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New Records of Two Zooxanthellate Scleractinian Corals (Anthozoa: Hexacorallia: Scleractinia) from Korea

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ABSTRACT

The two zooxanthellate scleractinian corals are newly recorded in Korea: *Psammocora albopicta* Benzoni, 2006 of the family Psammocoridae and *Oulastrea crispata* (Lamarck, 1816) of the family Faviidae. These families are also newly recorded in Korea. Specimens were collected from the subtidal zones of Jeju-do Island, Korea by SCUBA diving from 1999 to 2014. Two scleractinians are described based on the morphological characters of skeletal structures. *Psammocora albopicta* is distinguished by its encrusting cerioid growth form, high density of corallites, small calicular diameter, single styliform columella, and fewer rows of enclosed septa. *Oulastrea crispata* is characterized by its encrusting plocoid growth form, polygonal calicular shape, irregular paliform lobes, and papillose columella.

Keywords: Scleractinia, Psammocoridae, Faviidae, *Psammocora*, *Oulastrea*, Korea

INTRODUCTION

The classification of scleractinian corals has changed significantly over the past 20 years since molecular techniques were applied to scleractinian systematics in the late 20th century (Stolarski and Roniewicz, 2001; Budd et al., 2010; Veron, 2013).

Recent scleractinians comprise 777 zooxanthellates and 711 azooxanthellates worldwide (Roberts et al., 2009).

The family Psammocoridae includes seven species of one genus according to the World Register of Marine Species (2014). These species are zooxanthellate (Cairns, 1999, 2007; Cairns et al., 1999; Daly et al., 2007), and are characterized by the various growth forms with cerioid arrangement, enclosed and petaloid septa, and synapticulotheca in the skeletal structures. The classification of the genus *Psammocora* has changed as follows (Benzoni et al., 2007). This genus was placed in the family Thamnasteriidae of the suborder Fungiida (Vaughan and Wells, 1943) or of the suborder Astrocoeniina (Wells, 1956), and was classified in the new family Psammocoridae (Chevalier and Beauvais, 1987) or the family Siderastreidae (Veron, 1995) under the suborder Fungiina. Since it was suggested that the family Siderastreidae is not monophyletic (Chen et al., 2004; Benzoni et al., 2007), the genus *Psammocora* has belonged to the family Psammocoridae based on a combined approach of morphological and molecular studies (Benzoni et al., 2007, 2010; Stefani et al., 2008a, 2008b).

The family Faviidae includes 126 species of 24 genera (Veron, 2000). These species are zooxanthellate (Cairns, 1999, 2007; Cairns et al., 1999; Daly et al., 2007), and are distinguished by the various growth forms, polygonal calicular shape, and paliform lobes in the skeletal structures. *Oulastrea crispata* is only species in the genus *Oulastrea*. The classification of the genus *Oulastrea* has changed as follows (Budd et al., 2012). This genus was placed in the subfamily Montastreinae of the family Faviidae (Wells, 1956). Then, the genus *Oulastrea* was considered in the family Faviidae (Veron, 2000). Recent researches from molecular studies, and micromorphological and microstructural studies indicate that the genus *Oulastrea* remains in the family *incertae sedis* (Budd et al., 2012).

One species in the genus *Psammocora* of the family Thamnasteriidae has been described in Korea: *Psammocora profundacella* (Song, 1982, 1991, 2004). No species in the genus *Oulastrea* of the family Faviidae has been reported in Korea. In this study, *Psammocora albopicta* of the family Psammocoridae and *Oulastrea crispata* of the family Favii-

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dae are newly recorded from Jeju-do Island, Korea.

