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Choniomyzon inflatus n. sp. (Crustacea: Copepoda: Nicothoidae) associated with *Ibacus novemdentatus* (Crustacea: Decapoda: Scyllaridae) from Japanese waters

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Abstract A new species of parasitic copepod, *Choniomyzon inflatus* n. sp., is described based on specimens collected from the external egg masses of the smooth fan lobster *Ibacus novemdentatus* Gibbes captured in the North Pacific Ocean off Ainan, Ehime Prefecture, western Japan. The new species differs from its congeners in having a globular to ovoid prosome, in bearing asymmetrically arranged denticles at a rounded apex of both the terminal segment of the antenna and the maxilliped, and in lacking serrate lobes on the basis of legs 1 and 2. The species is similar in size and shape to the host's eggs, which may be interpreted as egg mimicry. The new species is the first member of *Choniomyzon* Pillai, 1962 from subtropical regions.

Introduction

Choniomyzon Pillai, 1962 is one of the 22 valid genera of the siphonostomatoid copepod family Nicothoidae Dana, 1849 (Boxshall & Halsey, 2004; Ohtsuka et al., 2005; Boyko, 2009). Only two species have been recognised in the genus to date.

Choniomyzon panuliri Pillai, 1962 was described by Pillai (1962) from the abdomen of a spiny lobster, *Panulirus homarus* (Linnaeus), collected off the Kerala Islands, India. Later, Bradford (1975) redescribed *C. panuliri* using specimens from the external egg masses of another spiny lobster, *P. versicolor* (Latreille), captured off the British Solomon Islands, but she recognised some differences between her and Pillai's (1962) specimens. Recently, *C. panuliri* was found again on the external egg masses of *P. versicolor* collected from the Great Barrier Reef, Australia (Shields et al., 2006; Shields, 2011). This copepod seems to be associated with lobsters of the genus *Panulirus* White, 1847, which are widely distributed over the tropical waters of the Indo-West Pacific.

Choniomyzon libiniae Santos & Björnberg, 2004 was described from the external eggs of an epialtid crab, *Libinia spinosa* H. Milne-Edwards, collected off Saõ Sebastiãno Island, Brazil (Santos & Björnberg, 2004). The adult female of *C. libiniae* is smaller than that of *C. panuliri*. The two species also differ in the ornamentation of the antenna and legs. *C. libiniae* hatches as a nauplius and then passes through at least three copepodid stages. Among the 22 genera in the family Nicothoidae (Boxshall & Halsey, 2004; Ohtsuka et al., 2005; Boyko 2009), eggs hatch into nauplii only in species of two genera, *Choniomyzon* and *Choniosphaera* Connolly, 1929, whereas, in other

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genera, eggs hatch into the first copepodid stage (Bradford, 1975; Ohtsuka et al., 2005).

In the present paper, we describe a new species of copepod associated with the external egg masses of the smooth fan lobster *Ibacus novemdentatus* Gibbes collected from Japanese waters. This represents a third species of *Choniomyzon*.

Materials and methods

Female smooth fan lobsters *Ibacus novemdentatus* were caught by trawl-net at a depth of approximately 100 m in the western North Pacific Ocean off Ainan, Ehime Prefecture, western Japan, on 22 January, 2012. The lobsters were transported live on the following day to a laboratory at Tokyo University of Marine Science and Technology. Copepods were carefully removed from the external egg masses of the lobsters, photographed and preserved in 70% ethanol. Specimens were soaked in lactophenol before dissection under a dissecting microscope (Olympus SZX7). The appendages of the copepods were observed with a compound microscope (Olympus BX51) using the wooden-slide technique of Humes & Gooding (1964). Drawings were made with the aid of a drawing tube attached to the compound microscope. Measurements in micrometres are shown as mean and standard deviation.

The ultrastructure of appendages was observed using a Topcon SM-300 scanning electron microscope (SEM). Specimens were fixed in 2.5% glutaraldehyde for 10 min immediately after anaesthesia with 10% $MgCl_2$ solution and rinsed twice with 0.1 M sodium cacodylate buffer. They were then fixed in 2% OsO_4 for 1 h, dehydrated through a graded ethanol series and finally preserved in 70% ethanol. We observed the specimens under the SEM without drying.

Type-specimens are deposited in the Crustacea collection at the National Museum of Nature and Science, Tsukuba (NSMT) and in the Museum of Fishery Science in Tokyo University of Marine Science and Technology, Tokyo (MTUF). The terminology for the copepods follows Huys & Boxshall (1991) and the scientific names of the lobsters follow Holthuis (1985).

