

First record of *Holophryxus fusiformis* Shiino, 1937 (Crustacea, Isopoda, Dajidae) from the sakura shrimp, *Lucensosergia lucens*, in Taiwan

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Abstract.— *Holophryxus fusiformis* Shiino, 1937, a species of dajid isopod that attaches to the carapace of sakura shrimp, *Lucensosergia lucens* (Hansen, 1922), is reported from the sea of Taiwan for the first time. This species was first described as infesting *Prehensilosergia prehensilis* (Bate, 1881) from Kanbara, Shizuoka Prefecture, Japan. The current finding represents the second occurrence of *H. fusiformis* and identifies a new host. Approximately 1% of the sakura shrimps in Yilan, Taiwan are infected by *H. fusiformis*. *Holophryxus fusiformis* has been found offshore from both Yilan, Taiwan and Nagasaki and in Suruga Bay, Japan; thus, the distribution of the parasite possibly follows the Kuroshio Current. When large quantities of parasites occur in the sea of Taiwan, the parasites are likely to flow into the Japanese waters along with the Kuroshio Current, subsequently influencing the production of the Japanese sakura shrimps. The establishment of a monitoring program for infection of the dajid in sakura shrimps between Taiwan and Japan is recommended. This study provides additional information on this species, including a new host, distribution, redescription, infection rate, and morphological variation.

Key words: North West Pacific, Kuroshio current, *Holophryxus*, crustacean parasite

Introduction

Lucensosergia lucens (Hansen, 1922), commonly known as the sakura shrimp, has been found in Yilan, Taiwan in recent years and is important to the government supported local fishery. The sakura shrimp fishery in Taiwan is concentrated in Donggang, Pingtung and Guishan Island, Yilan (Zhuang *et al.*, 2014). The Donggang fishing ground in Pingtung was developed around 1977, and the production volume of the sakura shrimp increased after Omori *et al.* (1988) verified the species identity of the sakura shrimp. The fishing ground in Yilan grew considerably in scale after 2006 (Zhuang *et al.*, 2014). The Yilan sakura shrimp fishing ground is located in Guishan Island with coordinates of 24°45'N–24°54'N 121°54'W–122°02'W. The

Kuroshio Current passes in the open sea east of this area, contributing to increased catches from February to July; fishing activity is prohibited in other months. The Yilan fishing ground produces 650 metric tons of sakura shrimp per year (Zhuang *et al.*, 2015). Because sakura shrimp undertake diurnal migration, they travel to a sea depth of 150–250 m during the day and return to a sea depth of 50–70 m at night (Chen *et al.*, 2010; Zhuang *et al.*, 2018). Therefore, fishermen throw fishing nets to a depth of approximately 150–200 m in early morning (Chen *et al.*, 2010; Zhuang *et al.*, 2018).

Yellow spindle-shaped “rucksacks” are often found attached to the carapaces of sakura shrimp, and a majority of these sack-like objects can be easily removed. Fishermen from Toucheng, Yilan, believe these sacks are the

eggs of the sakura shrimp, whereas others view them as parasites. The locals call these objects “corn kernels” because of the similarities in color and size. Under a magnifying glass or microscope, these objects resemble the pupa of insects, distinctively showing pereopod-like structures. The identity of these objects has been a concern among sakura shrimp specialists in Yilan.

Holophryxus is a genus in Dajidae, which is a family of marine isopod crustaceans in the sub-order Cymothoidea. The genus was established by Richardson (1905) and, according to Boyko *et al.* (2008), there are eight valid species in the genus. When attached to host shrimp, the parasites of this genus resemble a fleshy growth on the back of the shrimps, making the shrimps appear as if they are wearing rucksacks. Identification of the collected specimens showed similarities to an isopod species discovered by Shiino (1937) in Japanese waters.

Materials and Methods

Sakura shrimps and their parasites were sampled from May to June in 2017 at the Daxi fishing harbor in Toucheng, Yilan. The specimens were preserved in 70% ethanol on ice and stored at -20°C in the laboratory. Fifteen female specimens of the parasite were collected from carapaces of *Lucensosergia lucens*. The specimens were stained with methylene blue for 10 min and then observed under the stereoscopic microscope (SMZ1500, Nikon, Tokyo, Japan) with a CCD system connected to a computer with imaging software (NIS element D, Nikon, Tokyo, Japan). After the appearance of the parasite was examined, the female marsupium was dissected using a tweezer and needle to find the male in among the egg mass. The length measuring tool built-in the imaging software was used. Measurements provided are: body length of the parasite (BL: measured from tip of head to posterior end of abdomen along dorsal mid-line) and maximum body

width (BW). Specimens of *H. fusiformis* were deposited in the National Taiwan Museum, Taiwan (TMCD), and the Kitakyushu Museum of Natural History and Human History, Kitakyushu, Japan (KMNH IvR).