MATERIALS AND METHODS

Specimens were collected from the subtidal zones of Chagwi-do, Gapa-do, Gangjeong, Munseom, Seopseom, Jigwi-do, Pyoseon, and Seongsan in Jeju-do Island, Korea by SCUBA diving from 1999 to 2014. The previously studied (Song, 1982, 1991, 2004) and recently collected *Psammocora profundacella* were also examined to describe *Psammocora albopicta*. These specimens were collected from the subtidal zones of Munseom, Seopseom, and Jigwi-do in Jeju-do Island, Korea by SCUBA diving from 1978 to 2014. They were dissolved in sodium hypochlorite solution (Clorox: commercial bleach) with distilled water for 24 hours to remove all soft parts, washed in distilled water, and dried to observe the skeletal structures. The figures of the coralla were photographed with a digital camera (G12; Canon Inc., Tokyo, Japan and Optio WG2; Pentax Ricoh Imaging Co. Ltd., Tokyo, Japan). The skeletal structures of the corallites were examined with a stereomicroscope (Leica S8APO; Leica Microsystems, Wetzlar, Germany), photographed with a mounted camera (Leica Microsystems), and measured with an image analyzer (LAS ver. 3.6; Leica Microsystems). A series of multi-focused images were taken and combined with an image editing program (HeliconFocus 5.3 Pro; Helicon Soft Ltd., Kharkov, Ukraine) to provide clear images of detailed skeletal structures. This study partly followed Veron (2000), and Chevalier and Beauvais (1987) for the classification of scleractinian corals. The morphological and anatomical terms were referenced from Wells (1956) and Benzoni et al. (2007). The specimens are deposited at the Ewha Womans University Natural History Museum and the Korean Coral Resource Bank in Korea.

SYSTEMATIC ACCOUNTS

Phylum Cnidaria Hatschek, 1888
Class Anthozoa Ehrenberg, 1834
Subclass Hexacorallia Haeckel, 1866
Order Scleractinia Bourne, 1900
[1*]Family Psammocoridae Chevalier and Beauvais, 1987

Diagnosis. Corallum colonial, attached. Growth form encrusting or foliose or massive or columnar or branching. Enclosed septa developed. Petaloid septa developed. Synapticulotheca present.

Genus *Psammocora* Dana, 1846

Diagnosis. Rows of enclosed septa developed. Series of calices usually enclosed by a common wall. Septal furcation or ramification developed. Columella styliform.

[2*]***Psammocora albopicta*** **Benzoni, 2006 (Fig. 1)**

Psammocora sp. nov.: Yabe et al., 1936: 61, Pl. XLV, fig. 9.
Psammocora albopicta Benzoni, 2006: 49, figs. 1–3, 4a, 5; Benzoni et al., 2010: 424, fig. D; Denis et al., 2014: 157, fig. 1. a, b, electronic supplementary material a–c.

Material examined. Korea: Jeju-do: 1 ind., Seogwipo-si, Seopseom, 4 Aug 2011, Song JI, Hwang SJ (EWZS 5739); 1 ind., Seogwipo-si, Jigwi-do, 33˚13.313′N, 126˚39.175′E, 13 Oct 2012, Song JI, Hwang SJ, 15–17 m deep (EWZS 5740); 1 ind., Seogwipo-si, Jigwi-do, 33˚13.313′N, 126˚39.175′E, 13 Oct 2012, Song JI, Hwang SJ, 15–17 m deep (KCRB 1955); 2 inds., Seogwipo-si, Jigwi-do, 33.22493˚N, 126.65 100˚E, 13 Oct 2012, S. De Palmas, V. Denis, L. Ribas Deulofeu, 5–15 m deep (JIG 35, JIG 68).

Description. Corallum colonial, attached. Growth form submassive or encrusting or plate-like, unifacial, irregularly cerioid, 15–45 mm in width, 1–10 mm in thickness. Budding intratentacular. If present, 2–4 corallites in a series (average 2.3 corallites) enclosed by indistinctive common wall. Series of corallites linear or polygonal in shape. Distance between centers of corallites 0.55–2.12 mm (average 1.27 mm). Distance between centers of corallites within a series, 0.55–1.80 mm (average 0.99 mm). Distance between centers of corallites between series, 0.76–2.12 mm (average 1.36 mm). Corallites slightly immersed, but surface of corallum generally even or shallow. No distinctive ridges developed. 8–21 corallites in 5×5 mm (average 14.6 corallites). Calice polygonal or circular or irregular in shape, 0.68–2.19 mm (average 1.09 mm) in diameter. Calicular outlines not well defined. Fossa 0.16–0.36 mm (average 0.23 mm) in diameter. Columella single, styliform, 0.06–0.19 mm (average 0.12 mm) in diameter. Synapticulotheca weakly present. 5–8 septa reaching fossa (average 6.4 septa). Non-fused septa petaloid or lamellar in shape, 1–4 (average 2.8 septa), 0.08–0.70 mm (average 0.44 mm) in length, 0.06–0.24 mm (average 0.14 mm) in width. Septal furcation present, twice to fourth times (average 2.5). If present, enclosed septa lamellar in shape, developed incompletely or in one or two up to three rows (average 1.7 rows). Septal upper margins roughly dentated, granulated.

