Journal of Species Research 11(3):180-187, 2022

Three newly recorded species of Korean fouling bryozoans

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We found three fouling bryozoans from the materials collected from seven localities (ports, yacht marina, intertidal and subtidal zones) in the coastal seas of South Korea from 2003 to 2021. These three species, *Thalamoporella californica* (Levinsen, 1909), *Scruparia ambigua* (d'Orbigny, 1841), and *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985, and one genus *Scruparia* Oken, 1815 are newly added to the Korean bryozoan fauna. Of the three species, *Scruparia ambigua* and *Tricellaria inopinata* are cosmopolitan or widespread, and *Thalamoporella californica* is from the East Pacific Ocean in tropical/temperate water. It seems that some of the previously reported *T. occidentalis* in Korea have a high probability of being *T. inopinata*. In this study, some *Tricellaria occidentalis* reported by Seo (2005) are synonymized into *T. inopinata*. A total of 77 species of fouling bryozoans has been reported in Korea, with three new bryozoans resulting from this study. Descriptions and illustrations of the three fouling bryozoans using scanning electron microscopy are provided in this study.

Keywords: Korean fouling bryozoans, *Scruparia*, *Scruparia ambigua*, *Thalamoporella californica*, *Tricellaria inopinata*

DOI:10.12651/JSR.2022.11.3.180

Introduction

Bryozoa is a representative fouling animal along with barnacles, mollusks, sponges, and ascidians. Studies of fouling bryozoans are important because fouling marine organisms may provide insight into controlling biofouling of marine technology (Key *et al*., 1999; Chae and Seo, 2019).

After an unfamiliar bryozoan to Korean waters was first discovered attached to ropes at Tongyeong Marina in 2020, colonies started blooming there. In addition, similar species to *Tricellaria occidentalis*, which is the second most common species from the Korean intertidal zone (Seo, 2005; 2010) and also the second most common fouling species of Korean ports and harbour (Chae and Seo, 2019), were found from Geumjin Port in the East Sea. Furthermore, at the same time, one creeping species was found from the same port. These three species were considered to be new fouling bryozoans introduced from other seas because they were found from the marina and port.

About 70 fouling bryozoans were recorded from Korea by Bae and Lee (1981), Song (1985), Je *et al*. (2003), Gong and Seo (2003; 2004), Seo (2005), Seo and Min (2009), and Chae and Seo (2019). Recently, four species, *Pacificincola perforate*, *Primavelans glabricollaris*, *Conopeum reticulum*, and *C. seurati*, were added to the list of fouling bryozoans by Min *et al*. (2021) and Yu *et al*. (2021). A total of 74 species of fouling bryozoans from Korea are reported up to the present. We have found three fouling bryozoans and the purpose of this paper is to redescribe and illustrate of them.

Materials and Methods

All specimens were collected from seven localities during the period from 2003 to 2021 and were preserved in 95% ethanol. Specimens were collected from the natural substrates such as other bryozoans, rocks, and ropes of yacht marina and port. For identification, the external features of zooid were observed under stereomicroscope

Table 1. Sampling localities of three species in Korea waters.

Locality	Coordinates	Date	Depth
Geumjin port, East Sea	37°40′54.60″N, 129°03′8.11″E	31 October 2003	Intertidal
Ulleungdo Island, East Sea	37°31′37.27″N, 130°49′25.44″E	5 May 2014	Intertidal
Tongyeong yacht marina, South Sea	33°27′15.53″N, 128°26′4.45″E	29 July 2020 7 July 2021	1–2 m
Sado Island, South Sea	34°35′37.19″N, 127°33′20.39″E	28 July 2021	Intertidal
Geomundo Island, South Sea	34°00′22.40″N, 127°19′17.60″E	20 June 2020	20 m
Chengsan Island, South Sea	34°09′15.80″N, 126°52′51.20″E	13 June 2017	Intertidal
Hangaechang in Munseom Island, Jeju	33°13′38.60″N, 126°33′49.30″E	20 April 2014	10–20 m

(Stemi SV6, Carl Zeiss, Germany) and parts of specimens were bleached with hot aqueous sodium hypochlorite, washed, and gold coated (MCM-100, SEC, Korea), prior to examination using a scanning electron microscope (SNE-3200M Mini-SEM, SEC, Korea) at 15 kV accelerating voltage. Measurements were made on SEM images of zooids using Image J. Specimen localities mentioned in this paper are given in Table 1.