Taxonomic Account

Superfamily **Cryptoniscoidea** Kossmann, 1880

Family **Dajidae** Giard & Bonnier, 1887

Genus *Holophryxus* Richardson, 1905

Holophryxus fusiformis Shiino, 1937

(Figs. 1–4, 5B)

Material examined

Thirteen ovigerous females, TMCD003308–003311, KMNH IvR 500968, 500970, 500972, 500974, 500976, 500978, 500980, 500982, 500987, 7.0–10.12 mm BL, two non ovigerous females, KMNH IvR 500984, 500986, 7.00–7.50 mm BL, and ten males, TMCD003312, KMNH IvR 500969, 500971, 500973, 800975, 500977, 500979, 500981, 500983, 500985 (removed from each immediately preceding registration number female), 1.24–1.65 mm BL, ex. carapace of *Lucensosergia lucens*, Yilan, offshore of Toucheng, Guishan Island, Pacific coast of northeastern Taiwan ($24^{\circ}48'N$, $121^{\circ}56'E$), 80–120 m depth, fishing trawl net, 13 June, 2017, coll. Ming-Chih, Huang. One ovigerous female, KMNH IvR 500957, 6.8 mm BL, 3.5 mm BW, ex. carapace of *L. lucens*, west of the Naka-Kasayama Bank, offshore of Nagasaki, Kyushu, Japan, cruise N295 of T/V ‘Nagasaki-maru’, Nagasaki University, St-O ($32^{\circ}12.504'N$, $128^{\circ}56.631'E$ – $32^{\circ}12.682'N$, $128^{\circ}59.150'E$), 380–386 m, using a beam trawl net, 22 Nov, 2009, coll. M. Shimomura.

Description of female (KMNH IvR 500968)

Body symmetrical and spindle-shaped, 2.30 times as long as maximum width, dorsum vaulted, weakly grooved ventrally; bulging slightly on each lateral margin (Fig. 1A–C).

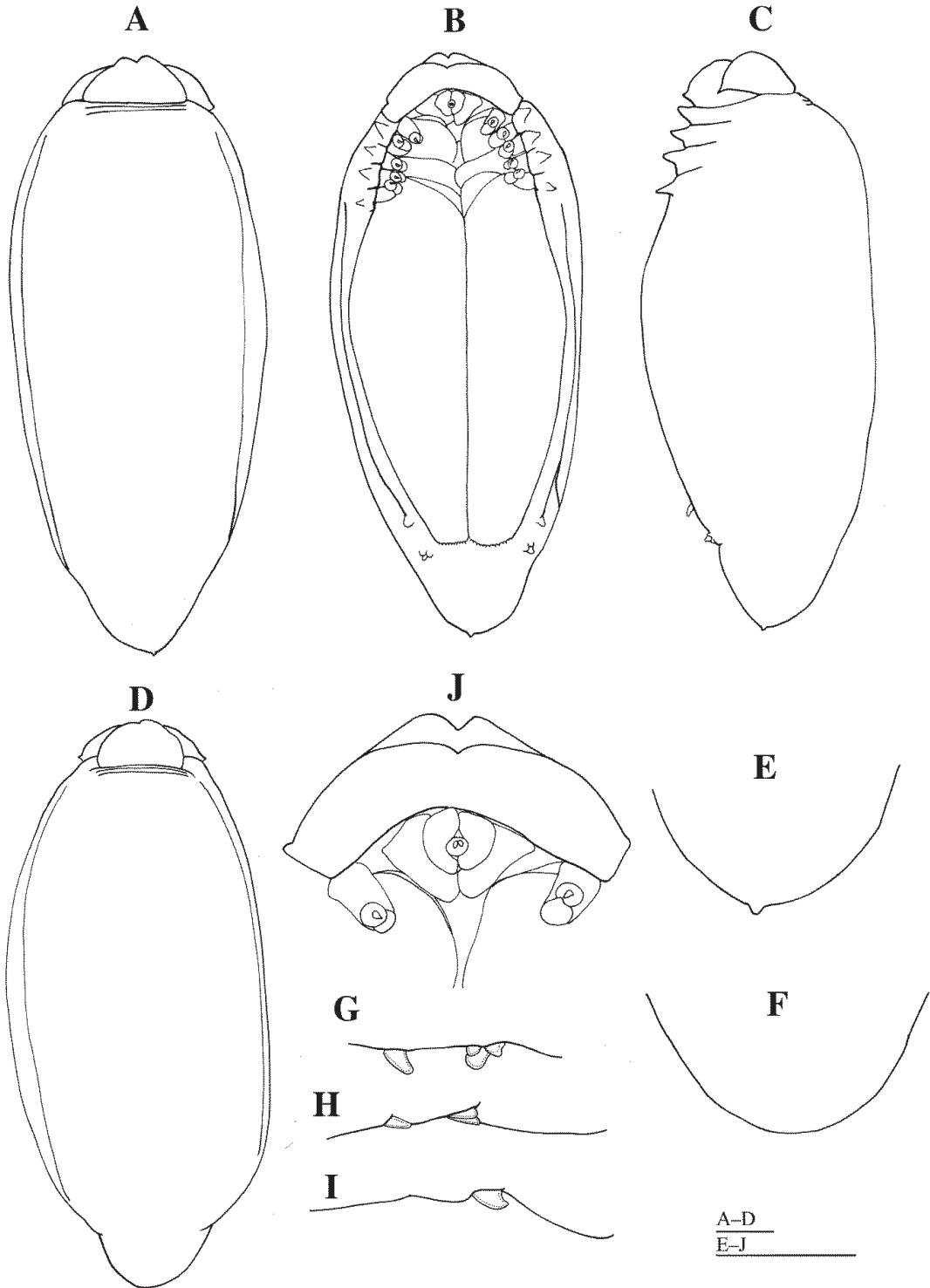


Fig. 1. *Holophryxus fusiformis* Shiino, 1937, A–C, E, G, J, female (KMNH IvR 500968), D, F, I, female (KMNH IvR 500970), H, female (KMNH IvR 500972): A, D, habitus, dorsal; B, habitus, ventral; C, habitus, lateral; E, F, posterior end of pleon, dorsal; G–I, papillae on posterior part of pereon, lateral; J, head and pereomere 1, ventral. Scale bars = 1 mm.