Color. Dark brown in living.

Habitat. The species inhabits 5–17 m deep subtidal zones.

Korean name: [1*]그물코돌산호과 (신칭), [2*]작은그물코돌산호 (신칭)

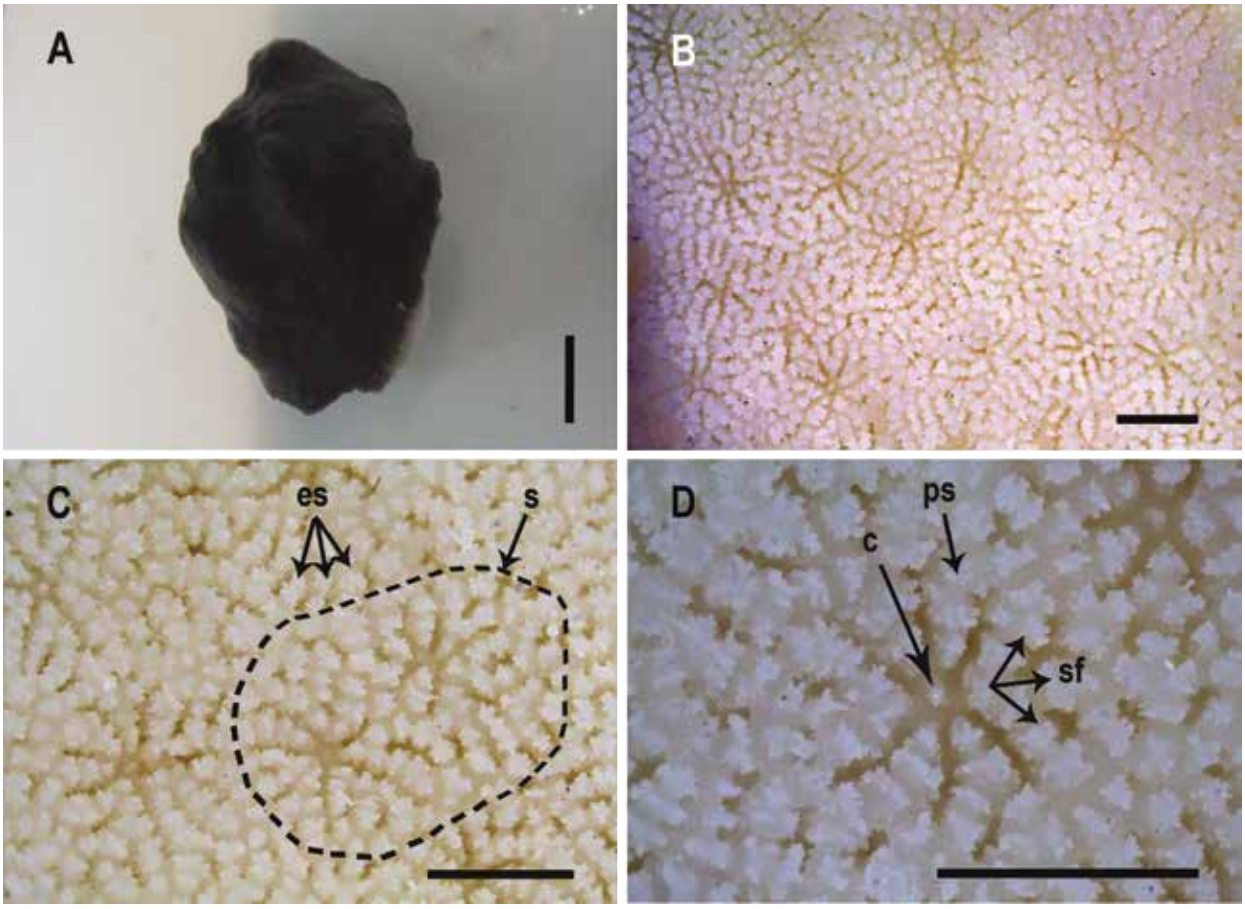

Fig. 1. *Psammocora albopicta*. A, Corallum, encrusting; B, Growth form, cerioid; C, Enclosed septa (es), series of corallites (s); D, Collumella (c), single styliform, petaloid septa (ps), septal furcation (sf). Scale bars: A=1 cm, B–D=1 mm.