Order Siphonostomatoida Burmeister, 1835
Family Nicothoidae Dana, 1849
Genus *Choniomyzon* Pillai, 1962

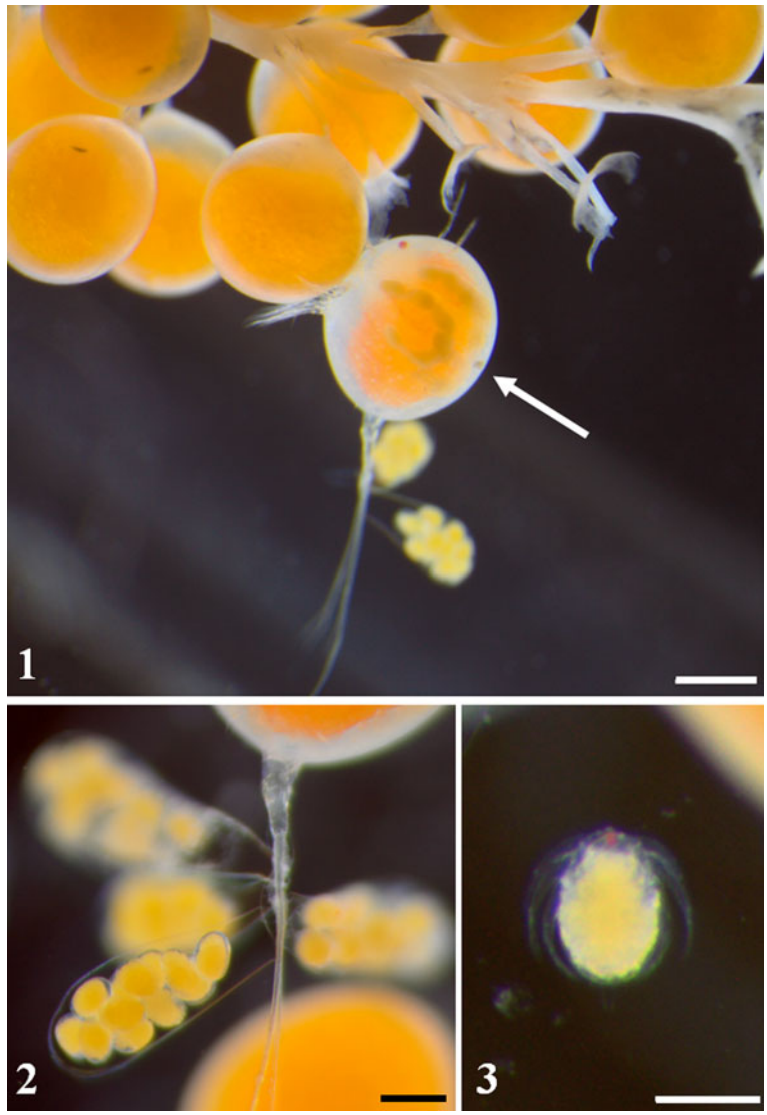
Choniomyzon inflatus n. sp.

Type-host: The smooth fan lobster *Ibacus novemdentatus* Gibbes (Decapoda: Scyllaridae).
Type-locality: Western North Pacific Ocean, off Ainan (32°88′N, 132°17′E), Ehime Prefecture, western Japan.
Type-material: Holotype, female (NSMT-Cr 22190), ex *I. novemdentatus*, western North Pacific Ocean, off Ainan (32°88′N, 132°17′E), Ehime Prefecture, western Japan, 22 January 2012. Paratypes, 13 females (4 females, whole specimens, NSMT-Cr 22191; 3 females, whole specimens, MTUF Ar00002; 1 female, completely dissected and mounted on glass slides, NSMT-Cr 22192; 2 females, completely dissected and mounted on glass slides, MTUF Ar00003; 3 females, whole specimens after preparation for observation under SEM, MTUF Ar00004), ex *I. novemdentatus*, western North Pacific Ocean, off Ainan (32°88′N, 132°17′E), Ehime Prefecture, western Japan, 22 January 2012.
Other material examined: 6 females (2 females, whole specimens, NSMT-Cr 22193; 2 females, completely dissected and mounted on glass slides, NSMT-Cr 22194; 2 females, whole specimens, MTUF Ar00005), ex *I. novemdentatus*, western North Pacific Ocean, off Ainan (32°88′N, 132°17′E), Ehime Prefecture, western Japan, 22 January 2012.
Attachment site: Egg masses of host (Fig. 1).
Etymology: The specific name of the new species is a reference to its swollen prosome, which resembles a balloon.

