during low tide. At the sampling points, where the water depth was less than 20 cm, the upper layer of sediment was scooped into a plastic bottle using a spoon (a flat spoon of 12×15 cm or a rectangular spoon of 4×7 cm, depending on the degree of surface irregularity). All the collected specimens were fixed in 5–10% formaldehyde 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 for observation of the appendages and the remaining material was dried.

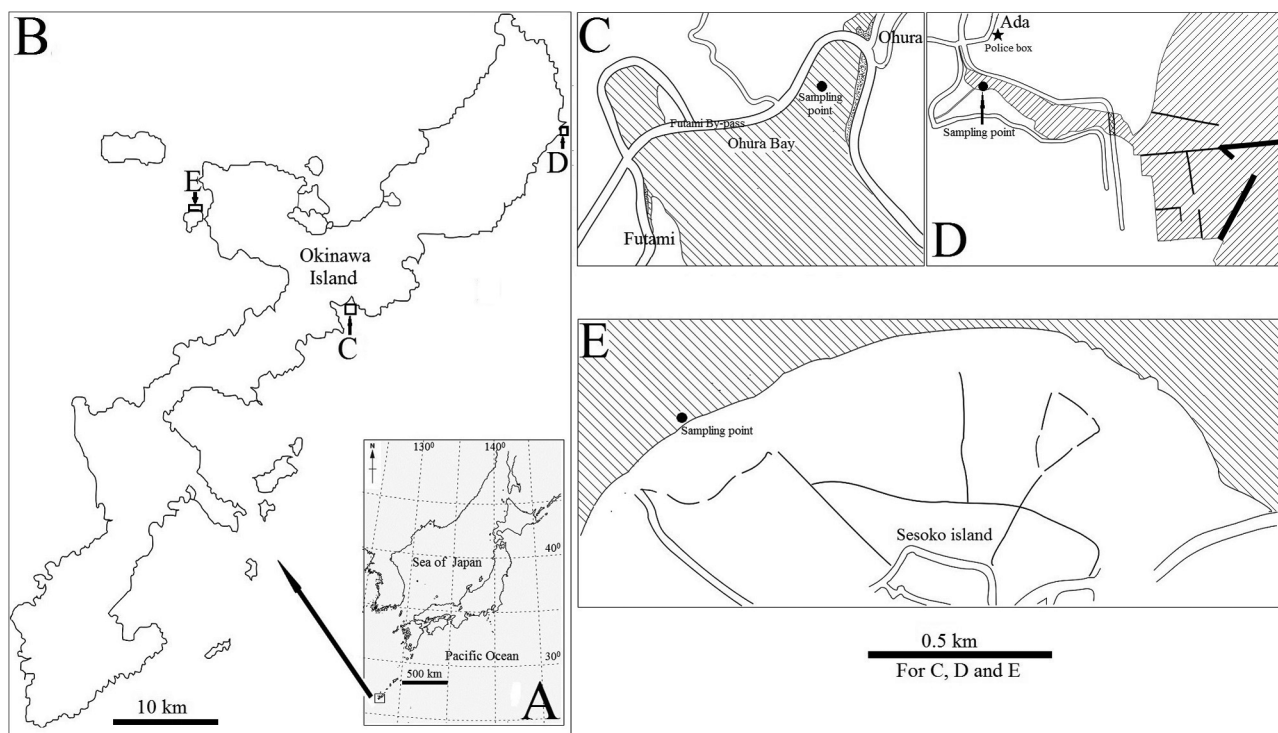


FIGURE 1. Maps showing location of the study area. A. map of Japan B. map of the Okinawa Islands C–E. sampling sites of *Loxocochna noharai* sp. nov., *L. santosi* sp. nov. and *L. sesokoensis* sp. nov., respectively.

The appendages and valves were dissected under a binocular microscope. The dissected specimens were then observed and sketched using a differential interference contrast microscope with a camera lucida (BX-50, OLYMPUS). Dried valves and individuals were coated with gold with a quick auto coater (JFC-1500, Ion Sputtering Device), then they were observed using a scanning electron microscope (JSM-5600LV, JEOL).

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

Taxonomy

Superfamily Cytheroidea Baird, 1850

Family Loxoconchidae Sars, 1925

Genus *Loxoconcha* Sars, 1866

Loxoconcha noharai sp. nov.

(Figs 2–5)

Type series. All specimens were collected at Ohura estuary (Fig. 1C), Okinawa Island, 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 2, 3). 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. 2). Fused zone almost as wide as infold (Fig. 2). All lateral pore canals of sieve-type and scattered sparsely with 74 pores per valve. Muscle scars (Fig. 3I, L): 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.

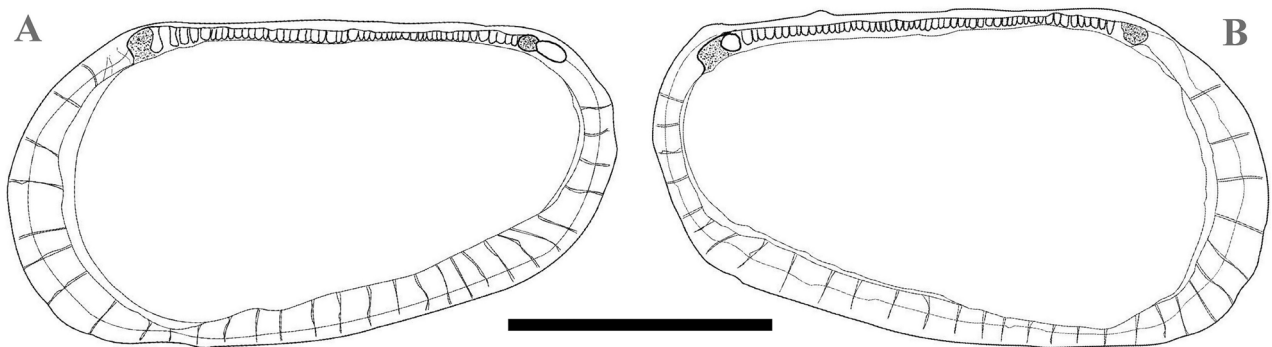


FIGURE 2. Carapace of *Loxoconcha noharai* sp. nov. A. male right valve in internal lateral view (SUM-CO-2135, paratype) B. male left valve in internal lateral view (SUM-CO-2136, paratype). Scale: 200 μ m.