Table 1. Comparison on *Psammocora albopicta* morphological characters between this study and previous studies

Morphological character		Reference	
		This study	Benzoni (2006)
Corallum (mm)	Growth form	Encrusting or massive or plate-like	Encrusting or massive or irregularly shaped
	No. of corallites	8–21 (average 14.6) in 5×5 mm	(mean 58±8) in 10×10 mm
Corallites (mm)	Calicular diameter	0.68–2.19 (average 1.09)	(mean 0.95±0.06)
	Fossa diameter	0.16–0.36 (average 0.23)	(mean 0.3±0.04)
	Type of columella	Single styliform	Single styliform
	Columella diameter	0.06–0.19 (average 0.12)	(mean 0.17±0.04)
Septa	No. of septa reaching fossa	5–8 (average 6.4)	(mean 8±1)
	No. of rows of enclosed septa	Incomplete or if present, 1–3 (average 1.7)	(mean 2.4±0.4)
Intercorallite distance within series (mm)		0.55–1.80 (average 0.99)	(mean 1.01±0.15)
Intercorallite distance between series (mm)		0.76–2.12 (average 1.36)	(mean 1.67±0.21)
Color		Dark brown	Dark brown or dark green

Table 2. Comparison on *Psammocora profundacella* morphological characters between this study and previous studies

Morphological character		Reference		
		This study	Song (1982, 1991, 2004)	Veron (2000), Benzoni et al. (2010)
Corallum (mm)	Growth form	Encrusting or plate-like	Massive	Encrusting or submassive or massive
	No. of corallites in 5×5 mm	4–7 (average 5.1)	5–8 (average 6.6)[a]	–
Corallites (mm)	Calicular diameter	1.29–2.46 (average 1.89)	Small, slightly concave, 2×4–5×5; 1.17–3.29 (average 2.02)[a]	1.4–1.7
	Fossa diameter	0.23–0.65 (average 0.43)	0.38–0.64 (average 0.53)[a]	0.4–0.5
	Type of columella	Single styliform /2–6 smaller processes	Single styliform /0–4 smaller processes[a]	Single styliform /3–6 smaller processes
	Columella diameter :single/processes	0.10–0.21 (average 0.15) /0.05–0.09 (average 0.07)	0.10–0.16 (average 0.14) /0.04–0.14 (average 0.08)[a]	0.2–0.4
Septa	No. of septa reaching fossa	7–13 (average 9.7)	8–12 (average 9.8)[a]	10–13
	No. of rows of enclosed septa	1–3 (average 1.9)	1 or 2[a]	Up to 6 (generally 1 or 2)
Intercorallite distance within series (mm)		1.25–1.90 (average 1.49)	0.81–2.55 (average 1.44)[a]	1.2–1.8
Intercorallite distance between series (mm)		1.94–3.89 (average 2.56)	1.40–3.79 (average 2.41)[a]	2.1–2.9
Color		Brown or green	–	Uniform grey, brown, tan or cream usually with dark corallite centers; tentacles mostly transparent or green or pink
Material examined[b]		EWZS 3007; EWZS 3772; EWZS 5037; KCRB 951; KCRB 1950; KCRB 1953	EWZS 4158	–

[a]Data re-measured and added in this study.
[b]Material examined. Korea: Jeju-do: 4 inds., Seogwipo-si, Munseom, 3 Dec 1978, Song JI, 30 m deep (EWZS 4158); 1 ind., Seogwipo-si, Seopseom, 5 Nov 2009, Song JI, Hwang SJ (EWZS 3007); 1 ind., Seogwipo-si, Seopseom, 11 May 2009, Song JI, Hwang SJ (EWZS 3772); 1 ind., Seogwipo-si, Seopseom, 6 Oct 2011, Song JI, Hwang SJ, 10-11 m deep (EWZS 5037); 1 ind., Seogwipo-si, Jigwi-do, 33°13.313′N, 126°39.175′E, 13 Oct 2012, Song JI, Hwang SJ, 15-17 m deep, green polyp (KCRB 951); 2 inds., Seogwipo-si, Seopseom, Hangyechang, 33°13′46.7″N, 126°35′46.1″E, 29 Oct 2014, Hwang SJ, Lee WG, 10 m deep, green (KCRB 1950); 2 inds., Seogwipo-si, Seopseom, Hangyechang, 33°13′46.7″N, 126°35′46.1″E, 29 Oct 2014, Hwang SJ, Lee WG, 10 m deep, brown (KCRB 1953).