Systematic Accounts

Class Gymnolaemata Allman, 1856
Order Cheilostomata Busk, 1852
Suborder Thalamoporellina Ostrovsky, 2013
Superfamily Thalamoporelloidea Levinsen, 1902
Family Thalamoporellidae Levinsen, 1902
Genus *Thalamoporella* Hincks, 1887

1. *Thalamoporella californica* (Levinsen, 1909) (Fig. 1)

?*Steganoporella rozieri* form *gothica* Hincks, 1880: 380.
Thalamoporella rozieri Robertson, 1908: 277.
Thalamoporella rozieri var. E. (*californica*), Levinsen, 1909: 184.
Thalamoporella californica Hastings, 1930: 716; Osburn, 1950: 111; Soule, 1959: 33; Chaney, Soule and Soule, 1989: 345; Soule, Soule and Chaney, 1999: 21.
Not *Thalamoporella californica*: Long and Rucker, 1969: 62.

Material examined. Korea: Gyeongsangnam-do: Tongyeong yacht marina, 29 July 2020; MABIK IV00172393–MABIK IV00172395, 7 July 2021.
Substratum. Ropes.
Description. Colony light beige in color when alive, erect, dichotomously branching (Fig. 1A, B). Zooids distinct, rectangular, 0.39–0.57 mm long (0.47 ± 0.04 mm), 0.22–0.33 mm wide (0.25 ± 0.02 mm). Orifice subcircular, 0.12–0.18 mm long (0.14 ± 0.01 mm), 0.12–0.16 mm wide (0.14 ± 0.01 mm), approximately longer than wide, articulations tiny, arcuate distally with wide, shallow, concave sinus proximally; a pair of large and conspicuous adoral tubercles present or absent lateral to orifice (Fig. 1C). Cryptocyst flat, densely granulated, uniformly perforated, with two different sized opesiules. Avicularium nearly as long as autozooid, 0.44–0.49 mm long (0.46 ± 0.02 mm), acute triangular, tapering to rounded point, with smooth distal platform, vicarious or interzooidal, directed to distal: interzooidal avicularium situated at bifurcation of zooidal row; rostrum raised with slightly biconcave rim, length 65–70% of avicularium length; mandibular pivots developed, conspicuous; mandible tapering to rounded like round triangle, with smooth surface; opesia large, quadrated, gently concave proximal margin; cryptocyst, imperforate, smooth (Fig. 1D). Spicules only C-shaped calipers, no straight compasses (Fig. 1E). Ovicells very large, distinctive, hyperstomial, comprising two halves with median groove as typically thalamoporellid, 0.04–0.44 mm wide (0.43 ± 0.02 mm) (Fig. 1F).
Distribution. Korea, East Pacific (Monterey Bay to southern California, Colombia, and Galapagos Islands).
Remarks. Two species of the genus *Thalamoporella*, *T. lioticha* and *T. sibogae*, have previously been reported from Korea (Rho and Seo, 1984: 1990; Seo, 1992: 1998a; 1998b; 2005; 2010; Chae *et al*., 2016). In this study, we add *Thalamoporella californica* to the Korean bryozoan fauna. Both *T. lioticha* and *T. sibogae* encrust on substrates, and have two spicules (calipers and compasses); on the contrary, *T. californica* is cellariform with chitinous joints and has a number of only C-shaped calipers without a compass. In addition, avicularium is spatula shaped in *T. lioticha* and *T. sibogae*, whereas *T. californica* has a round triangular avicularium.