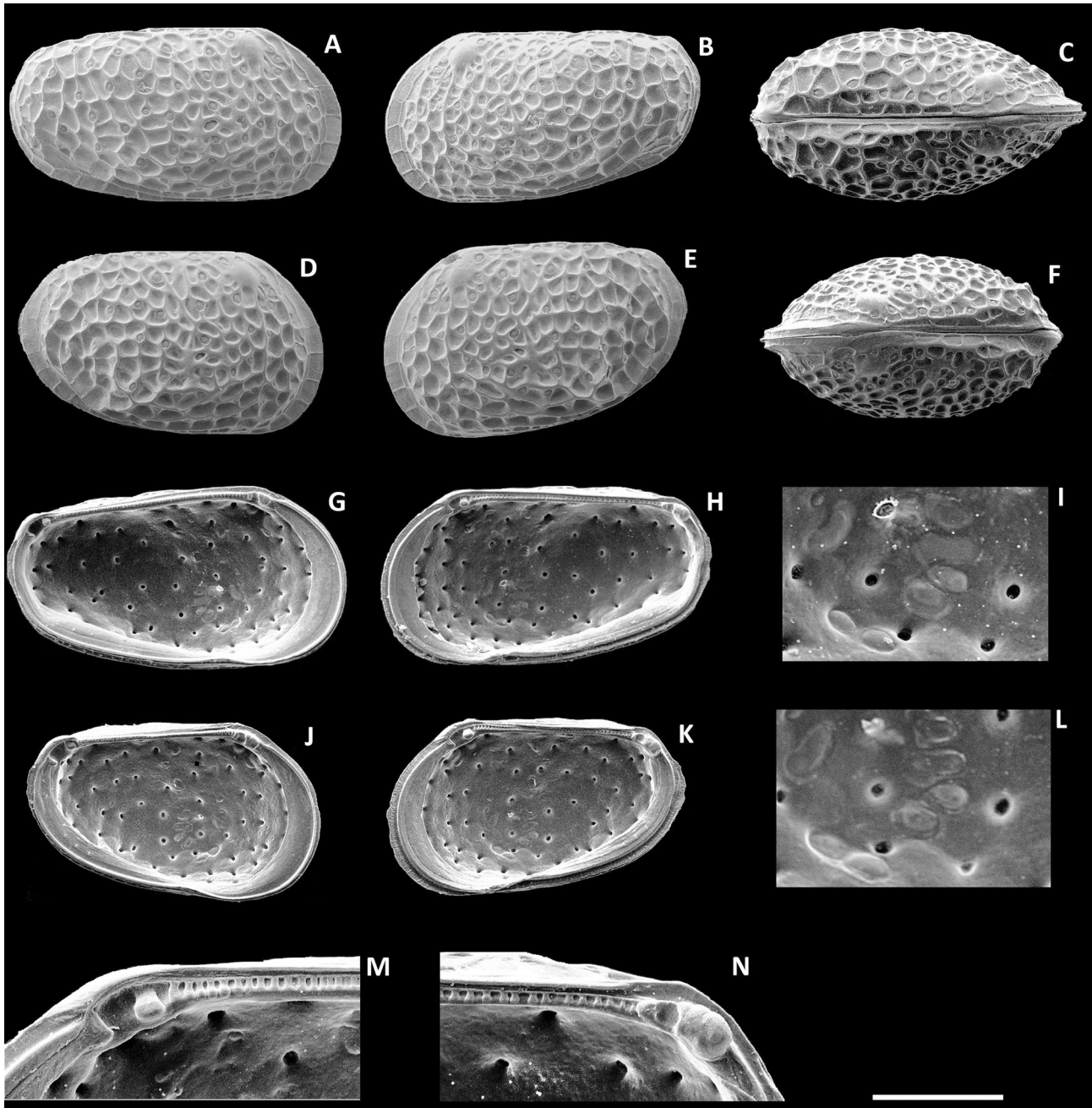


FIGURE 3. Carapace of *Loxoconcha noharai* sp. nov. A. male right valve in external lateral view (SUM-CO-2137, holotype) B. male left valve in external lateral view (SUM-CO-2138, paratype) C. male carapace in dorsal view (SUM-CO-2139, paratype) D. female right valve in external lateral view (SUM-CO-2140, paratype) E. female left valve in external lateral view (SUM-CO-2141, paratype) F. female carapace in dorsal view (SUM-CO-2142, paratype) G. male left valve in internal lateral view (SUM-CO-2143, paratype) H. male right valve in internal lateral view (SUM-CO-2144, paratype) I. muscle scars of male right valve (SUM-CO-2144, paratype) J. female left valve in internal lateral view (SUM-CO-2145, paratype) K. female right valve in internal lateral view (SUM-CO-2146, paratype) L. muscle scars of female right valve (SUM-CO-2146, paratype) M & N. anterior and posterior elements of hingement on male right valve (SUM-CO-2144, paratype). Scale: 200 μ m for A–H, J, K, 60 μ m for I, L, M, N.

Antennula (Fig. 4A). Five articulated podomeres, length ratios from proximal to distal 16:15:6:13:13, width decreasing gradually in this order. First podomere stout without setae. 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.



FIGURE 4. *Loxoconcha noharai* sp. nov. A, C, F, male (SUM-CO-2137, holotype) B, E, G, male (SUM-CO-2147, paratype) D, male (LO2044, paratype). A. antennula B. antenna C. mandibula D. maxillula E. fifth limb F. sixth limb G. seventh limb C', D'. enlarged details of C and D, respectively. Scale: 100 μ m for A–G, 50 μ m for C' & D'.

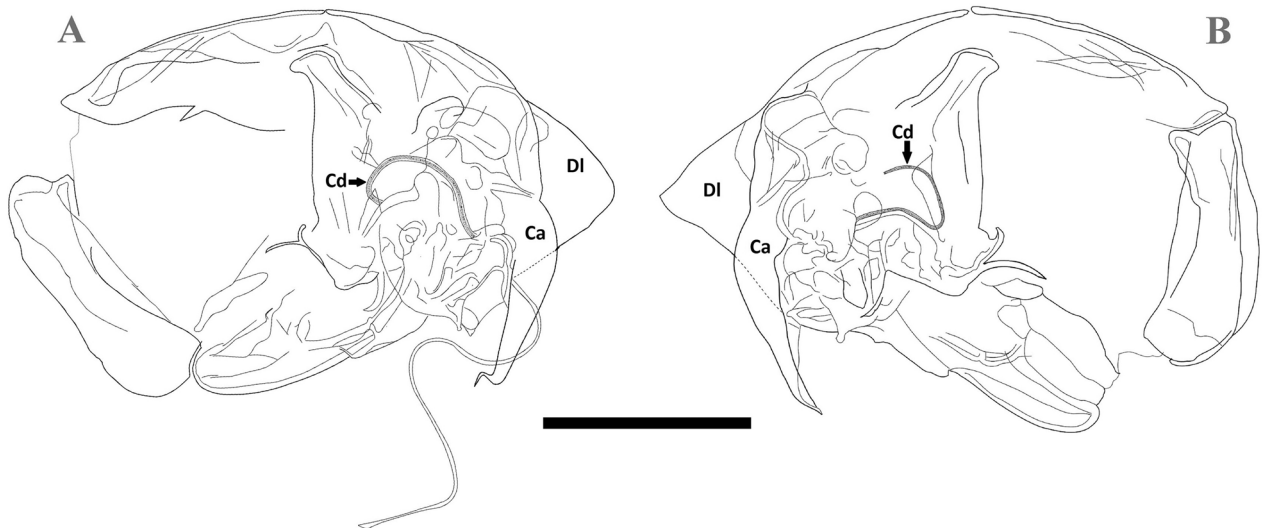


FIGURE 5. *Loxoconcha noharai* sp. nov., male holotype (SUM-CO-2137). A. right copulatory organ B. left copulatory organ. Abbreviation: Ca, clamping apparatus, Cd, copulatory duct, DI, distal lobe. Scale: 100 μ m.