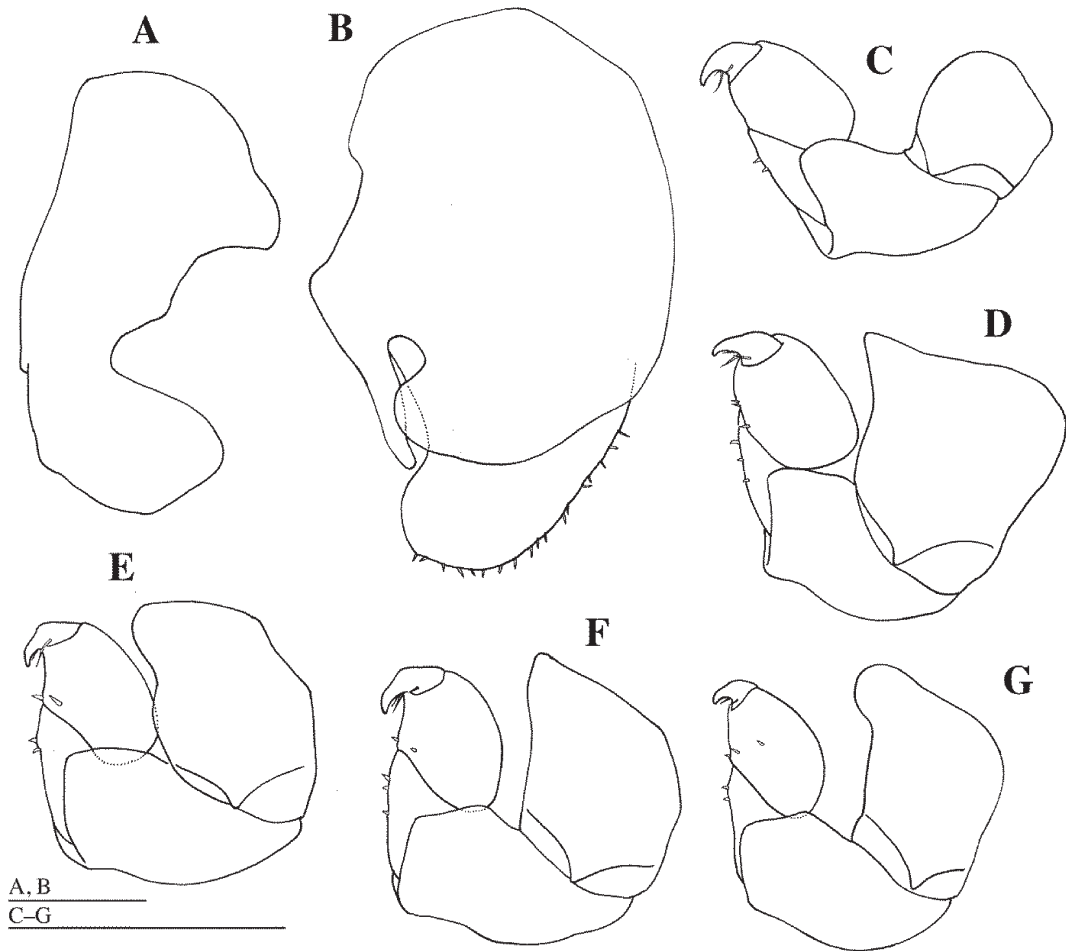


Fig. 2. *Holopryxus fustiformis* Shiino, 1937, A–G, female (KMNH IvR 500968): A, left maxilliped, ventral; B, left oostegite 1, ventral; C, left pereopod 1, medial; D, left pereopod 2, medial; E, left pereopod 3, medial; F, left pereopod 4, medial; G, left pereopod 5, medial. Scale bars = 500 μm .

Cephalon without eyes; anterior margin rounded ventrally, bilobed with deeply concave dorsal surface. Acute points presented on posterior-lateral margin of cephalothorax and lateral margins of first to fourth pereomeres (Fig. 1B, C), forming fringe that clings onto the carapace of the host. A pair of single spine-shaped papillae and a pair of three papillae grouped on posterior ventrolateral parts of pereon (Fig. 1B). Pleon unsegmented, posterior margin rounded with tiny terminal acute point; lacking pleopods and uropods.

Antenna 1 forming broad lamella, surround-

ing oral cone (Fig. 1J). Antenna 2 broader (Fig. 1J). Oral cone conical, surpassing cephalon ventrally (Fig. 1J). Maxilliped unilobed, irregular-shaped, deeply concave laterally (Fig. 2A).