Thalamoporella californica is similar to *T. arabiensis* Amui and Kaselowsky, 2006 from Gulf of Aden in having features such as an erect, typically thalamoporellid ovicell and only C-shaped calipers without compass spicules. However, *T. arabiensis* is different from *T. cal-*

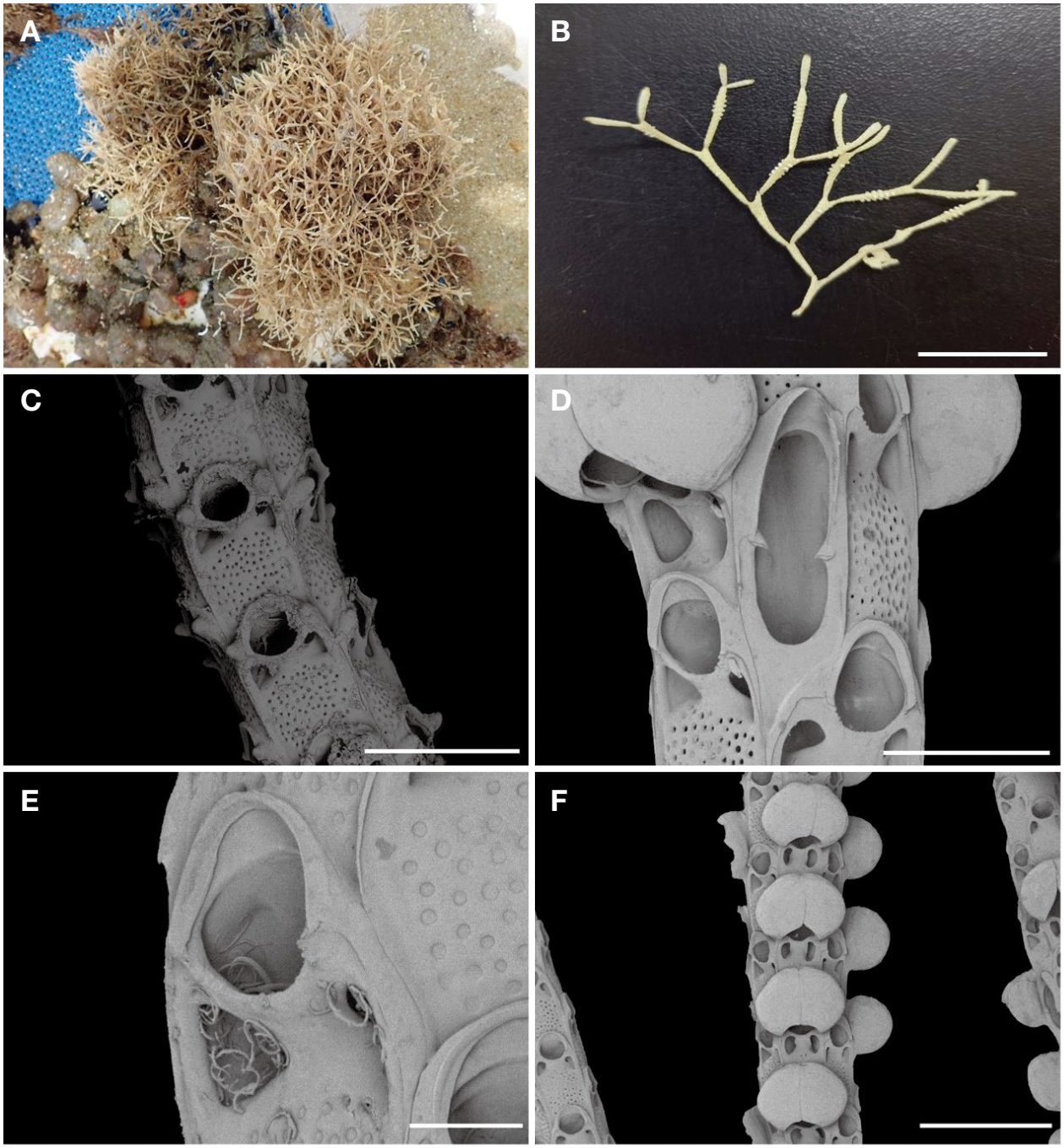

Fig. 1. *Thalamoporella californica* (Levinsen, 1909). A, Colony; B, Dichotomous branch; C, Adoral tubercles of orifice and zooidal arrangement; D, Avicularium; E, C-shaped calipers; F, Ovicells. Scale bars: B = 10 mm; C, F = 0.5 mm; D = 0.2 mm; E = 0.05 mm.