Antenna (Fig. 4B). 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. 4C, C'). 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. 4D, D'). Thin branchial plate with 16 long plumose setae. Basal podomere bearing a palp and 3 endites; palp with 4 setulous 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. 4E). Four articulated podomeres, length ratios from proximal to distal 26:23:12:15. First podomere with 2 setulous setae at anterior margin, 2 short setulous setae at anterior distal end, and 1 setulous 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. 4F). Four articulated podomeres, length ratios from proximal to distal 34:32:11:16. First podomere with 2 setulous setae along anterior margin, 1 setulous seta at anterior distal end, and 1 setulous 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. 4G). Four articulated podomeres, length ratios from proximal to distal 29:28:13:19. First podomere with 2 setulous setae along anterior margin, 1 short setulous seta at anterior distal end, and 1 setulous 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. 5). Outline sub-circular. Basal part relatively large, and as a blunt triangle. Thin distal lobe triangular. Clamping 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 1.

TABLE 1. Dimensions of the valves of three new species of the genus *Loxoconcha*.

Species name	Sex	Valve	Height (mm)			Length (mm)		
			Mean	Range	N	Mean	Range	N
<i>Loxoconcha noharai</i> sp. nov.	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> sp. nov.	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> sp. nov.	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.

Remarks. No brush-shaped organ was observed in any of the 7 male dry specimens and 4 male wet specimens examined. This new species resembles *Loxoconcha 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 maxillula. In the male copulatory organ, the distal lobe of *Loxoconcha noharai* sp. nov. 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. Clasping apparatus of both species overlapping the distal lobe, however, part of the clasping apparatus extending outside the distal margin of *Loxoconcha noharai* sp. nov. is longer and larger than that of *L. uranouchiensis*. In *L. noharai* sp. nov., the plumose setae at the posterior margins of the first podomeres of all three limbs bears several long setulae. The maxillula of this new 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 sp. nov.

(Figs 6–9)

Type series. All specimens were collected at estuary in Ada (Fig. 1D), Okinawa Island, 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. In honour of 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. Gongyloidont 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 6, 7). 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. 6). Fused zone mostly as wide as infold (Fig. 6). All lateral pore systems sieve-type, with 74 pores per valve. Muscle scars (Fig. 7I, L): 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 gongyloidont with strong crenulations on median element.

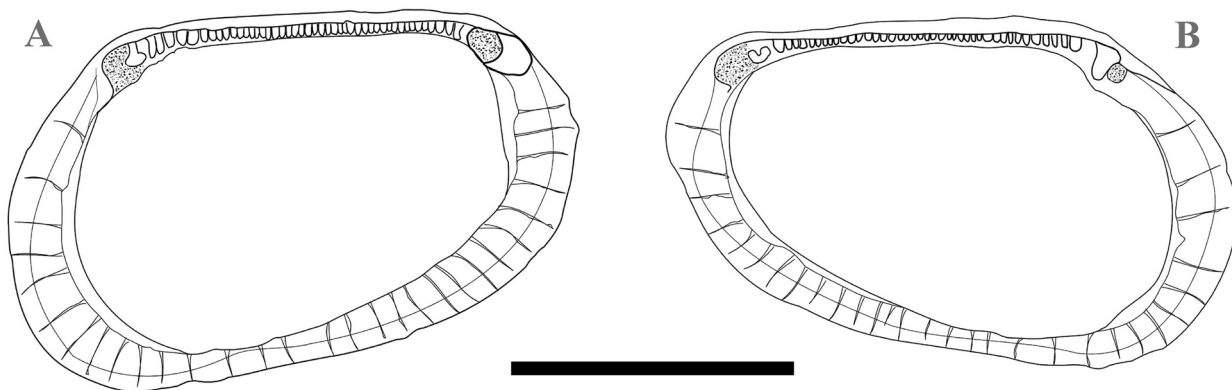


FIGURE 6. Carapace of *Loxoconcha santosi* sp. nov. A. female right valve in internal lateral view (SUM-CO-2150, paratype) B. female left valve in internal lateral view (SUM-CO-2150, paratype). Scale: 200 μ m.

Antennula (Fig. 8A). 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. 8B). 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. 8C, C'). 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. 8D, D'). 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. 8E). 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.