Description of female (Figs. 1–25)

Body (Figs. 4–6, 20–21) length 2,270 ± 90 ($n = 16$) from anterior head to base of caudal rami. Prosome length, prosome width, prosome depth, urosome length and caudal ramus length are 1,160 ± 40, 950 ± 50, 1,020 ± 50, 260 ± 20 and 860 ± 70, respectively ($n = 16$). Prosome globular to ovoid, formed by cephalosome and first 3 pedigerous somites; length and depth of prosome 1.19 and 1.07 times greater than width, respectively.

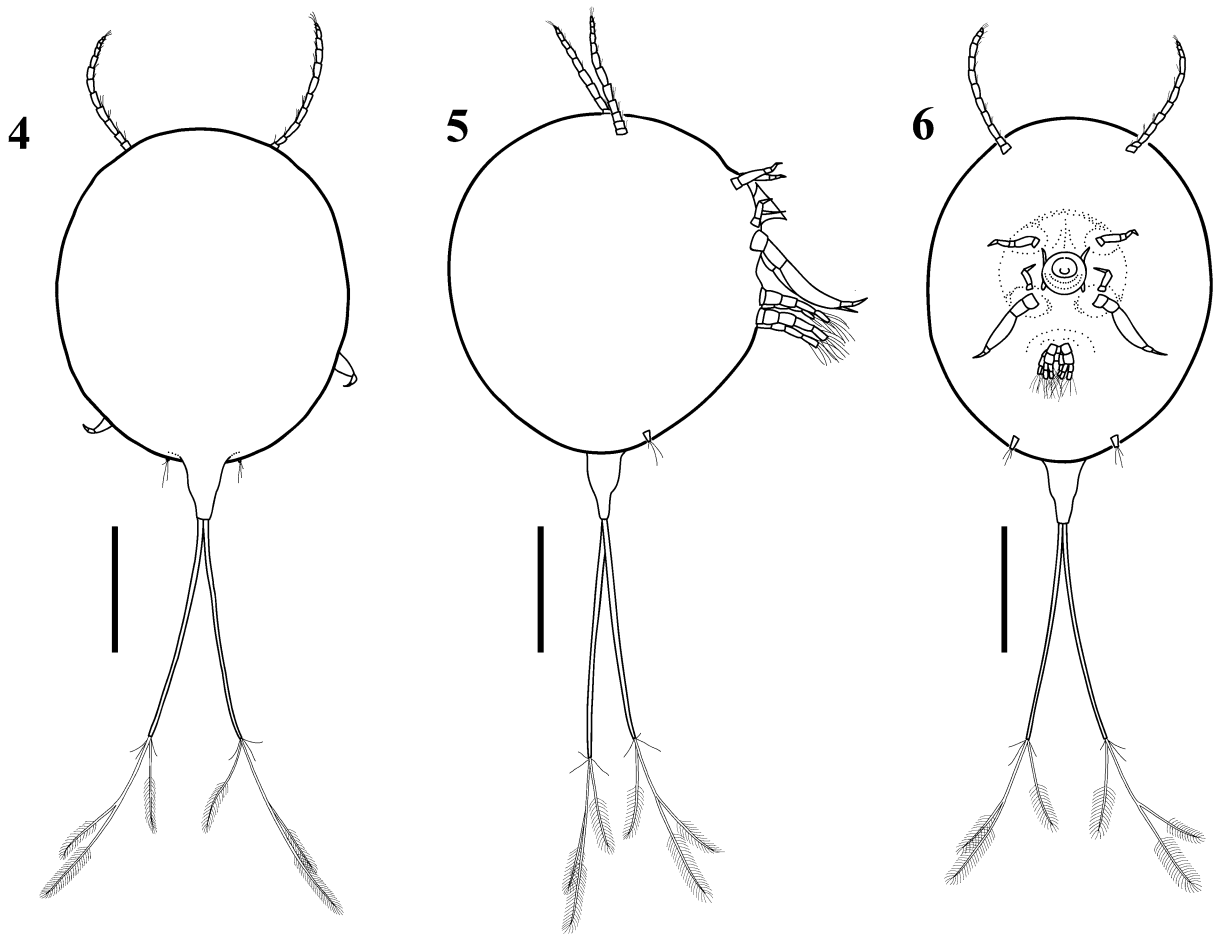
Antennules (Fig. 7) 12-segmented; each segment ornamented with setae except fifth segment (1, 1, 2, 2, 0, 1, 1, 2, 1, 1 + aesthetasc, 3, 4 + aesthetasc). Antennae (Fig. 8) prehensile, 4-segmented; first and second segments unarmed; third segment carrying robust serrate seta and naked seta (Figs. 9, 23);