ifornica in having no tubercles and avicularia (Amui and Kaselowsky, 2006). *Thalamoporella prominens* (Levinsen, 1909) also resembles *T. californica* in that it has cellariform colonies with joints and no adoral tubercles, but smaller and larger ones are present in older zooids (i.e., absent or present adoral tubercles); however, *T. prominens* differs in having both calipers and compasses (Soule *et al*., 1999). Table 2 provides a comparison of characteristics and distribution among the five *Thalamoporella* species mentioned above: *T. arabiensis*, *T. californica*, *T. lioticha*, *T. prominens*, and *T. sibogae*. In regard to distribution, *T. arabiensis* was recorded from the Indian Ocean and *T. prominens* from the Torres Strait. The three *Thalamoporella* found from Korea, *T. californica*, *T. lioticha*, and *T. sibogae*, were from the Pacific Ocean.

Table 2. Comparison of major morphological characters and distribution of five species in genus *Thalamoporella*.

	T. arabiensis	*T. californica*	*T. lioticha*	*T. prominens*	*T. sibogae*
Colony form	Erect	Erect	Encrusting	Erect	Encrusting
Adoral tubercles	Absent	Absent Present	Absent	Absent Present	Absent
Avicularium	Absent	Acute triangular	Spatulate	Subacute triangular/ V-grooved at the tip	Spatulate
Spicules (calipers, compasses)	Calipers	Calipers	Calipers, compasses	Calipers, compasses	Calipers, compasses
Distribution	Indian (Gulf of Aden)	East Pacific (Monterey Bay to southern California, Colombia and Galapagos Islands)	West Pacific (Japan)	Indo-West Pacific (Torres Strait)	Japan and Indo-West Pacific (Banda Sea, Philippines, Sulu Archipelago)