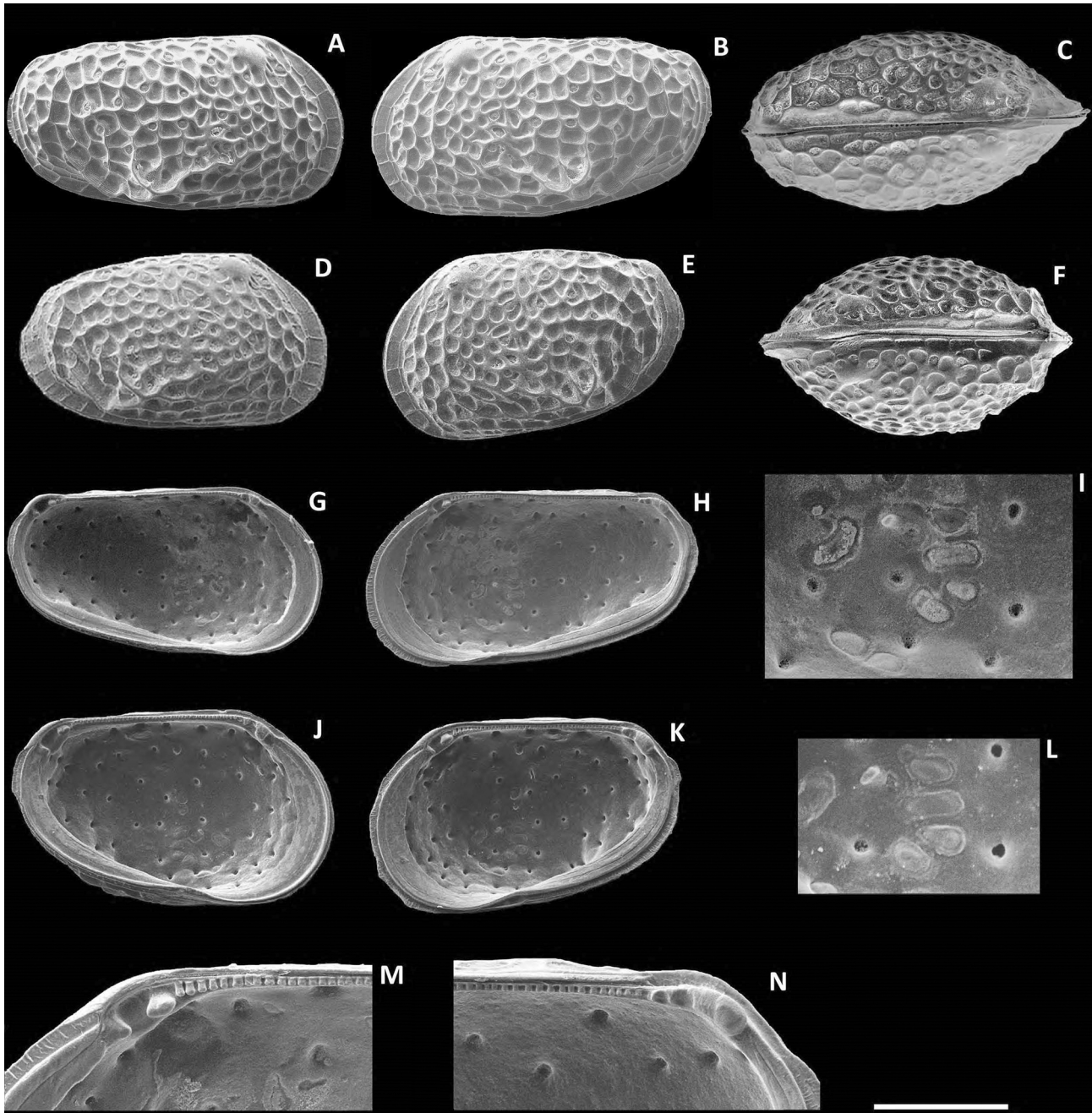


FIGURE 7. Carapace morphology of *Loxoconcha santosi* sp. nov. A. male right valve in external lateral view (SUM-CO-2151, holotype) B. male left valve in external lateral view (SUM-CO-2151, holotype) C. male carapace in dorsal view (SUM-CO-2152, paratype) D. female right valve in external lateral view (SUM-CO-2153, paratype) E. female left valve in external lateral view (SUM-CO-2154, paratype) F. female carapace in dorsal view (SUM-CO-2155, paratype) G. male left valve in internal lateral view (SUM-CO-2156, paratype) H. male right valve in internal lateral view (SUM-CO-2157, paratype) I. muscle scars of male right valve (SUM-CO-2159, paratype) J. female left valve in internal lateral view (SUM-CO-2158, paratype) K. female right valve in internal lateral view (SUM-CO-2159, paratype) L. muscle scars of female right valve (SUM-CO-2159, paratype) M & N. anterior and posterior elements of hinging on male right valve in internal lateral view (SUM-CO-2157, paratype). Scale: 200 μ m for A–H, J, K, 60 μ m for I, L, M, N.

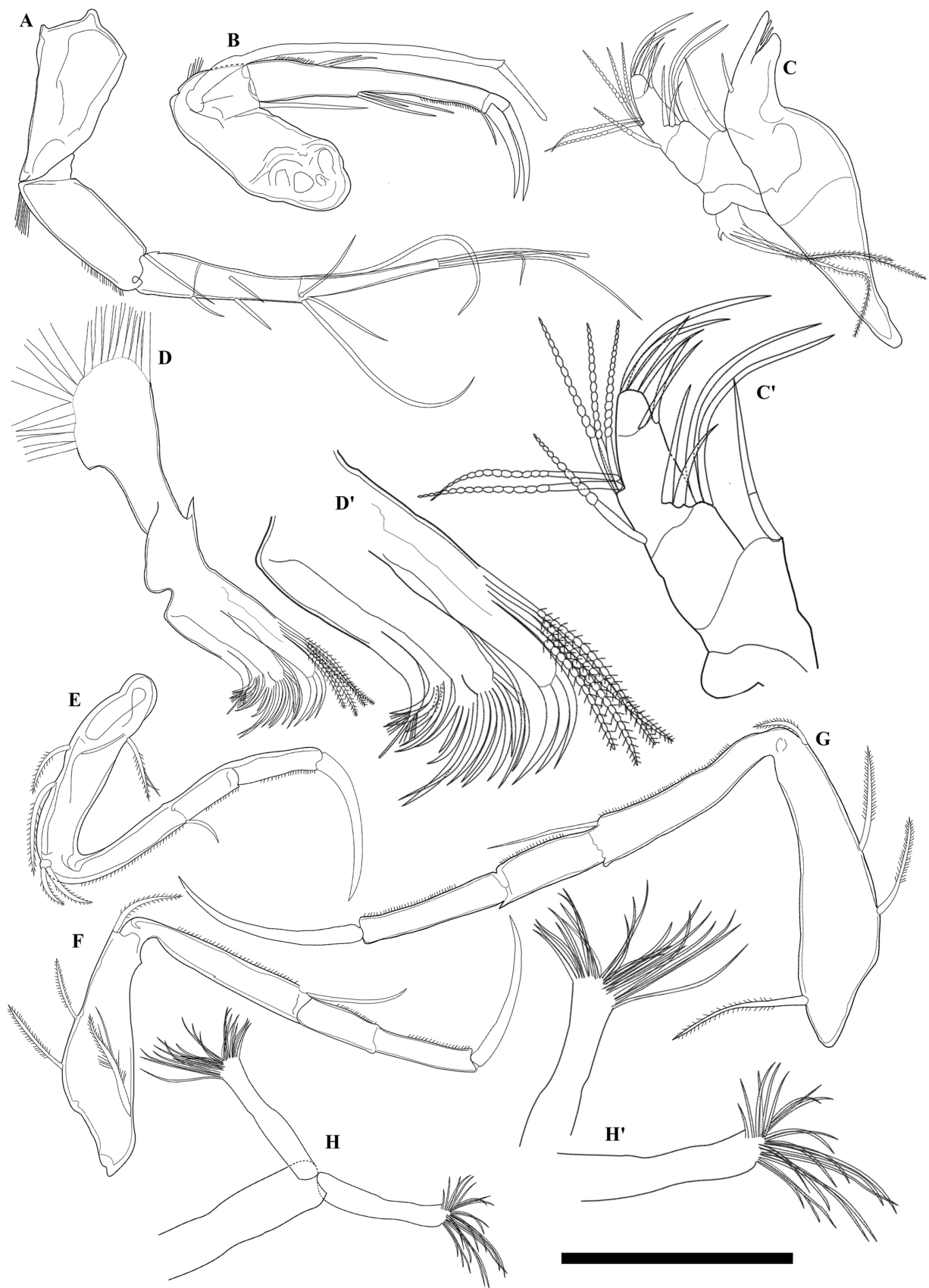


FIGURE 8. *Loxoconcha santosi* sp. nov. A, B, E, F. Male (SUM-CO-2160, paratype) C, H. male (SUM-CO-2161, paratype) D, G. male (SUM-CO-2162, paratype). A. antennula B. antenna C. mandibula D. maxillula E. fifth limb F. sixth limb G. seventh limb H. brush-shaped organ C', D', H'. enlarged details of C, D, H, respectively. Scale: 100 μ m for A–H, 50 μ m for C' D' H'.