Five pairs of oostegites present (Fig. 1B, 2B); oostegite 1 bilobed, with medial projection on first article. Oostegite 5 unilobed, covering 80% of ventral side of body.

Pereopods 1–5 subequal in shape and size (Fig. 2C–G): bases swollen dorsally; ischia subequal length of bases; meri fused with carpi, triangular in outline, ventrally with 2 or 3 small robust setae; propodi oval, ventrally with

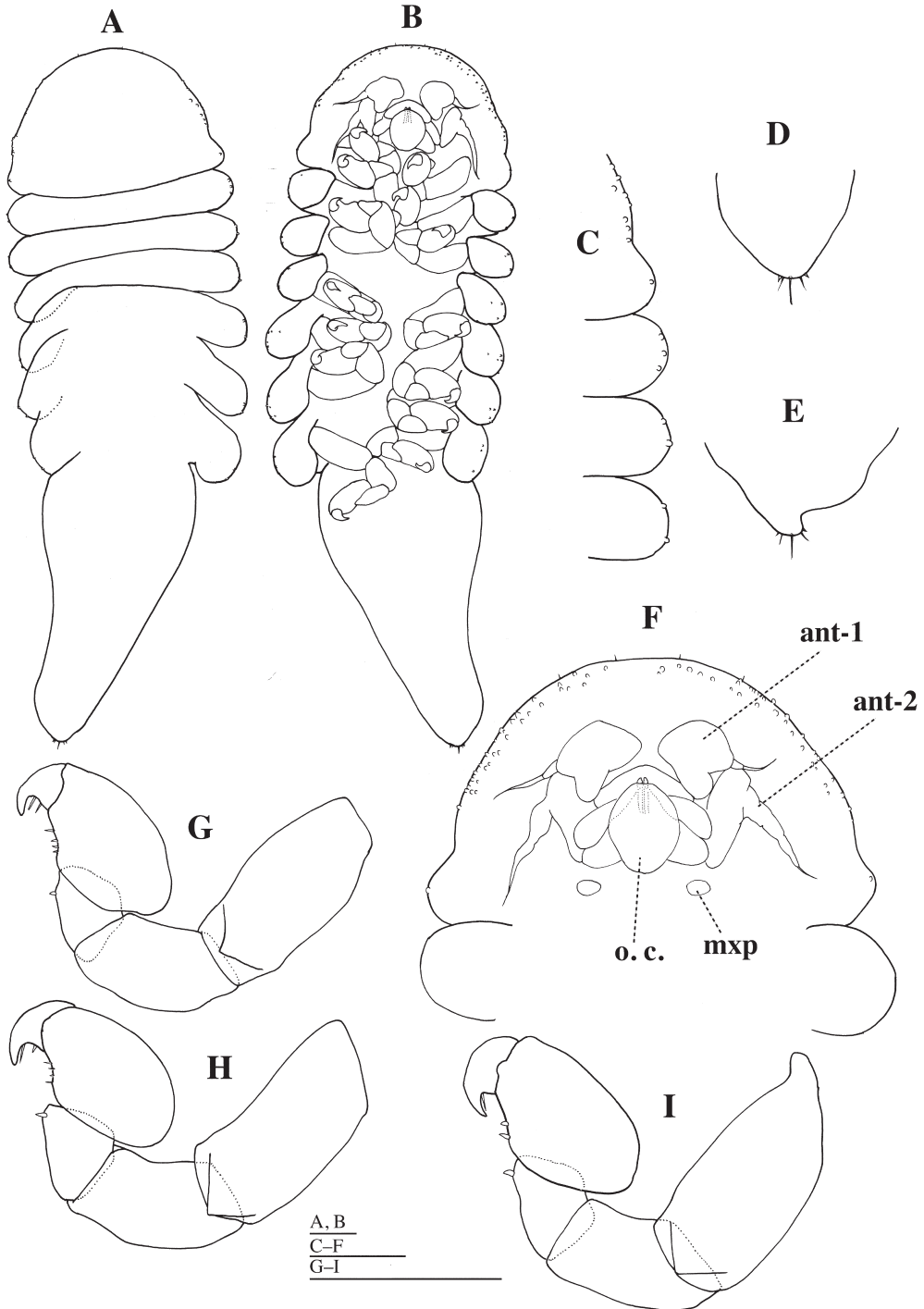


Fig. 3. *Holophryxus fusiformis* Shiino, 1937, A–D, F–I, male (KMNH IvR 500969), E, male (KMNH IvR 500981): A, habitus, dorsal; B, habitus, ventral; C, lateral part of head, and pereomeres 1–4, dorsal; D, E, posterior end of pleon, dorsal; F, head and pereomere 1, ventral, pereopod 1 omitted; G, left pereopod 1, medial; H, left pereopod 2, medial; I, left pereopod 3, medial. Abbreviations: ant-1, antenna 1; ant-2, antenna 2; o. c., oral cone; mxp, maxilliped. Scale bars = 100 μ m.

0–3 small robust setae; dactyli hook-like, with 2 or 3 setae ventrally.