Barnacles and tube worms live in ectosymbiosis with the corallum.

Remarks. The ecology of *Psammocora albopicta* was first reported from Korea (Denis et al., 2014). The ecological paper reported that typical circular white patterns on the surface of *P. albopicta* were occasionally observed as described in the original paper (Benzoni, 2006). *Psammocora albopicta* (Table 1) and *P. profundacella* (Table 2) of this study are described in the summary, and compared with those of previous studies (Song, 1982, 1991, 2004). The materials from previous studies (Song, 1982, 1991, 2004) and recent specimens of *Psammocora profundacella* in Korea were examined (Table 2). *Psammocora albopicta* differs from *P. profundacella* by the high density of corallites, short intercorallite distance, small calicular diameter of 1 mm, small fossa, and single styliform columella.

Distribution. Pacific Ocean: Korea (Jeju-do Island), Japan (Udo), Philippines, Indonesia (Misool), Australia (Point Vernon, Gneering Shoals, Cook Island, Julian Rocks, Moreton Bay); Indian Ocean: Kuwait (Kubbar Island, Umm Al-Maradem, Qit'at Benaya), Yemen (Balhaf), Saudi Arabia (Jana Island), Malaysia (Pulau Telor).

[1*]Family Faviidae Gregory, 1900

Diagnosis. Corallum colonial, attached. Growth form massive or encrusting in cerioid or plocoid arrangement. Budding extratentacular or intratentacular. Coenosteum present. Costae developed. Paliform lobes developed.

[2*]Genus *Oulastrea* Milne Edwards and Haime, 1848

Diagnosis. Corallum massive or encrusting, plocoid. Budding extratentacular or intratentacular. Paliform lobes before large septa. Columella papillose. Septa spiny or granulated. Coenosteum costate.

[3*]***Oulastrea crispata*** **(Lamarck, 1816) (Fig. 2)**

Astrea crispata Lamarck, 1816: 265.

Oulastrea crispata: Milne Edwards and Haime, 1850: 116, Pl. 9, fig. 4; Vaughan, 1919: 453; Yabe et al., 1936: 54, Pl. 9, figs. 4a, 4b; Pl. 42, figs. 1–4; Vaughan and Wells, 1943: 122, 125; Nemenzo, 1955: Wells, 1956: F405, fig. 301 2a, 2b; Eguchi, 1968: C14, Pl. C19, figs. 3, 6; Veron, 1986: 508; 2000: 229, figs. 1–4; Nishihira and Veron, 1995: 367; Dai and Horng, 2009: 58; Chen et al., 2011: 46; Hoeksema and Vicente, 2014: 430, figs. 1–4.

Material examined. Korea: Jeju-do: 1 ind., Seogwipo-si, Munseom, 19 Nov 1999, Lee YJ, 14 m deep (EWZS 3989); 2 inds., Jeju-si, Chagwi-do, 17 Aug 2001, Song JI (EWZS 4008); 2 inds., Seogwipo-si, Seongsanpo, 18 Aug 2001, Song JI (EWZS 3992); 2 inds., Seogwipo-si, Gapa-do, 33.17315˚N, 126.27747˚E, 10 Oct 2012, S. De Palmas, V. Denis, L. Ribas Deulofeu, 5–15 m deep (GAP 49, GAP 50); 2 inds., Seogwipo-si, Seongsanilchulbong, 33.45744˚N, 126.93608˚E, 11 Oct 2012, S. De Palmas, V. Denis, L. Ribas Deulofeu, 5–15 m deep (SUN 29, SUN 30); 2 inds., Seogwipo-si, Pyoseon, 33.30598˚N, 126.77989˚E, 19 Oct 2012, S. De Palmas, V. Denis, L. Ribas Deulofeu, 5–15 m deep (PYO 3, PYO 10); 1 ind., Seogwipo-si, Gangjeong-deungdae, 33˚13′19.7″N, 126˚28′44.5″E, 28 Oct 2014, Hwang SJ, Lee WG, 16 m deep, green oral part (KCRB 1817).