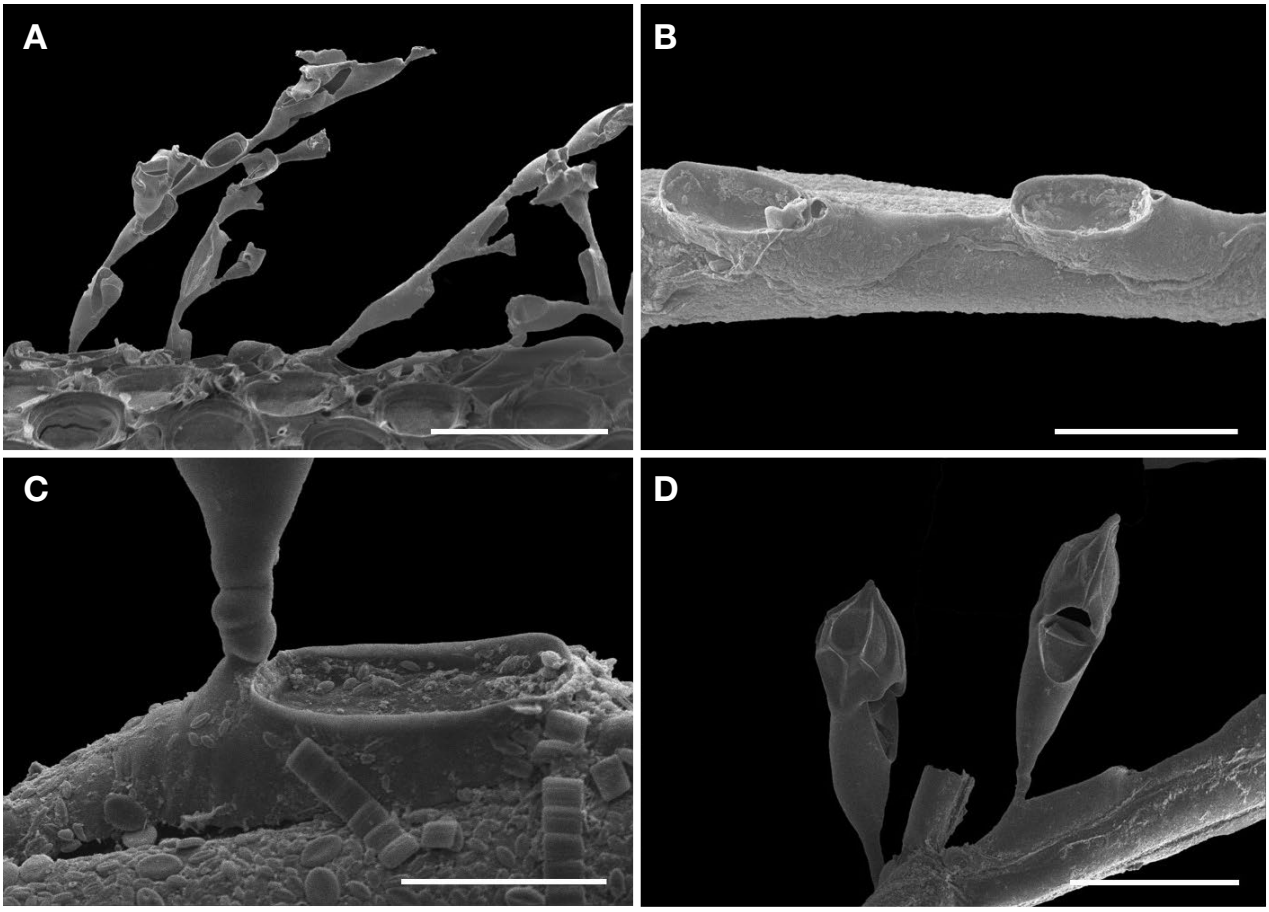

Fig. 2. *Scruparia ambigua* (d'Orbigny, 1841). A, Colonies: erect with creeping, attaching to other bryozoans; B, Two creeping autozooids, each with frontally budded zooids; C, Detailed autozooid and budding of erect zooid; D, Ovicell, frontal (right) and side (left) view. Scale bars: A = 0.5 mm; B = 0.2 mm; C = 0.1 mm; D = 0.3 μm.

Long and Rucker (1969) reported *T. californica* from Japan. However, spatulate avicularia of their Japanese specimen are clearly different from those of *T. californica*, which are triangular in shape with a round tip, de-

scribed by Soule (1959), Chaney *et al*. (1989), and Soule *et al*. (1999).

Suborder Scrupariina Silén, 1941
Superfamily Scruparioidea Gray, 1848
Family Scrupariidae Gray, 1848
Genus *Scruparia* Oken, 1815

2. *Scruparia ambigua* (d'Orbigny, 1841) (Fig. 2)

Eucratea ambigua d'Orbigny, 1841: 11.
Scruparia ambigua: Ryland and Hayward, 1991: 25; Gordon and Mawatari, 1992: 17; Hayward and Ryland, 1998: 108.