Description of male (KMNH IvR 500969)

Body elliptical, 3.11 times as long as maximum width, dorsoventrally flattened (Fig. 3A, B). Cephalon without eyes, completely fused with first pereomere, tiny tubercles distributed on surface. Pereomeres 2–4 completely separated and flat, pereomeres 5–7 fused dorsally; lateral margins rounded with 2 or 3 tiny tubercles (Fig. 3C). Pleonite completely fused with pereomere 7, forming an elongated cone, posterior margin rounded with fine setae terminally (Fig. 3D); lacking pleopods and uropods (Fig. 3A, B).

Antenna 1 broad and swollen, flagellum 2-segmented; flagellum of antenna 2 elongated. Oral cone oval; maxilliped tiny (Fig. 3F).

Pereopod 1–7 subequal in shape and size; bases rectangular; ischia slightly shorter than bases; meri fused with carpi, triangular in outline, ventrally with 0 or 1 robust seta; propodi oval, ventrally with 2–4 robust setae; dactyli hook-like, with 1 or 2 setae ventrally. (Fig. 3G–I, Fig. 4)

Coloration

Female body color predominantly beige and yellow (Fig. 5B), pleon a pale green color. Male white color.

Variation

In females, the backward pair of papillae range in number from 1 to 3 (compare KMNH IvR 500972 and 500970, Fig. 1G–I), and the forward pair is absent in one specimen (KMNH

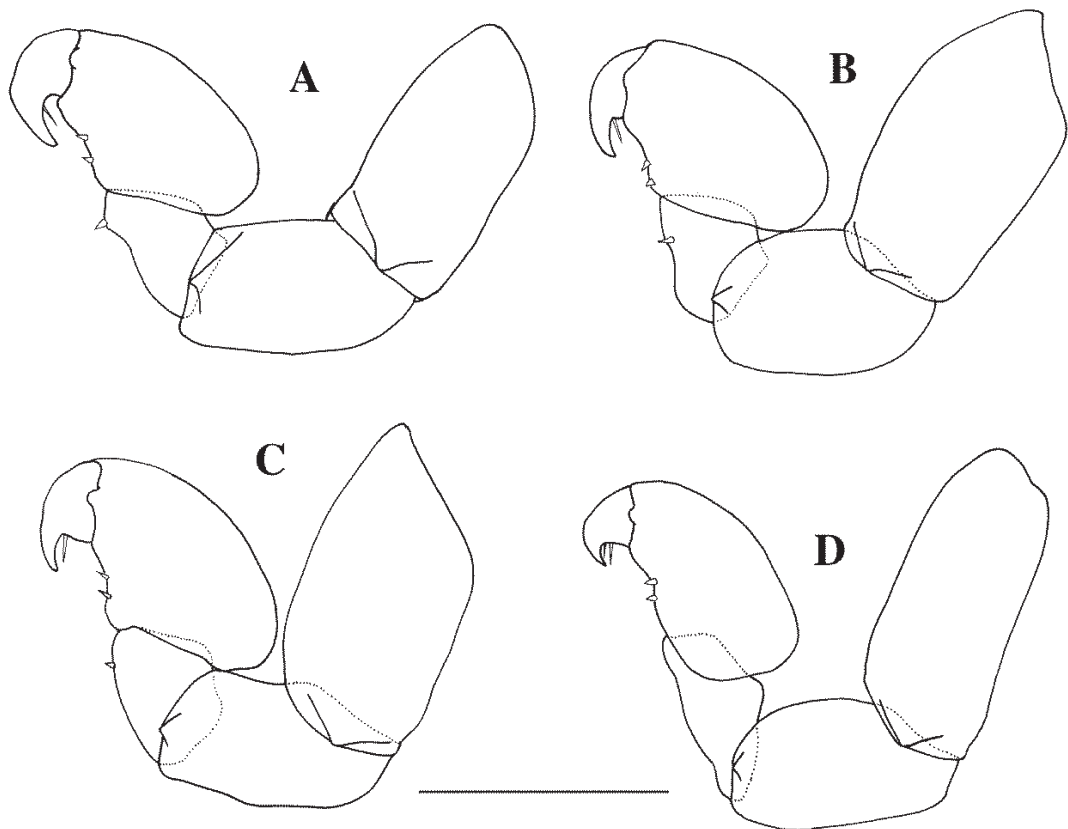


Fig. 4. *Holophryxus fusiformis* Shiino, 1937, A–D, male (KMNH IvR 500969), A, left pereopod 4, medial; B, left pereopod 5, medial; C, left pereopod 6, medial; D, left pereopod 7, medial. Scale bar = 100 μ m.