Figs. 1–3 *Choniomyzon inflatus* n. sp., digital photograph of live specimens. 1. Adult female (arrow) associated with an egg of *Ibacus novemdentatus*; 2. Egg-sacs of a female; 3. Newly hatched nauplius. *Scale-bars*: 1, 500 μm; 2, 200 μm; 3, 100 μm

terminal segment elongate, with rounded apex with 12–14 denticles arranged asymmetrically (Fig. 22). Oral cone (Figs. 10, 24) funnel-shaped, with anterior median gap, consisting of 2 concentric rings, with outer ring bordered by flexible membrane. Mandible (Fig. 10) stout with pointed tip projecting into oral cone. Maxillule (Figs. 10–11) bilobed and situated lateral to oral cone; inner lobe with 1 outer and 2 distal long setae; outer lobe bearing 1 large seta and 2 short setae. Maxilla (Fig. 12) 3-segmented; terminal segment bearing small spine at mid-length and 8–10 denticles arranged in row at rounded apex. Maxilliped (Fig. 13) long and prehensile, 5-segmented; each segment except terminal segment bearing short inner distal spine; terminal segment with 12–14 denticles arranged asymmetrically at rounded apex, similar to those on antenna (Figs. 14, 25).

Legs 1 and 2 (Fig. 15–16) biramous, consisting of coxa, basis and 2-segmented rami; basis without serrate lobes; both rami with spines and long plumose setae; exopod shorter than endopod; leg armature formula as follows:



Figs. 4–6 *Choniomyzon inflatus* n. sp. (MTUF Ar00002), adult female. 4. Habitus, dorsal; 5. Habitus, right lateral; 6. Habitus, ventral. *Scale-bars*: 500 μm

	Coxa	Basis	Exopod segment		Endopod segment	
			1	2	1	2
Leg 1	0–1	1–0	I–0	II,3,1	0–1	1,3,2
Leg 2	0–0	1–0	I–0	0,3,1	0–1	1,3,1

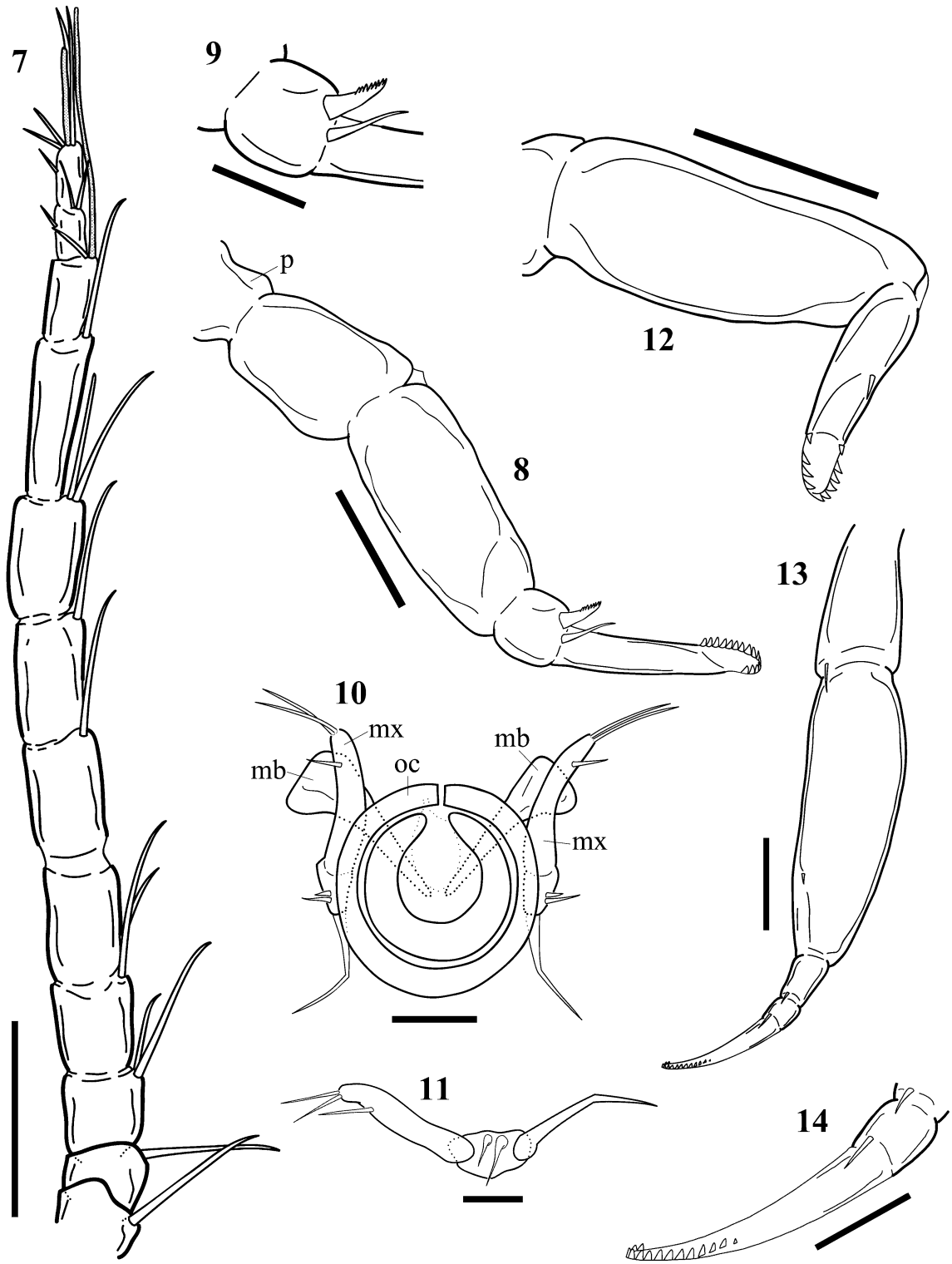
Leg 3 (Fig. 17) represented by process bearing 3 setae, situated on postero-lateral part of ventral side of prosome. Leg 4 absent. Urosome (Fig. 18) short and narrow, not overlapped by prosome; indistinctly 4-segmented; genital system in first segment. Caudal rami (Fig. 19) long and slender; each with 3 small setae (III, VI and VII) plus 2 long seta (IV and V), seta V divided again into short outer and long inner branches, and caudal seta I and II absent.