Material examined. Korea: Gangwon-do: Gangneung, Geumjin Port, 31 October 2003: Jeollanam-do: Geomundo Island, 20 June 2020; MABIK IV00172396, Jeju Island: Hangaechang in Munseom Island, 20 April 2012.
Substratum. Other bryozoan: *Amastigia xishaensis*, *Ijimaiellia ijimai*, and *Tricellaria inopinata*.
Description. Colony delicate, encrusting, composed of erect from creeping, uniserial chains of zooids (Fig. 2A). Zooids smooth, slender, club-shaped, comprising oval dilatation and thin proximal tube by expand from a narrow proximal to central, 0.34–0.42 mm long (0.38 ± 0.03 mm) (Fig. 2B). Mural rim raised. Gymnocyst smooth, narrow distally and laterally, tapering proximally; proximal tube with weak transverse striae. Opesia large, rectangle, almost parallel to the basal wall of zooid, 0.13–0.19 mm long (0.15 ± 0.02 mm), 0.06–0.09 mm wide (0.07 ± 0.01 mm), occupying 38–45% of zooidal length (Fig. 2B, C). Operculum semicircular. Budding of erect zooid from proximal side of opesia of creeping zooid; creeping zooid budding distally (Fig. 2B, C). Reproductive zooids arising as erect zooids from creeping zooids. Ovicell distinct bivalved, large, oval, like an ice cream cone, distal to a maternal zooid, partially overhanging orifice (Fig. 2D). Spines and avicularia lacking.
Distribution. Cosmopolitan, including Korea (East Sea, South Sea, and Jeju Island).
Remarks. In the genus *Scruparia*, three species have been recognized worldwide: *Scruparia ambigua* (d'Orbigny, 1841), *S. chelata* (Linnaeus, 1758), and *S. spiralis* Hasenbank, 1932. In regard to distribution, *Scruparia chelata* (Linnaeus, 1758) was recorded from the Europe and North Atlantic Ocean and *S. spiralis* was found from the Indian Ocean. *Scruparia ambigua* from Korea is known to be cosmopolitan (http://bryozoa.net-1 May 2022), except in polar waters (Hayward and Ryland, 1998) (Table 3).

Table 3. Distribution among three species belonging to *Scruparia*.

	S. chelata	*S. spiralis*	*S. ambigua*
Distribution	Europe and North Atlantic	Indian	Cosmopolitan

Suborder Flustrina Smitt, 1868
Superfamily Buguloidea Gray, 1848
Family Candidae d'Orbigny, 1851
Genus *Tricellaria* Fleming, 1828

3. *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985 (Fig. 3)

Tricellaria inopinata d'Hondt and Occhipinti Ambrogi, 1985: 36; Dyrynda *et al*., 2000: 2001; De Blauwe and Faasse, 2001: 103; Johnson *et al*., 2012: 297; De Blauwe, 2022: 162.
Tricellaria occidentalis: Seo, 2005: 365 (part).

Material examined. Korea: Gangwon-do: Gangneung, Geumjin Port, 31 October 2003; Gyeongsangbuk-do: Ulleungdo Island, Hyeonpo-ri, 5 May 2014, intertidal; Jeollanam-do: Chengsan Island, Eup-ri, 13 June 2017, port; HNIBRIV340–344, Jeollanam-do: Yeosu, Sado Island, 28 July 2021.
Substratum. Rocks and ropes.
Description. Colony light yellow in color, erect, bushy, arborescent in form, composed of branches softly curved and rolled inward (Fig. 3A). Branching with joint, dichotomous. Internode consisted of 3–7 zooids (most three). Zooids biserial, alternate, elongate, vary in size, narrow proximally, 0.30–0.52 mm long (0.43 ± 0.08 mm) (Fig. 3B). Opesia oval to elliptical, 0.09–0.22 mm long (0.18 ± 0.04 mm), 0.05–0.12 mm wide (0.09 ± 0.02 mm). All zooids five to six tubular jointed spines, asymmetrically placed, located above middle of length of opesia; two to three spines turned slightly outward, located at outer distal side, robust, elongate, sometimes one spine in middle very thin compared to other spines; two to three spines at inner side, slender and generally straight compared with outer distal side spines (Fig. 3B). Proximal one of disto-external spines mostly divided (Fig. 3D). Axial zooids at bifurcations mostly six spines (sometimes five) tubular with jointed, asymmetrically placed, autozooids spines-like shapes and positions; medina spines one or two are long, prominent (Fig. 3C). Scutum attached to proximal to middle of inner margin of opesia, flabellate, forked into two or several irregularly lobed distally, large enough to cover most of opesia (Fig. 3B, C). Only lateral avicularia found, moderately large, triangular with hooked rostrum: lateral margin serrated by projecting lateral avicularia (Fig. 3B, D). Ovicell globular, smooth, perforated with 8 to 20 irregularly pores, longer than wide, 0.07–0.16 mm long (0.13 ± 0.03 mm), 0.09–0.14 mm wide (0.12 ± 0.02 mm) (Fig.