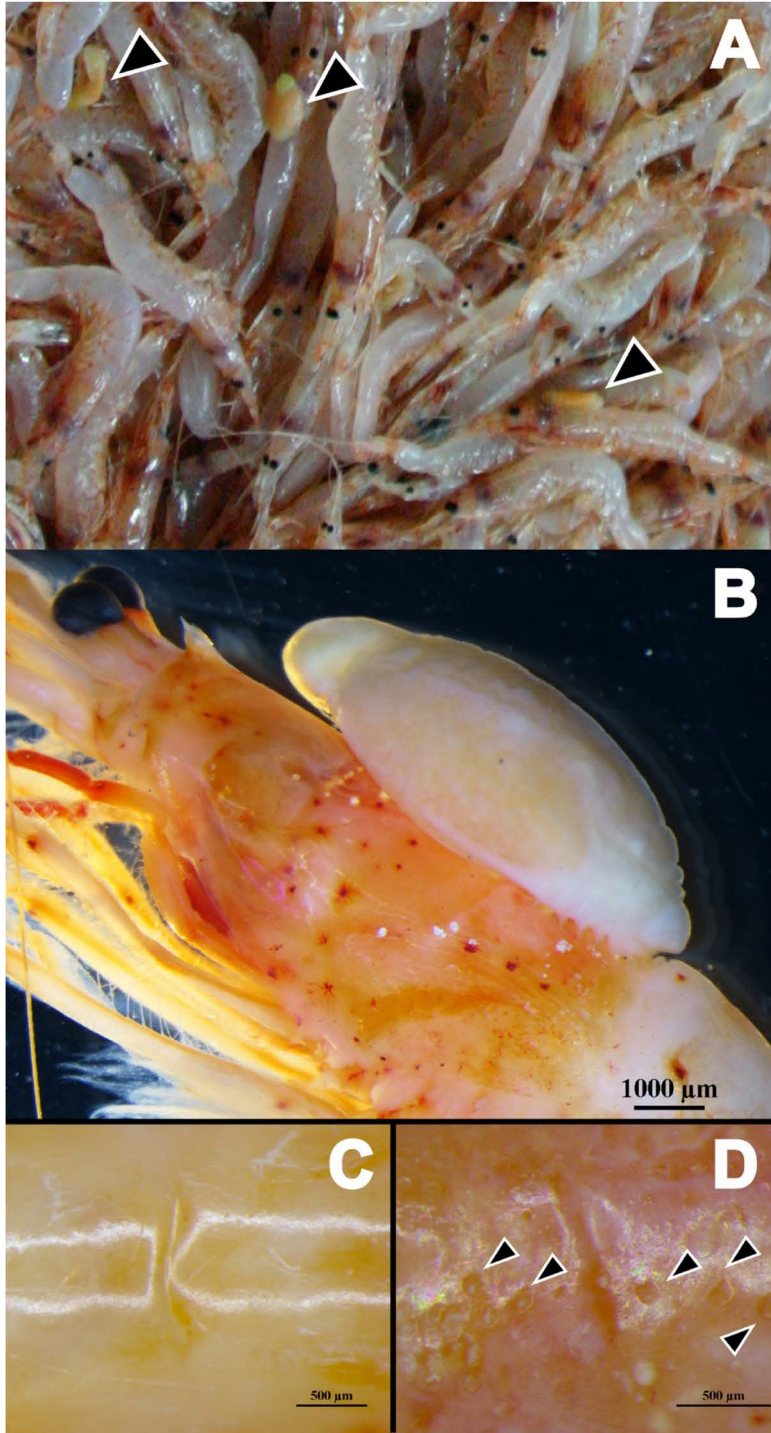


Fig. 5. A, *Lucensosergia lucens* with infected parasite, *Holophryxus fusiformis* (arrows indicate); B, *H. fusiformis*, female (7.1 mm BL), which attached to the top of *L. lucens* carapace; C, normal *L. lucens* carapace; D, patterns and holes (arrows indicate) in *L. lucens* carapace after infected by *H. fusiformis*.

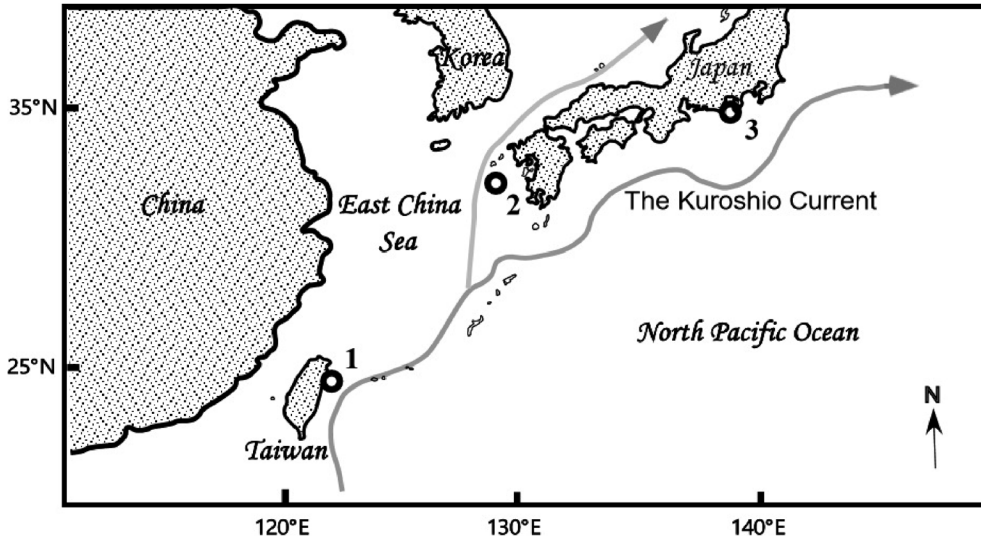


Fig. 6. The locations of *Holophryxus fusiformis* including (1) Yilan offshore, (2) Nagasaki offshore and (3) Suruga Bay. The Kuroshio Current is indicated by the gray line.