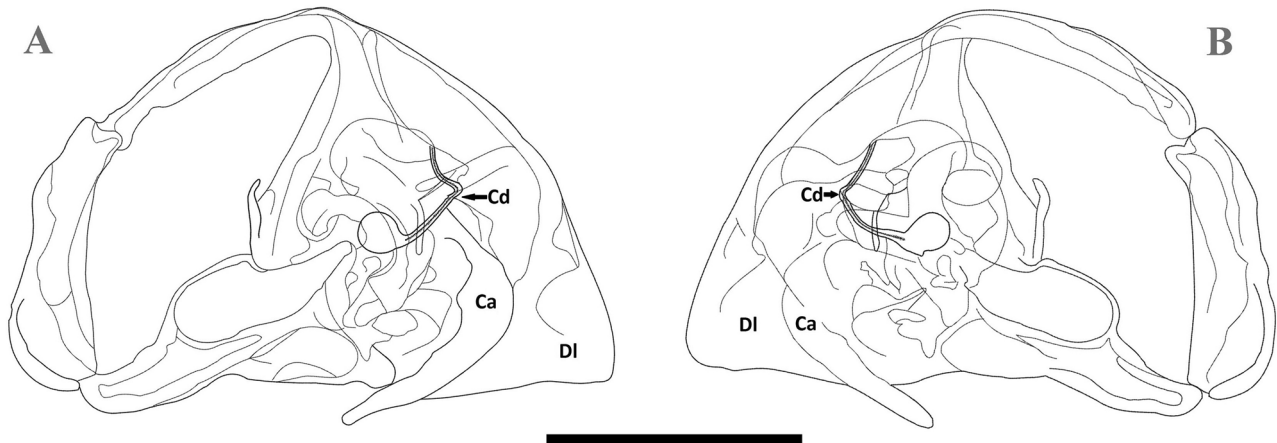


FIGURE 9. *Loxoconcha santosi* sp. nov., male holotype (SUM-CO-2151). A. right copulatory organ B. left copulatory organ. Abbreviation: Ca, clasper apparatus, Cd, copulatory duct, DI, distal lobe. Scale:100 μ m.

Sixth limb (Fig. 8F). Consisting of 4 articulated podomeres, length ratios from proximal to distal 34:30:13:16. First podomere bearing 2 setulous setae along anterior margin, 1 setulous seta at anterior distal end, and 1 long setulous 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. 8G). 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 setulous setae in middle of anterior margin, 1 short setulous seta at anterior distal end, and 1 setulous 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. 9). Sub-circular shape in general. Basal part relatively large, with a blunt triangular shape. Distal lobe large, and thin with a triangular shape. Clasper 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. 8H, H'). Three-pronged fork shape in general; consisting of pair of branches, with about 23 fine setae on each distal margin.

Dimensions. See Table 1.

Remarks. The carapace outline and appendage morphology of *Loxoconcha santosi* sp. nov. are similar to those of *L. uranouchiensis*, 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* sp. nov. has a triangular shape, whereas that of *L. uranouchiensis* has a sub quadrangular-like shape, with small process at anterior end. In the new species, 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 new 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* sp. nov. resemble those of *L. noharai* sp. nov. 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* sp. nov. consists of a bunch of 4 long plumose setae, while that of *L. santosi* sp. nov. is composed of a bunch of 3 long plumose setae and 1 very small reduced seta. Unlike in *L. noharai* sp. nov., the seventh limb in *L. santosi* sp. nov. is much larger and longer than the fifth and sixth limbs.

Loxoconcha sesokoensis sp. nov.

(Figs 10–13)

Type series. All specimens were collected at the northwest coast of Sesoko-jima (Fig. 1E), 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 gongyodont 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 10, 11). 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 (Figs 10). Fused zone mostly as wide as infold (Figs 10). All lateral pore canals of sieve-type, arranged sparsely with 85 pores per valve. Muscle scars (Fig. 11I, L): 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 gongyodont with crenulations in median element except for third and eleventh teeth from posterior terminal tooth.

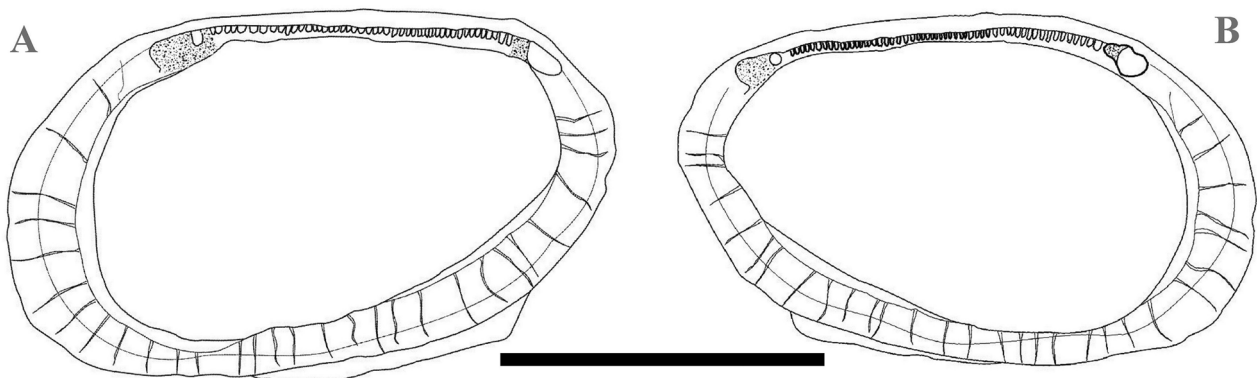


FIGURE 10. Carapace of *Loxoconcha sesokoensis* sp. nov. A. female right valve in internal lateral view (SUM-CO-2165, paratype) B. female left valve in internal lateral view (SUM-CO-2166, paratype). Scale: 200 μ m.

Antennula (Fig. 12A). 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.