Figs. 7–14 *Choniomyzon inflatus* n. sp. (NSMT-Cr 22192, MTUF Ar00003), adult female. 7. Left antennule, dorsal, aesthetacs shown as stippled; 8. Left antenna, ventral; 9. Third segment of left antenna, ventral; 10. Oral region, ventral; 11. Right maxillule, antero-lateral; 12. Left maxilla, antero-dorsal; 13. Left maxilliped, ventral; 14. Terminal segment of left maxilliped, ventral. *Abbreviations*: mb, mandible; mx, maxillule; oc, oral cone; p, pedestal. *Scale-bars*: 7,8,11,12,14, 50 μm; 9, 25 μm; 10,13, 100 μm ▶

Egg-sac (Fig. 2) club-shaped and connected with caudal rami by membranous stalks; 9–14 eggs in each sac; up to 4 egg sacs per female.

Variability of measurements

The non-type material all shares important morphological characteristics with the type-material. Their body measurements ($n = 9$) are: body length 2,760 ± 200;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prosome length 1,640 ± 160; prosome width 1,460 ± 140; prosome depth 1,550 ± 140; urosome length 260 ± 30; and caudal ramus length 860 ± 60. width 1,460 ± 140; prosome depth 1,550 ± 140; urosome length 260 ± 30; and caudal ramus length 860 ± 60. The prosome of these specimens is larger than that of the type-material (*t*-test, $p < 0.001$), but there are no significant differences in length of the urosome or the caudal ramus between the types and other specimens (*t*-test, $p = 0.949$ and 0.998, respectively). These large females have 25–44 eggs per sac.

Remarks

The antenna appears to provide the clearest diagnostic characters that enable us to identify the three species of *Choniomyzon*. The adult female of *C. libiniae* can be distinguished from that of *C. panuliri* by the arrangement of ornamentation on the antenna (Santos & Björnberg, 2004): *C. libiniae* has a finger-like structure on the terminal segment, whereas *C. panuliri* has a serrate terminal segment. The terminal segment of the antenna in *C. inflatus* n. sp. is similar to that in *C. panuliri*, but it is not expanded at the apex, as in the latter species. The number of segments of the antenna is also different: *C. panuliri* and *C. libiniae* have five and three segments respectively, whereas *C. inflatus* has four.