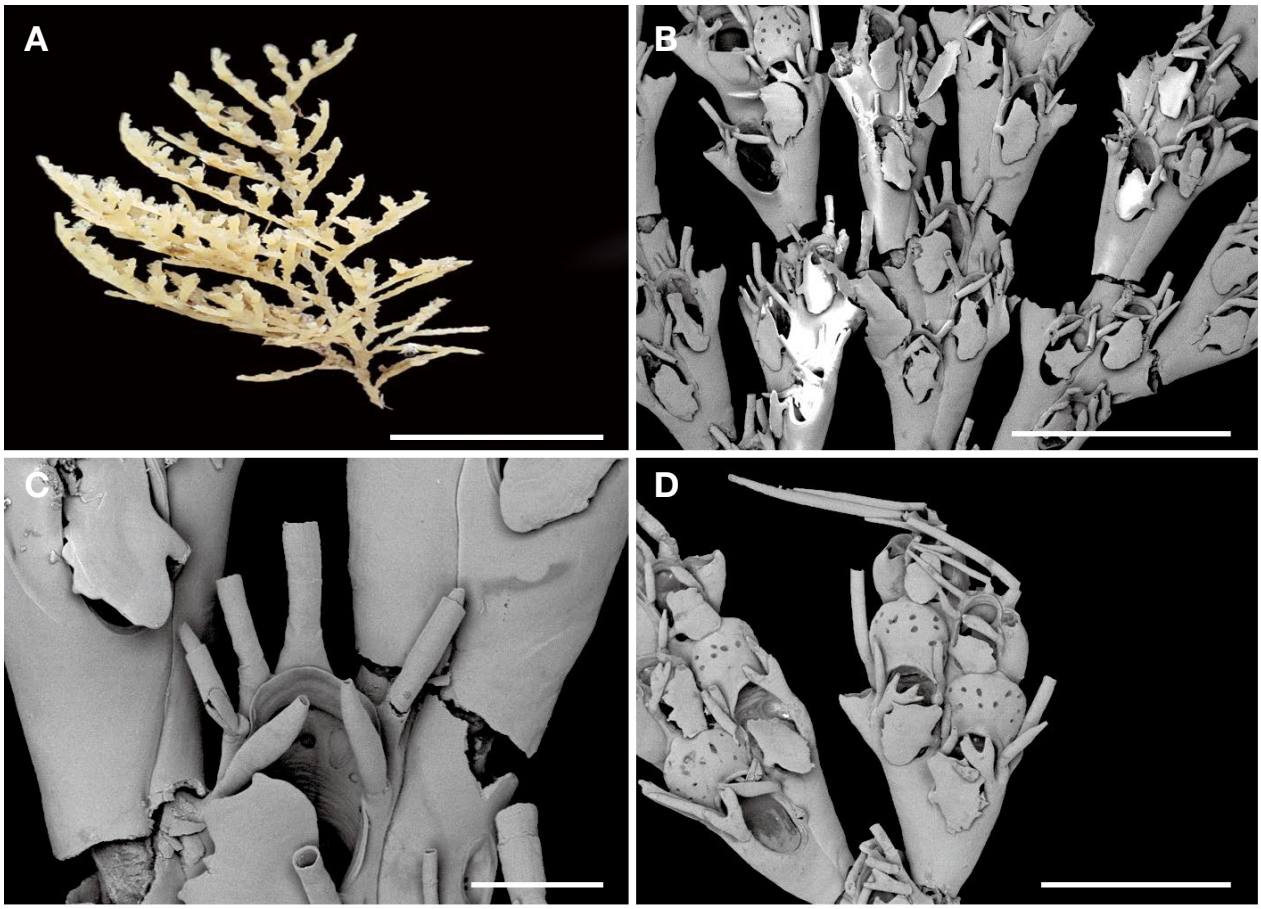

Fig. 3. *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985. A, Colony; B, Zooidal arrangement, spines and scutums; C, Axial zooids at bifurcations; D, Ovicells, divided disto-external proximal spines and lateral avicularia. Scale bars: A = 10 mm; B = 0.3 mm; C = 0.05 mm, D = 0.2 mm.