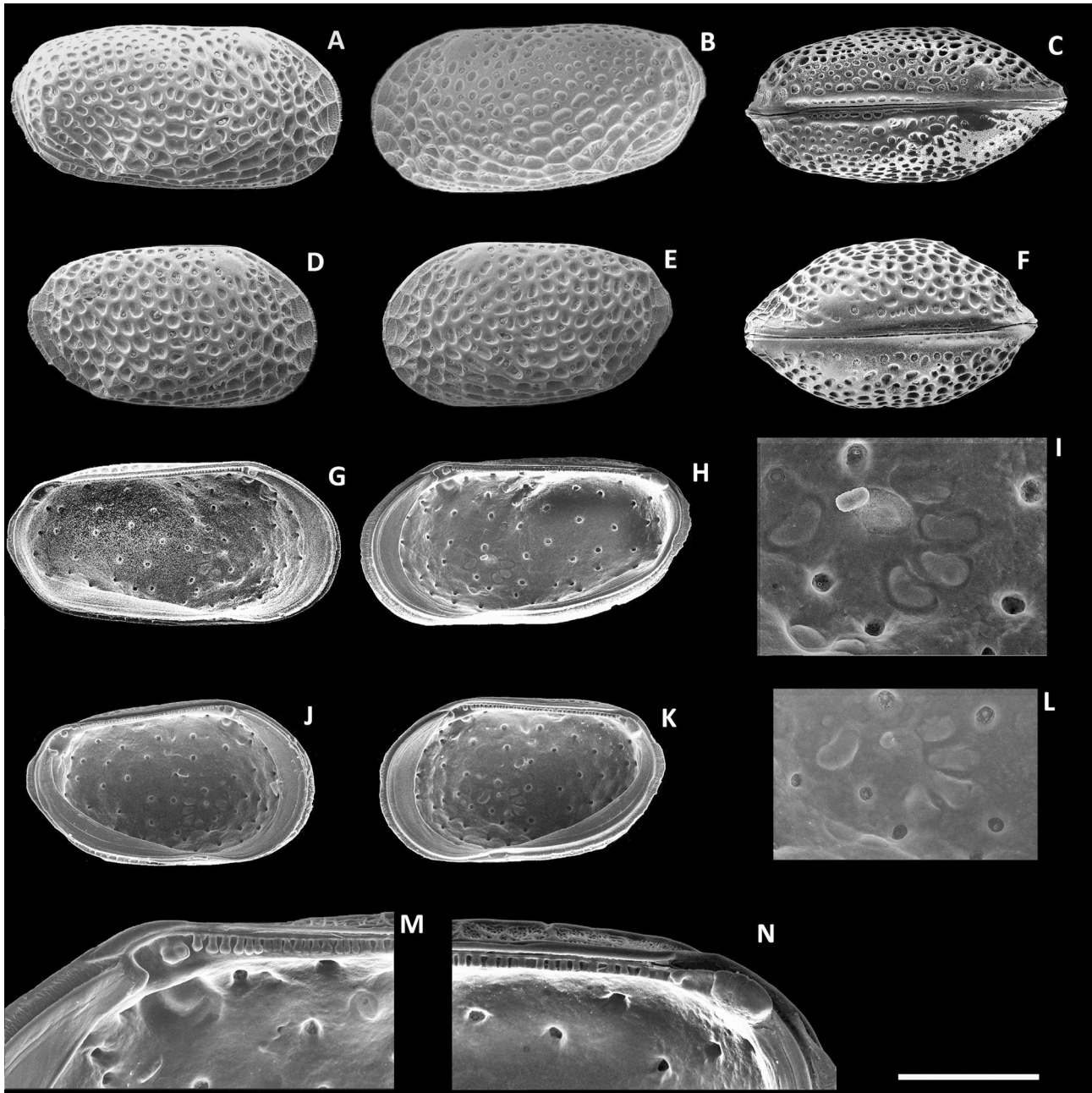


FIGURE 11. Carapace morphology of *Loxoconcha sesokoensis* sp. nov. A. male right valve in external lateral view (SUM-CO-2167, holotype) B. male left valve in external lateral view (SUM-CO-2168, paratype) C. male carapace in dorsal view (SUM-CO-2169, paratype) D. female right valve in external lateral view (SUM-CO-2170, paratype) E. female left valve in external lateral view (SUM-CO-2171, paratype) F. female carapace in dorsal view (SUM-CO-2172, paratype) G. male left valve in internal lateral view (SUM-CO-2173, paratype) H. male right valve in internal lateral view (SUM-CO-2174, paratype) I. muscle scars of male right valve (SUM-CO-2174, paratype) J. female left valve in internal lateral view (SUM-CO-2175, paratype) K. female right valve in internal lateral view (SUM-CO-2176, paratype) L. muscle scars of female right valve (SUM-CO-2176, paratype) M & N. anterior and posterior elements of hinging on male right valve (SUM-CO-2174, paratype). Scale: 200 μ m for A–H, J, K, 60 μ m for I, L, M, N.

Antenna (Fig. 12B). 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.

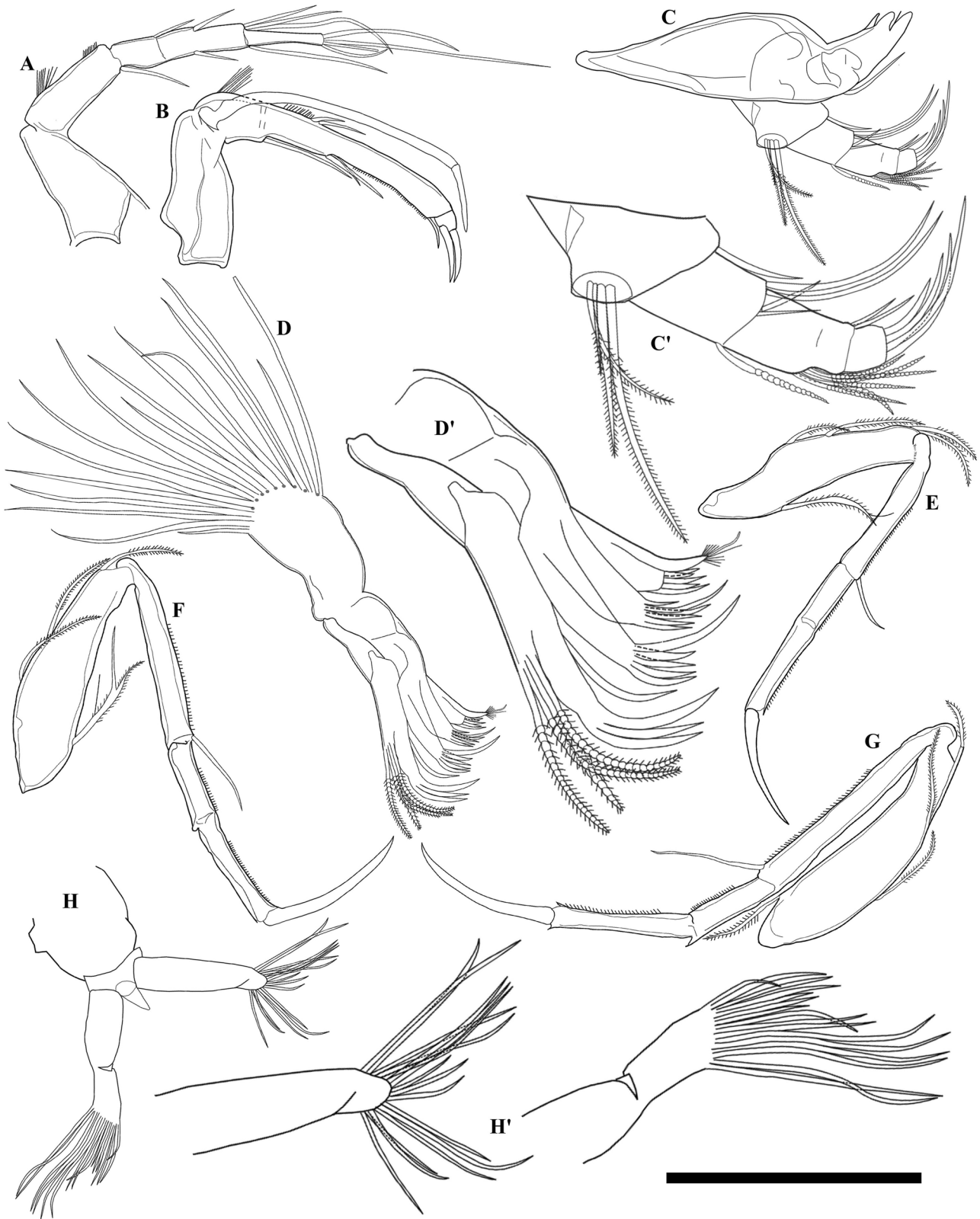


FIGURE 12. *Loxoconcha sesokoensis* sp. nov. A, C, D. Male (SUM-CO-2177, paratype) B, E-H. male (SUM-CO-2167, holotype). A. antennula B. antenna C. mandibula D. maxillula E. fifth limb F. sixth limb G. seventh limb H. brush-shaped organ C', D', H', enlarged details of C, D, H, respectively. Scale: 100 µm for A-H, 50 µm for C' D' H'.