Although *C. inflatus* is generally similar to *C. panuliri*, several differences are apparent between the type-material of the new species and the specimens of *C. panuliri* described by Pillai (1962) and Bradford (1975). Bradford observed a spine on the distal part of the inner lobe of the maxillule in *C. panuliri*, but Pillai did not find such a spine. The new species also has no spine in the same position. A number of other characteristics were found on Bradford's specimens but not on Pillai's, as follows: the fifth and tenth segments of the antennule are naked and bear an aesthetasc; the inner and outer lobes of the maxillule have an outer seta and two short setae; the second segment of the maxilliped has a single spine; and the egg sacs are attached to the caudal rami. These were also observed in *C. inflatus*. A serrate lobe was observed on the distal part of the basis of legs 1 and 2 in the specimens of *C. panuliri* described by both Pillai (1962) and Bradford (1975), but no such lobes were present in the new species.

Choniomyzon inflatus can be easily distinguished from *C. libiniae* by the form of the prosome which lacks wing-like protruding folds, the urosome not being overlapped by the prosome, four-segmented antennae, a rounded serrate apex of the terminal segment of the antenna, a serrate seta and a small seta on the third segment of the antenna, the maxilla with a serrate apex, and the maxilliped with an asymmetrical serrate border.

Choniomyzon inflatus hatches as a nauplius (Fig. 3), a life-cycle characteristic which is shared by its two congeners.

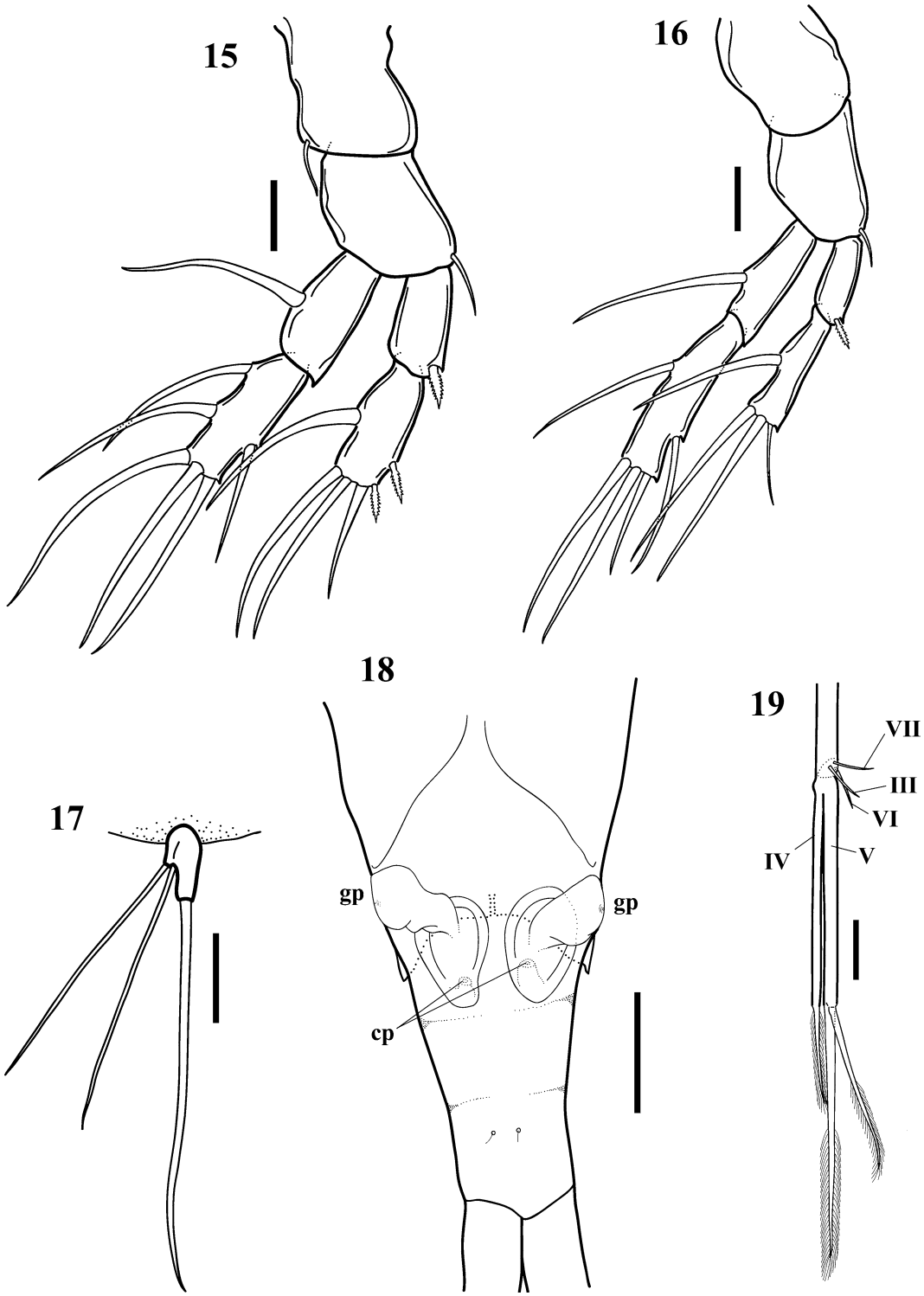
Figs. 15–19 *Choniomyzon inflatus* n. sp. (NSMT-Cr 22192, MTUF Ar00003), adult female. 15. Left leg 1, antero-ventral, plumes on the setae of both rami omitted; 16. Left leg 2, antero-ventra, plumes on the setae of both rami omitted; 17. Right leg 3, dorso-lateral; 18. Urosome, dorsal; 19. Left caudal ramus, ventral. *Abbreviations*: Roman numerals indicate caudal setae (Huys & Boxshall, 1991); cp, copulatory pore; gp, gonopore. *Scale-bars*: 15,16,18, 50 μm; 17, 20 μm; 19, 100 μm ▶