Description. Corallum colonial, attached. Growth form encrusting or massive, unifacial, plocoid, 17–101 mm in width, 1–20 mm in thickness. Budding extratentacular or intratentacular. 30–39 corallites in 30×30 mm (average 35.6 corallites). Distance between centers of corallites 1.30–7.64 mm (average 5.04 mm). Corallite 1.65×2.68–7.82×10.15 mm (average 5.07×6.25 mm) in calicular diameter. Calicular shape irregularly polygonal (tetragonal to heptagonal, usually hexagonal or pentagonal), or circular or elliptical. Calicular upper margins exserted, elevated. Fossa up to 4 mm, mostly 2 mm in depth. Columella papillose, 0.95×1.26–2.03×3.26 mm (average 1.70×2.13 mm) in diameter. Paliform lobes irregularly present before some larger septa. Theca indistinctively developed between septa. Septa alternating, hexamerously or pentamerously arranged from 13 to 56 in 3–5 cycles (average 32.3 septa in 4 incomplete cycles). Up to 61 septa developed in enlarged corallite of intratentacular budding. Septal fusion present at inner edges. In 3 cycles, pairs of S3 fused before S2. In 4 cycles, pairs of S4 fused before S3, fused S4s united with S2. S1 1.02–2.77 mm (average 1.77 mm) in length, 0.08–0.43 mm (average 0.23 mm) in width. Size, length, width of septa irregularly variable. Septa in previous cycles larger, thicker, more exserted than those in recently formed cycles. Septal upper margins rounded, elevated. Septa imperforate, covered by spines or granules. Costae 0.10–0.27 mm (average 0.17 mm) in width. Intercostal striae 0.06–0.29 mm (average 0.18 mm) in width.

Color. Coenosarc dark brown, oral disc green, and septal upper margins white in living.

Habitat. The species inhabits 5–16 m deep subtidal zones. Tube worms, bryozoans, bivalves, hydroids, and barnacles live in ectosymbiosis with the corallum.

Remarks. Fifty-six septa per corallite in five cycles (61 sep-

Korean name: [1*]뿔빗돌산호과 (신칭), [2*]별빗돌산호속 (신칭), [3*]별빗돌산호 (신칭)