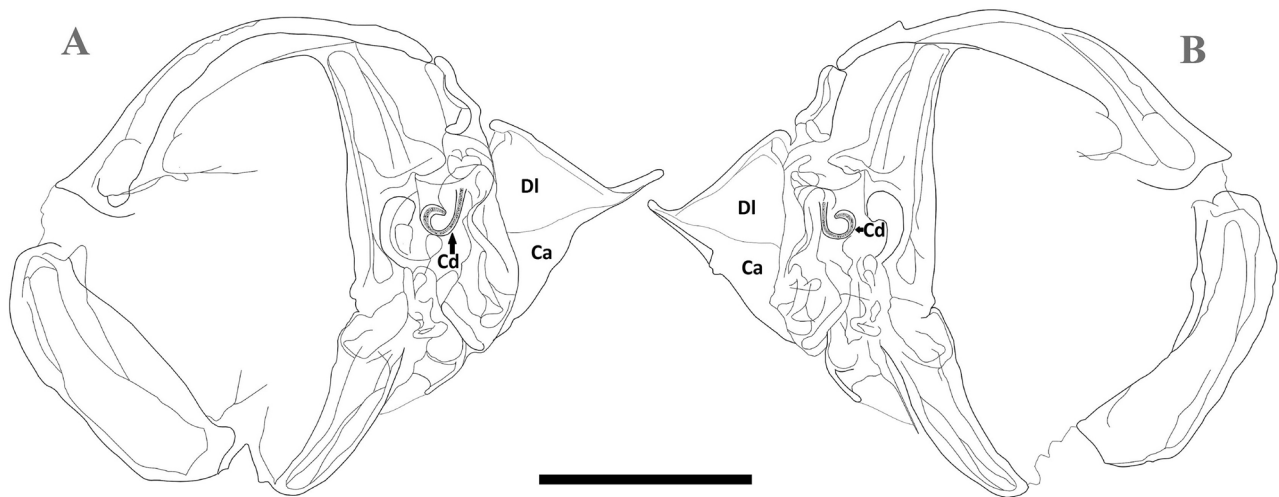


FIGURE 13. *Loxoconcha sesokoensis* sp. nov., holotype, male (LO2060). A. right copulatory organ B. left copulatory organ. Abbreviation: Ca, clasper apparatus, Cd, copulatory duct, DI, distal lobe. Scale: 100 μ m.

Mandibula (Fig. 12C, C'). 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. 12D, D'). 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. 12E). 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. 12F). 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. 12G). 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 (Figs 13). General shape oval. Basal part relatively large, triangular. Thin distal lobe triangular. Clasper 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. 12H, H'). Y-shaped in general; consisting of pair of branches, with 16 fine setae on each distal margin.

Dimensions. See Table 1.

Remarks. *Loxoconcha sesokoensis* sp. nov. 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 *Loxoconcha sesokoensis* sp. nov., 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).

Discussion

Adults of the two new species, *Loxoconcha noharai* sp. nov. and *L. santosi* sp. nov., share the same distribution pattern of pore systems located below the eye tubercle, belonging to Group B, according to Ishii *et al.* (2005) (Fig. 14A, B). However, in their A-1 stages, this pattern is not identical in the two species (Fig. 15).

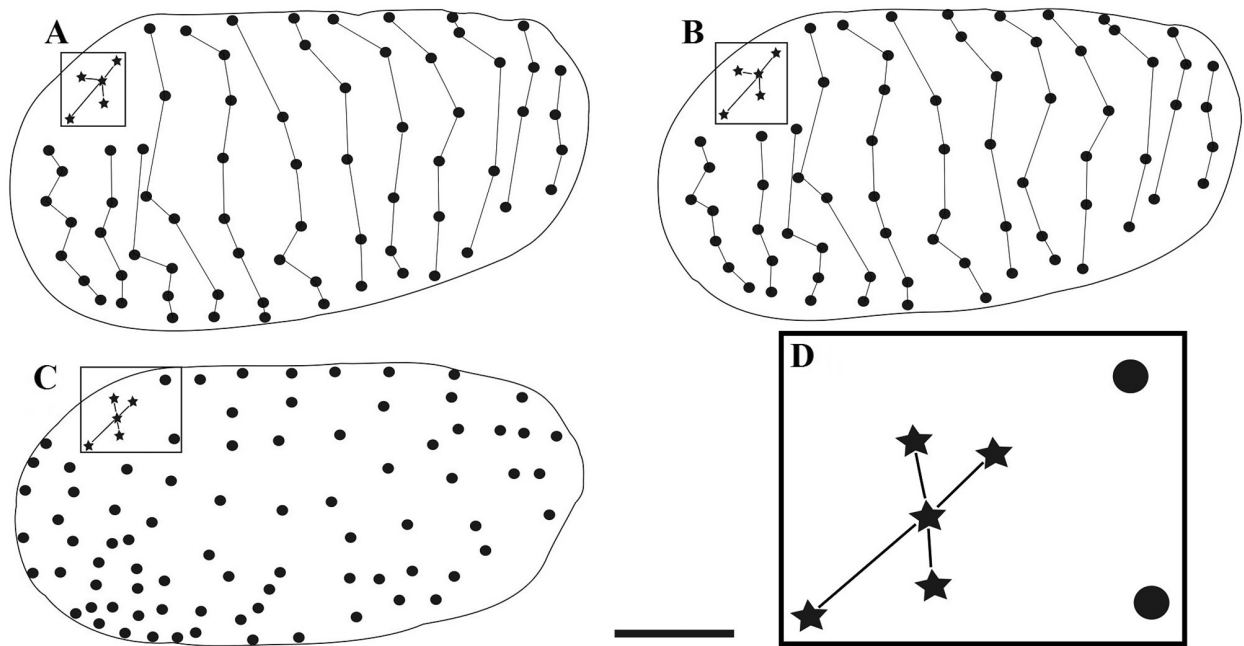


FIGURE 14. Distribution pattern of pore systems. A. male left valve in external lateral view of *Loxoconcha noharai* sp. nov. (SUM-CO-2138, paratype) B. male left valve in external lateral view of *L. santosi* sp. nov. (SUM-CO-2163, paratype) C. male left valve in external lateral view of *L. sesokoensis* sp. nov. (SUM-CO-2168, paratype) D. enlarged detail of C. Scale: 100 µm for A–C, 25 µm for D.

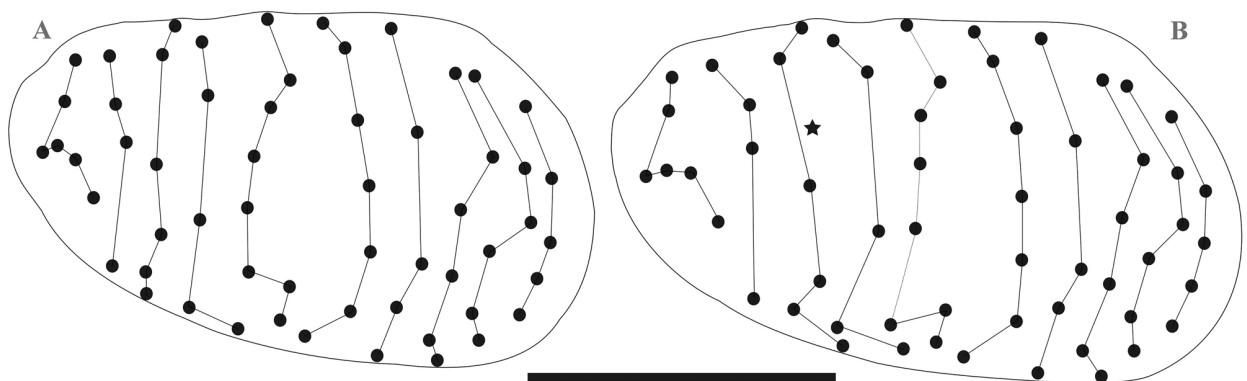


FIGURE 15. Distribution pattern of pore systems at the stage A-1. A. right valve in external lateral view of *Loxoconcha noharai* sp. nov. (SUM-CO-2149, paratype) B. right valve in external lateral view of *L. santosi* sp. nov. (SUM-CO-2164, paratype). In comparison with *L. noharai* sp. nov., circle shape: coexisting pores, star shape: additional pore. Scale: 200 µm.