Discussion

We collected *Choniomyzon inflatus* n. sp. on the external egg masses of the smooth fan lobster *Ibacus novemdentatus* caught in Japanese subtropical waters. Its two congeners, *C. panuliri* and *C. libiniae*, have been reported from tropical waters. Our discovery of *C. inflatus* represents the first record of specimens of the genus from the subtropical region.

Choniomyzon panuliri is associated with spiny lobsters of the palinurid genus *Panulirus* (see Pillai, 1962; Bradford, 1975; Shields et al., 2006), and *C. libiniae* is found on the epialtid brachyuran crab *Libinia spinosa* (see Santos & Björnberg, 2004). In the present study, *C. inflatus* was collected from the scyllarid lobster *I. novemdentatus*. Thus, different species of *Choniomyzon* utilise a variety of decapods as hosts.

Parasitic crustaceans often show mimicry of the egg or egg mass of their host. Bowman & Kornicker (1967) reported that a nicothoid copepod, *Sphaeronellopsis monothrix* Bowman & Kornicker, 1967, lays its eggs in the host ostracod's brood chamber singly, but those eggs are enclosed by a membrane into a group. Individual copepod eggs could presumably be removed from the brood chamber during grooming performed by the cleaning leg of the host; however, the copepod is able to avoid this hazard by laying its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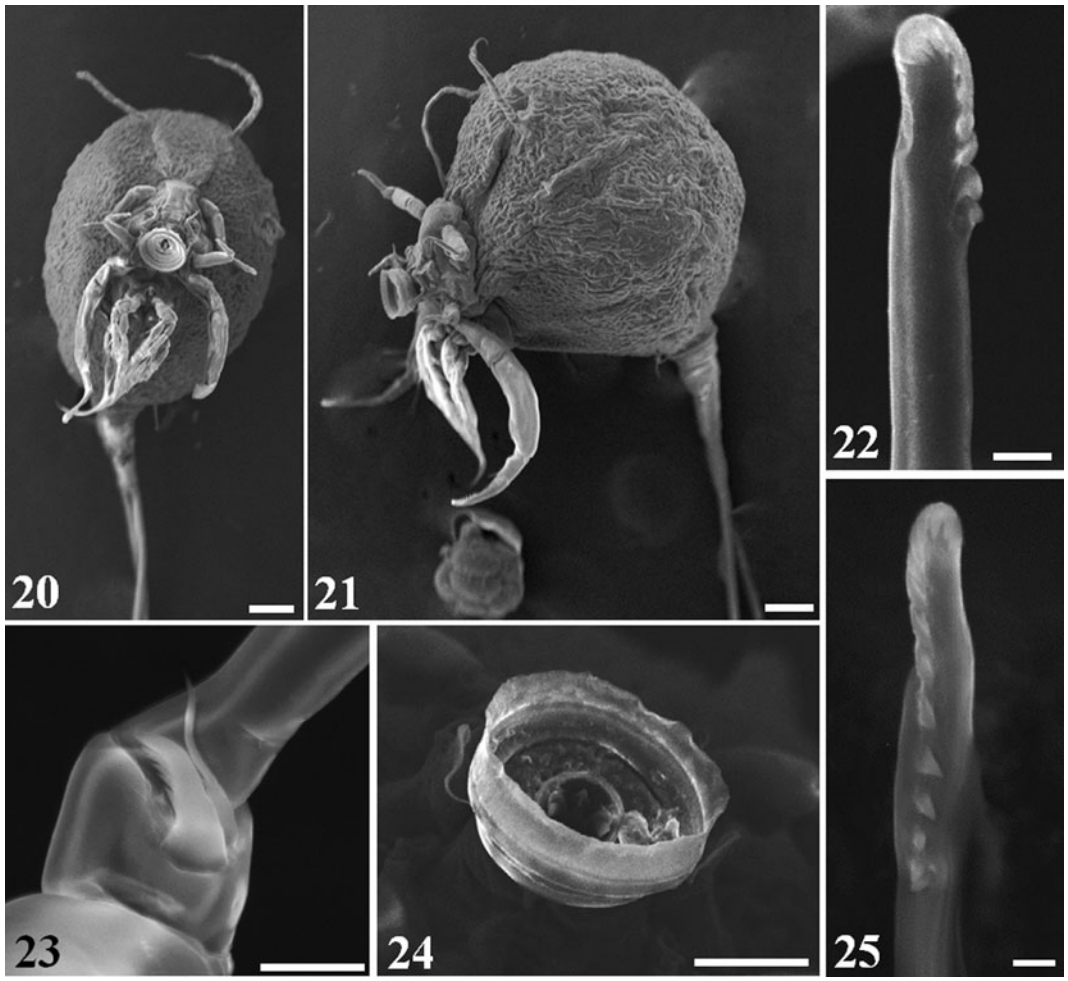