IvR 500970, Fig. 1I). A rounded posterior margin of the pleon without a terminal acute point was observed in one female (KMNH IvR 500970, Fig. 1F). In one male, the posterior margin of the pleon produced an irregularly-shaped anal cone (KMNH IvR 500981, Fig. 3E).

In females, the body coloration varies: body light yellow with white pigments around margin, head and pleon white (TMCD003308); body yellow, with no white pigment (TMCD003309); body beige, white pigments distributed over the whole dorsum, with white central line (TMCD003310); body orange, no white pigments, head and pleon white (TMCD003310).

Distribution

Suruga Bay, Pacific coast of central Japan is the type locality of this species (Shiino, 1937). Locations along the Kuroshio Current include Nagasaki, Kyushu, southwestern Japan, and Yilan, Guishan Island, Pacific coast of northern Taiwan (Fig. 6).

Ecological note

Holophryxus fusiformis females infest the

upper part of the carapace of sakura shrimp, *Lucensosergia lucens*, in Taiwan, with the parasite's pleotelson oriented toward the anterior and head toward the posterior end of the host (Fig. 5A, B); a dwarf male is found in the female's marsupium. Thirteen ovigerous females, two non ovigerous females and ten males of the parasite were obtained. Based on the sampling on 13 June, 2017, a total of 837 sakura shrimps were examined, with 9 infested females parasites found, thus, showing an approximately 1% prevalence rate in Yilan. The surface of carapaces of infested sakura shrimp specimens have several holes indicating attachment position of the female dajid isopods (Fig. 5C, D). This parasite was obtained from the fishing harbor and food processing plant in Toucheng, Yilan from May to June in 2017 and the period of infestation was also the same for sakura shrimp harvesting. According to Toucheng fishermen, as seawater temperature rises and summer approaches, the rate of the dajid infestation increases. In Japan, Shiino (1937) reported infection of *H. fusiformis* from *Prehensilosergia prehensilis* (Bate, 1881), the type host of the parasite.

Discussion

The present specimens from Taiwan were identified as *Holophryxus fusiformis*, in having an elongated body, rounded anterior margin of cephalon, produced acute points on the posterior-lateral margin of the cephalothorax and lateral margins of first to third pereomeres, and a rounded pleon. *Holophryxus fusiformis* can be separated from other congeners by the following features in females (Richardson, 1905, 1908; Koehler, 1911; Stephensen, 1913; Shiino, 1937; Schultz, 1978): elongated body (vs. ovate in *H. alaskensis* Richardson, 1905), rounded anterior margin of cephalon (vs. square lobes expanded laterally in *H. giardi* Richardson, 1908 and *H. quadratahumeralis* (Schultz, 1978)), produced acute points on the posterior-lateral margin of the cephalothorax and lateral margins of first to third pereomere (vs. rounded on those in *H. acanthephyrae* Stephensen, 1913), presence of five pairs of pereopods (vs. presence of sixth pair of pereopods in *H. septapodus* (Schultz, 1978)), and shorter pleon (vs. comparatively long pleon in *H. richardi* Koehler, 1911). *Holophryxus fusiformis* is most similar to *H. polyandrus* (Schultz, 1978), but it differs in the truncate anterior-ventral margin of the cephalon and triangular pleon (vs. rounded shape for both morphological features in *H. fusiformis*). The recorded host crustaceans of five of eight *Holophryxus* species are also different (Wasmer, 1988).

Several differences between the present specimens of *H. fusiformis* from Taiwan and Shiino's original description include: (1) different host: the host cited by Shiino (1937) was *P. prehensilis* from Japan, whereas the host in this study was *L. lucens*; (2) the number of oostegites: Japanese *H. fusiformis* were described with four but five were found in Taiwanese specimens; (3) the quadrangular plate at the end of pleotelson of Japanese male that is absent in Taiwanese males. The foremost problem is the different host, however, a literature re-

view showed that there was a time when sakura shrimps in Japan were called out *P. prehensilis* (Omori, 1969; Hayashi, 1992). The number of oostegites of *H. fusiformis* females described by Shiino (1937) is problematic, therefore it is necessary to reexamine the type material because the condition in all other species of *Holophryxus* and in Taiwanese *H. fusiformis* in this study is five oostegites. One of the Yilan male parasites (KMNH IvR 500981) produced an irregular-shaped anal cone on the posterior margin of the pleotelson which is similar to the quadrangular plate of a Japanese male described by Shiino (1937).