Most species of Ishii *et al.*'s Group B (loc. cit.) inhabited areas around Japan since the early Miocene. The present main habitat of Group B species seems to be brackish-water environments where species diversity in general is limited due to its unstable condition. *L. noharai* sp. nov. was collected at the mouth of Ohura estuary, while *L. santosi* sp. nov. was recovered from the estuary in Ada that is connected to the sea via a small channel (Fig. 1C, D). Both sampling sites have brackish water with frequently fluctuating salinities as a result of the interaction between water sources (fresh, brackish and marine waters), tidal fluctuations, variations in land run-off, and rainfall.

TABLE 2. Comparison of characters of the mandible and maxillula among some *Loxococoncha* species.

Author	Species	Mandibula			Maxillula	
		Exopodite	Setae antero-distally of 2nd podomere of endopodite	3rd podomere of endopodite	3 endites	Most ventral seta of 3rd endite
Okubo (1980)	Genus <i>Loxococoncha</i>	4 setae	5 or 6 setae	2 claws and 2 setae	6 stout setae on each	Large plumose appendix seta near inner endite
	<i>L. japonica</i>	4 setae	6 setae	2 claws and 2 setae	6 stout setae on each	Ditto
	<i>L. mitsuense</i>	4 setae	5 setae	2 claws and 2 setae	6 stout setae on each	Ditto
	<i>L. uranouchiensis</i>	4 setae	6 setae	2 claws and 2 setae	6 stout setae on each	Ditto
	<i>L. harimensis</i>	4 setae	5 setae	2 claws and 2 setae	6 stout setae on each	Ditto
	<i>L. bizenensis</i>	4 setae	5 setae	2 claws and 2 setae	6 stout setae on each	1 long whip-like seta anteriorly
Nakao and Tsukagoshi (2002)	<i>L. kosugii</i>	4 plumose setae and 1 short, simple seta	6 setae	4 simple setae and 1 short, plumose seta	Several equal-length, plumose setae	Bearing long setulae arranged in 2 rows.
	<i>L. pulchra</i>	As small branchial plate with few soft setae	6 setae	2 stout setae and 1 plumose seta	6, 7 and 4 setae, respectively	With long setulae arranged in 2 rows and terminating in spatula-like head.
Present study	<i>L. noharai</i> sp. nov.	4 setae	5 setae	4 simple setae	6, 6 and 4 setae, respectively	Bearing long setulae arranged in a cluster and terminating in a club-like process.
	<i>L. santosi</i> sp. nov.	3 setae and 1 small degenerated seta	5 setae	4 simple setae	6, 5 and 5 setae, respectively	Bearing long setulae formed a cluster and terminating in a club-like process.
	<i>L. sesokoensis</i> sp. nov.	4 setae	6 setae	4 simple setae	5, 6 and 5 setae, respectively	Bearing long setulae formed a cluster and terminating in a club-like process.

When comparing *L. sesokoensis* **sp. nov.**, with Ishii *et al.*'s (2005) results, the distributional pattern of the pore system below the eye tubercle in this new species is unique (Fig. 14C, D), i.e. neither belonging to Group A (fully marine; phytal, or bottom-dwellers) nor to Group B (brackish, bottom-dweller). Since Ishii *et al.* (loc. cit.) do not cover any coral reef *Loxococoncha* species, their grouping obviously cannot be applied to *L. sesokoensis* **sp. nov.**, 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 *Loxococoncha* species around Japan.

In previous descriptions of *Loxococoncha* species, Okubo (1980) defined the genus by the following features (Table 2): mandible with exopodite of 4 setae, third podomere distally with 2 claws and 2 setae; in the maxillula, each of 3 masticatory lobes distally consisting of 6 stout setae. Recently, Nakao & Tsukagoshi (2002) studied two *Loxococoncha* species from the Obitsu River Estuary, central Japan, and described them as follows (Table 2): basis bearing exopodite in the mandible of *Loxococoncha kosugii* being composed of 4 plumose setae and 1 short, simple seta; third podomere of endopodite bearing 4 simple setae and 1 short, plumose seta; in *L. pulchra*, third podomere of endopodite of the mandible bearing 2 stout setae and 1 plumose seta; 3 endites of the maxillula bearing 6, 7, and 4 setae, respectively; most ventral seta of 3rd endite with long hairs arranged in 2 rows and terminating in spatula-like head. In the present study, the exopodite of the mandible bearing 4 setae for *L. noharai* **sp. nov.**, *L. santosi* **sp. nov.** and *L. sesokoensis* **sp. nov.**; 3 endites of the maxillula consist of 6, 6 and 4 setae, respectively for *L. noharai* **sp. nov.**; 6, 5, and 5 setae, respectively for *L. santosi* **sp. nov.** and 5, 6 and 5 setae, respectively for *L. sesokoensis* **sp. nov.**; in the maxillula, the most ventral seta of 3rd endite in all three species bear long setules, forming a cluster and terminating in a club-like process. The plumose seta on the posterior margin of first podomere consisting of several long setulae is found at the fifth and sixth limbs in *L. santosi* **sp. nov.**, *L. sesokoensis* **sp. nov.**, and *L. noharai* **sp. nov.**, but also at the seventh limb in *L. noharai* **sp. nov.**

In the past, chaetotaxy of *Loxococoncha* species has not been given enough attention to, although it bears many potentially species specific characters. Especially the chaetotaxy of maxillulae should be included to the descriptions of species of the genus.

With the aim of confirming the new species, we compared their carapace morphology in external lateral view of with *Loxococoncha* species not only from around Japan but also from the western Pacific, e.g., Australia (Yassini & Jones 1995), Indonesia-Malaysia (Whatley & Zhao 1987, 1988), China (Brady 1869, 1880; Hou *et al.* 1981; Gou *et al.* 1983; Wang & Zhao 1985; Zhao 1985; Zhao *et al.* 1985), Korea (Cheong *et al.* 1986; Paik & Lee 1988; Huh & Paik 1992) and Taiwan (Hu & Tao, 2008). The here described three new species are morphologically different from other *Loxococoncha* species described from Japan and the Western Pacific.

Acknowledgements

Our thanks go to Prof. Takahiro Kamiya (Kanazawa University) and the members of the Ostracod Research Team of Shizuoka University for their valuable suggestions and continuous support, and also to the staff of the Sesoko Station of the Ryukyu University. 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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