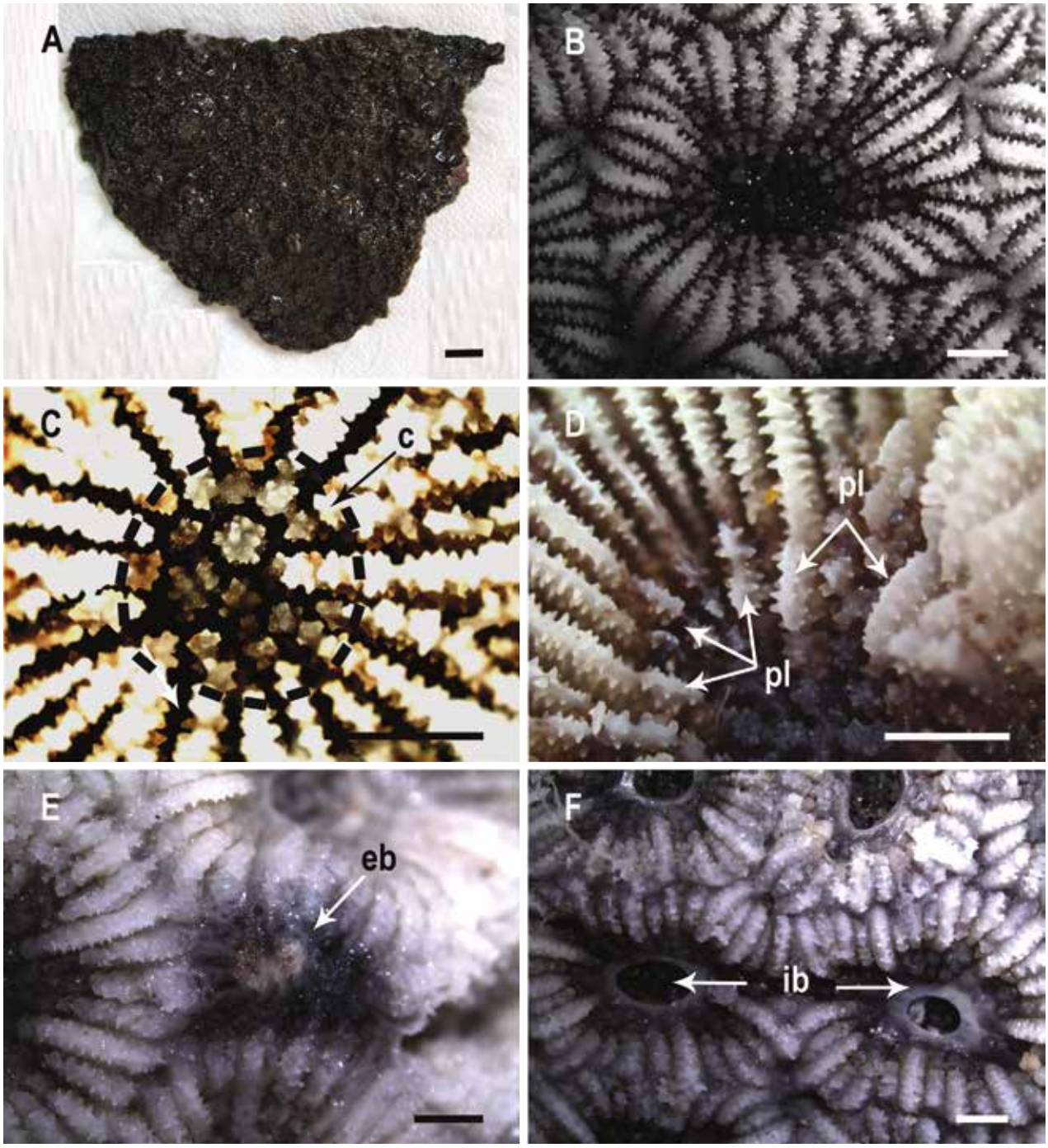

Fig. 2. *Oulastrea crispata*. A, Corallum, encrusting plocoid; B, Calicular shape, polygonal; C, Collumella (c) papillose; D, Paliform lobes (pl); E, Extratentacular budding (eb); F, Intratentacular budding (ib). Scale bars: A=1 cm, B–F=1 mm.

ta developed in an enlarged corallite of the intratentacular budding) are observed in this study (Table 3) and compared with a maximum of 45 septa in the previous study (Hoeksema and Vicente, 2014). Extratentacular budding has been one of the main keys to identify *Oulastrea crispata* (Vaughan and Wells, 1943; Nemenzo, 1955; Eguchi, 1968), but intratentacular and extratentacular buddings are observed as shown in recent studies (Lam, 2000; Hoeksema and Vicente, 2014).

Distribution. Pacific Ocean: Korea (Jeju-do Island), J

Table 3. Comparison on *Oulastrea crispata* morphological characters between this study and previous studies

Morphological character		Reference		
		This study	Nemenzo (1955)	Veron (2000), Hoeksema and Vicente (2014)
Corallum (mm)	Growth form	Encrusting or massive, unifacial, plocoid	Massive or encrusting, plocoid	Encrusting
	Size	17–101 in width, 1–20 in thickness	–	Approximately 60 in diameter
Corallites (mm)	Calicular shape	Polygonal or circular or elliptical	Circular or subcircular or deformed	Round to elliptical
	Calicular diameter	1.65×2.68–7.82×10.15 (average 5.07×6.25)	4–5 (full grown calice)	Approximately 5
	Depth of fossa	Up to 4, mostly 2	1.5–2	–
	Columella	Papillose	Crowded mass of coarse papillae	–
Septa	No.	13–56 (average 32.3)	32–36 (full grown calice)	Mostly 36, up to 45
	Cycle	Hexamerous or pentamerous 3–5 (average 4 incomplete cycles)	–	3
	1st septa	Large, thick, exserted	–	–
	Paliform lobes	Irregularly developed before large septa	Present, obscured by spines	–
Width of costae/intercostal striae (mm)		0.10–0.27 (average 0.17)/0.06–0.29 (average 0.18)	Equal in thickness, convergent	–
Coenosteum		Costate	Costate	–
Type of budding		Extra-, intra-tentacular	Extratentacular	Extra-, intra-tentacular
Color		Coenosarc dark brown, oral disc green, septal upper margins white	–	Black with white upper margins to the septa; tentacles dark brown or olive green, acrospheres white, skeleton dark taupe or black

apan (Southern Honshu, Southern Shikoku, Southern Kyushu, Okinawa), Taiwan, Thailand, China (Hong Kong), Australia, Philippines, Malaysia (Strait of Malacca), Indonesia (Bay of Jakarta, West Papua); Indian Ocean; Atlantic Ocean: France (Corsica).

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