Holophryxus fusiformis primarily lives on the sakura shrimps; therefore, the distribution of sakura shrimps is closely related to this parasite. In the 1980s it was believed that the sakura shrimps were distributed only in Suruga Bay, Japan, but they were later found in Donggan, Taiwan by Omori *et al.* (1988). Thereafter, the sakura shrimps have been recorded from the shores of Donggan, Taiwan to Fangshan (Pingtung), Dawu (Taitung), and Guishan Island (Yilan) (Zhuang *et al.*, 2014). *Holophryxus fusiformis* specimens identified in this study were primarily found in Yilan infesting sakura shrimps. There are currently no data on the rate of infestation in the open seas of Donggan, Pingtung, but the fishing season in this year (2017) has ended and further investigations are required. One of the authors of the present study (MS) also collected a specimen of sakura shrimp infested by *H. fusiformis* from offshore of Nagasaki, Kyushu, Japan. Based on this locality, the distribution of *H. fusiformis* can be deduced to be strongly associated with the flow of the Kuroshio Current. Shiino (1937) reported finding a considerable number of parasites in Kanbara, Shizuoka Prefecture, Japan. According to personal communications by Dr. Hasegawa, the probability of parasites occurring in Suruga Bay during 2003 to 2017 is extremely low (ex. lower than 0.01%). The prevalence of parasites is also possibly related to

the environment, where they can occur in large quantities one year and reduced in number or be completely absent in the next year (Nagasawa *et al.*, 1988).

In addition, the Kuroshio Current may transport these parasites or larvae to Suruga Bay, Japan and influence the reproduction of Japanese sakura shrimps when large quantities of parasites occur in Taiwan. It is therefore recommended to establish a monitoring program for areas between Taiwan and Japan to collectively protect the marine resource of sakura shrimps.

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■ Literature Cited

- Boyko, C. B., Bruce, N. L., Hadfield, K. A., Merin, K. L., Ota, Y., Poore, G. C. B., Taiti, S., Schotte, M., & Wilson, G. D. F. (Eds.), 2008 onwards. *Holophryxus* Richardson, 1905. In: World Marine, Freshwater and Terrestrial Isopod Crustaceans database. Accessed through: World Register of Marine Species at <http://www.marinespecies.org/aphia.php?p=taxdetails&id=146980> on 2017-11-16.
- Chen, S. R., Huang, J. Z., Chen, Y. H., & Wu, L. J., 2010. Flowing crystals—Taiwan sakura shrimp. *Science Development*, 452:32–39. (in Chinese)
- Hayashi, K., 1992. Debdrobranchiata crustaceans from Japanese waters. ix + 300 pp. Seibutsu Kenkyusha, Tokyo. (in Japanese with English abstract)
- Koehler, R., 1911. Isopodes nouveaux de la famille des dajidés provenant des campagnes de la Princesse-Alice. *Bulletin de l'Institut Océanographique (Fondation Albert Ier, Prince de Monaco)*, 196: 1–34.
- Nagasawa, K., Imai, Y., & Ishida, K., 1988. Long-term changes in the population size and geographical distribution of *Pennella* sp. (Copepoda) on the saury, *Cololabis saira* (Brevoort), in the western North Pacific Ocean and adjacent seas. *Hydrobiologia*, 167/168: 571–577.
- Omori, M., 1969. The biology of a sergestid shrimp *Sergestes lucens* Hansen. *Bulletin of the Ocean Research Institute, University of Tokyo*, 4: 1–83, 1 pl.
- Omori M., Ukishima, Y., & Muranaka, F., 1988. New record of occurrence of *Sergia lucens* (Hansen) (Crustacea, Sergestidae) off Tung-kang, Taiwan, with special reference to phylogeny and distribution of the species. *Journal of the Oceanographical Society of Japan*, 44: 261–267.
- Richardson, H., 1905. Isopods from the Alaska Salmon Investigation. *Bulletin of the Bureau of Fisheries*, 24: 211–221.
- Richardson, H., 1908. On some isopods of the family Dajidae from the northwest Pacific Ocean, with descriptions of a new genus and two new species. *Proceedings of the United States National Museum*, 33: 689–696.
- Schultz, G. A., 1978. More planktonic isopod crustaceans from Subantarctic and Antarctic Seas. *Antarctic Research Series. Biology of the Antarctic Seas VII*, 27: 69–89.
- Shiino, S. M., 1937. *Holophryxus fusiformis*, a new species of Dajidae, Epicaridea. *Annotationes Zoologicae Japonenses*, 16(3): 188–192.
- Stephensen, K., 1913. Report on the Malacostraca collected by the "Tjalfe"-Expedition, under the direction of cand. mag. Ad. S. Jensen, especially at W. Greenland. *Videnskabelige Meddelelser fra Dansk Naturhistorisk*

Forening I Kobenhavn, 64: 57–134.

- Wasmer, R. A., 1988. Parasitic isopod *Holophryxus acanthephyrae* Stephensen (Epicaridea: Dajidae) from the subantarctic South Pacific, with notes on its synonymy and host. *Proceedings of the Biological Society of Washington*, 101(1): 20–30.
- Zhuang, S. C., Chen, W. K., & Xiao, S. D., 2018. The research of sakura shrimp fishery in Yilan Bay. *Taiwan Fisheries Research Institute Newsletter*, 61: 5–9. (in Chinese)
- Zhuang, S. C., Chen, W. K., Xiao, S. D., Chen, R. Y., & Wu, J. X., 2015. Resource evaluation and management of sakura shrimp fisheries in Yillan Bay (I). *Annual report of Taiwan Fisheries Research Institute 2015*, p3. (in Chinese)
- Zhuang, S. C., Chen, W. K., Zhang, K. Y., & Wu, J. X., 2014. The classification of sakura shrimp in Yilan Bay. *Taiwan Fisheries Research Institute Newsletter*, 47: 4–6. (in Chinese)

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