3D). Ancerstrula not observed.

Distribution. Korea, and wide distribution (http://bryozoa.net/ 6 May 2022).

Remarks. This species resembles to *Tricellaria occidentalis* (Trask, 1857), which is a typical fouling bryozoan from Korea. According to Dyrynda *et al*. (2000), the morphology and variation of the scutum of this species are the key diagnostic features which are used to distinguish between *T. inopinata* and *T. occidentalis*. The scutum of *T. inopinata* is variable in shape within a single colony, flabellate, forked into 2 or several irregularly lobes, an extensive structure over-arching the opesia with an irregular margin, whereas *T. occidentalis* has slender or slightly spatulate scutum (d'Hondt and Occhipinti Ambrogi, 1985; Dyrynda *et al*., 2000; De Blauwe and Faasse, 2001; Johnson *et al*., 2012; De Blauwe, 2022).

Tricellaria occidentalis from Geumjin Port reported by Seo (2005) is synonymized into *T. inopinata*. Other specimens need to be reexamined. *Tricellaria inopinata* looks conspicuous with a less curved colony than *T. occidentalis*.

Results and Discussion

With the increase in marine ship activities such as domestic and international travel, the maritime trade, and fisheries, sessile animals are easily spread all over the world, not limited to one region or country. *Tricellaria inopinata* is known as the most noteworthy cases showing how easily spread species can become (Marchini *et al*., 2015). Dyrynda *et al*. (2000) noted that "although first named from material collected in the Venice Lagoon in 1985, *T. inopinata* was subsequently identified as invasive there and of unspecified Pacific origin." It seems that some of the previously reported *T. occidentalis* in Korea have a high probability of being *T. inopinata* which is newly added to the Korean bryozoan fauna.

Thalamoporella californica is known to attach to algae from the intertidal to 15 m deep (Soule *et al*., 1999). Recently in 2020, *T. californica*, of which all colonies were attached to ropes, was first observed from Tongyeong yacht marina in the southern coast of Korea at depth of 1−2 m. The yacht marina, which is a common artifi-

cial structure that sees a lot of fouling animals, does not only have a lot of ship activity but also has a lot of ropes, which is a preferred substrate for fouling bryozoans. Tongyeong yacht marina was monitored on 7 July 2021 because it could be expected that *T. californica* will rapidly spread to nearby ports and marinas due to the activity of ships. It was confirmed that the colony size more than doubled. This species in distribution is currently restricted only to Tongyeong yacht marina. As previously described, *Thalamoporella californica* is known to attach to algae, and has not been reported on artificial substrates. In this study, *T. californica* was collected from rope, an artificial substrate, for the first time. *T. californica* is distributed in Monterey Bay to southern California, California Channel Island, Gulf of California, Colombia, and Galapagos Islands (Soule *et al*., 1999), so it is considered to be an introduced species from the eastern Pacific Ocean.

Scruparia ambigua creep over other bryozoans *Amastigia xishaensis*, *Ijimaiellia ijimai*, and *Tricellaria inopinata*. Also, *S. ambigua* from the ports and harbors of New Zealand was found, growing on bushy fouling bryozoans (Gordon and Mawatari, 1992). Unfortunately, Korean *S. ambigua* does not occur on artificial substrates like glass (Gordon and Mawatari, 1992).

With the addition of the three species redescribed herein, the Korean fouling bryozoans increased to 77 species. Of the three species, two (*Scruparia ambigua* and *Tricellaria inopinata*) are cosmopolitan or widespread (http://bryozoa.net-6 May 2022), and one other (*Thalamoporella californica*) is from the East Pacific Ocean (southern California, Gulf of California, Colombia, and Galapagos Islands) in tropical/temperate water.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2021R1A6A3A01088449), and was supported by National Marine Biodiversity Institute of Korea (2022M01100). Furthermore, this research was supported by a grant from the Honam National Institute of Biological Resources (HNIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (HNIBR202101101).

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Submitted: July 19, 2022
Revised: July 21, 2022
Accepted: July 22, 2022