Figs. 20–25 *Choniomyzon inflatus* n. sp. (MTUF Ar00004), scanning electron micrographs. 20. Adult female, ventral; 21. Adult female, left lateral; 22. Terminal segment of right antenna, left lateral; 23. Third segment of left antenna, ventral; 24. Oral region, postero-ventral; 25. Terminal segment of right maxilliped, left lateral. *Scale-bars*: 20,21, 100 μm; 22,23,25, 10 μm; 24, 50 μm

eggs in groups within sacs, each sac mimicking one of the ostracod eggs in size and shape (Bowman & Kornicker, 1967). Instead of being removed as a foreign particle, the egg-sac of *S. monothrix* is retained within the brood chamber and cleaned by the host with the same care as given to its own eggs (Bowman & Kornicker, 1967). Similarly, Ritchie & Høeg (1981) observed that the externa of a parasitic barnacle, *Lernaeodiscus porcellanae* Müller, 1852, mimics the host's egg mass in form and position. The infested host, a crab *Petrolisthes cabrilloi* Glasell, ventilates and grooms the externa as it would care for its own brood (Ritchie & Høeg, 1981). The egg-sacs of a parasitic nicothoid copepod, *Neomysidion rahotsu* Ohtsuka, Boxshall & Harada, 2005, also mimic the eggs of the host mysid, *Siriella okadai* Ii, which has been interpreted as being important in preventing removal by the grooming activities of the host (Ohtsuka et al., 2005, 2007). The prosome of adult females of *C. inflatus* also simulates the external eggs of its host, *I. novemdentatus*, in its shape and size, and their caudal rami are similar to the morphology of the egg attachment filaments of the host. This mimicry appears to be an adaptation to avoid ejection as a foreign particle by the host. Like other decapod crustaceans, ovigerous individuals of *I. novemdentatus* always groom their brooded eggs with the fifth pereiopods (Bauer, 1989; Wakabayashi, personal

observation). Assuming that the host is able to distinguish foreign particles from the brooded eggs by inspecting their shape and size, we infer that the egg mimicry in *C. inflatus* helps prevent it being removed from the host's eggs.

Choniomyzon inflatus exhibits size variability in its prosome. Moreover, the colour of its live body is very similar to that of the eggs (Fig. 1). These findings suggest that *C. inflatus* exploits the yolk of the host's eggs, as in the case of *Neomysidion rahotsu*, which is an active consumer of host eggs (Ohtsuka et al., 2005, 2007). The trunk of the female *N. rahotsu* undergoes extreme expansion and modification after the female consumes the host's eggs (Ohtsuka et al., 2005, 2007). In *C. inflatus*, increase and decrease in the size of the prosome may also depend on its nutritional state. If this is the case, it may be possible to find smaller and more transparent individuals than the type-specimens. In addition, large females tend to produce more eggs, suggesting that reproductive efficiency depends on body size. Since nicothoid copepods have been reported to suck the host's blood (Hansen, 1897; Bowman & Kornicker, 1967), the new species may also survive on the gills of non-ovigerous hosts, as suggested for *C. panuliri* by Shields et al. (2006). Further studies on the life-history of this new species should be carried out in order to determine whether it is an egg predator, which site or sites on the host are utilised by its males and copepodids, and whether it is also associated with male hosts.

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