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Description of a New Species of *Aquilonastra* (Asteroidea: Valvatida: Asterinidae) from Langkawi Island, Malaysia

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A new species of *Aquilonastra* O'Loughlin in O'Loughlin and Waters, 2004 is described on the coast of Langkawi Island, Malaysia. This new species is distinguished from 32 congeners based on the number of arms, madreporites, superomarginal and subambulacral spines, the absence of secondary abactinal plates, the shape of abactinal spines, and the attachment site of gonads.

Key Words: Echinodermata, *Aquilonastra aileenae* n. sp., taxonomy, Indian Ocean, Andaman Sea.

Introduction

Aquilonastra O'Loughlin in O'Loughlin and Waters, 2004 is the most diverse genus within the family Asterinidae, comprising 32 species characterized by generally small, flat, and stellate bodies (O'Loughlin and Rowe 2006; O'Loughlin 2009; Mah and Blake 2012; O'Loughlin and Bribiesca-Contreras 2015, 2017). *Aquilonastra* usually occurs at shallow depths in tropical to temperate waters in the Indo-West Pacific region (O'Loughlin and Rowe 2006).

In this genus, both asexual reproduction via fissiparity (Achituv and Sher 1991; Sterling and Shuster 2011) and sexual reproduction have been documented. In sexually reproducing forms, some species exhibit benthic development (Komatsu et al. 1979), whereas others undergo pelagic development (Komatsu 1975; Kano and Komatsu 1978). Some morphological traits differ between species according to their reproductive and developmental modes: more than five arms and multiple madreporites indicate fissiparity, actinal gonopores indicate benthic development, abactinal gonopores indicate pelagic development (Byrne 2006; O'Loughlin and Rowe 2006).

Taxonomic studies on sea stars in Malaysia have been limited (e.g., Zulfigar et al. 2008; Woo et al. 2014; Fairouz et al. 2018). Only two *Aquilonastra* species have been documented in Malaysian waters: *A. coronata* (von Martens, 1866) and *A. corallicola* (Marsh, 1977) (O'Loughlin and Rowe 2006; Fairouz et al. 2018). In this study, we identified a new species of the genus *Aquilonastra* from Langkawi Island and Singa Besar Island, in the Strait of Malacca.

Materials and Methods

Eight specimens were hand-collected from under rocks in the intertidal zone of Langkawi Islands, Malaysia (Fig. 1), and fixed for preservation using 99.5% ethanol. Subsequent examination was conducted under a binocular microscope (Swift S7, Swift Optical Instruments, USA). Both the radius (R) and interradius (r) were measured. The holotype underwent dissection, specifically excising an abactinal portion of the disc and the arm, to facilitate observation of the internal skeleton and gonads. To observe the underlying plate, integuments and spines were removed from one of the arms by applying commercial bleach containing approximately 5% sodium hypochlorite solution. Detached abactinal, superomarginal, inferomarginal, actinal, and adambulacral spines were immersed in a drop of sodium hypochlorite solution to eliminate remnant tissues, followed by cleaning with purified water. Subsequently, they were mounted on an aluminium plate, air-dried, coated with gold-palladium, and observed under a scanning electron microscope (SEM) (JSM-6380LV, JEOL, Tokyo, Japan). The specimens were deposited at the Centre for Marine and Coastal Studies, Universiti Sains Malaysia (USMCRC).

In this study, the morphological terminology followed O'Loughlin and Waters (2004) and O'Loughlin and Rowe (2006). O'Loughlin and Bribiesca-Contreras (2015, 2017) revised the diagnostic characters of the genus *Aquilonastra*, and the same diagnosis is followed in this paper.

Taxonomy

Family **Asterinidae** Gray, 1840

Genus ***Aquilonastra*** O'Loughlin
in O'Loughlin and Waters, 2004

Aquilonastra aileenae n. sp.

(Figs 2, 3)

Material examined. Holotype: USMCRC-Echi 0031 (R=8.2 mm, r=5.8 mm), 20 August 2020, Pantai Pasir Hitam, Langkawi Island, Langkawi Islands, Malaysia, 6°26.007'N, 99°47.773'E (Fig. 1), at an intertidal depth, fixed in 99% ethanol.

Paratypes: USMCRC-Echi 0032 (R=9.1 mm, r=6.4 mm), 0033 (R=7.7 mm, r=4.6 mm), 0034 (R=6.4 mm, r=4.5 mm), 0035 (R=5.5 mm, r=3.6 mm), data as for holotype; USMCRC-Echi 0036 (R=8.7 mm, r=6.5 mm), 0037 (R=5.6 mm, r=4.1 mm), 0038 (R=3.3 mm, r=2.9 mm), 2 March 2017, Singa Besar Island, Langkawi Islands, Malaysia, 6°13.548'N, 99°44.603'E, at an intertidal depth, fixed in 99% ethanol.

Description of holotype. R, 8.2 mm; r, 5.8 mm. Arms five, broadening proximally, gradually tapering toward arm tips, forming broad stellate body (Fig. 2A, B). Abactinal skeleton convex, exhibiting regular close meshwork (Fig. 2B). Each mesh smaller than surrounding abactinal plates, containing one papula (Fig. 2B, C). Papulae absent on in-

terradii and lateral side of arms (Fig. 2B). Abactinal plates ovate or 3–6-lobed, with glassy convexities (Figs 2D, 3A), regularly arranged in longitudinal and transverse series (Fig. 2B). Carinal abactinal plates distinct, partially imbricated by flanked abactinal plates, regularly arranged in a longitudinal series. Primary radial plates four-lobed, arranged in circular series around anal area (Fig. 2E). Madreporite single, adjacent to two of five primary radial plates. Secondary abactinal plates absent (Fig. 2B). Each abactinal plate bearing 6–14 abactinal spinelets arranged in crescent form rows (Fig. 2C). Abactinal spines 0.03–0.05 mm in length, straight, domed to short conical, distally smoothed or with serration (Figs 2C, 3B).

Superomarginal plates round to rounded triangular, as large as or slightly larger than adjacent abactinal plates, arranged in regular longitudinal series at abactinolateral portion of arms (Fig. 2F). Inferomarginal plates transversely elongated rectangles with abradially rounded corners, two-fold larger than corresponding superomarginal plates, arranged in regular longitudinal series along body fringe. Each supero- and inferomarginal plate bearing 7–13 spinelets and 24–43 spinelets and spines (Fig. 2G), respectively. Supero- and inferomarginal spinelets 0.03–0.04 mm in length, straight, conical, with splayed thorns distally (Figs 2G, 3C). Two types of inferomarginal spines: on lateral side of plate, 0.11 mm in length, straight, spatulate, distally serrated (Figs 2G, 3D); on actinal side of plate, same shape as actinal spines.

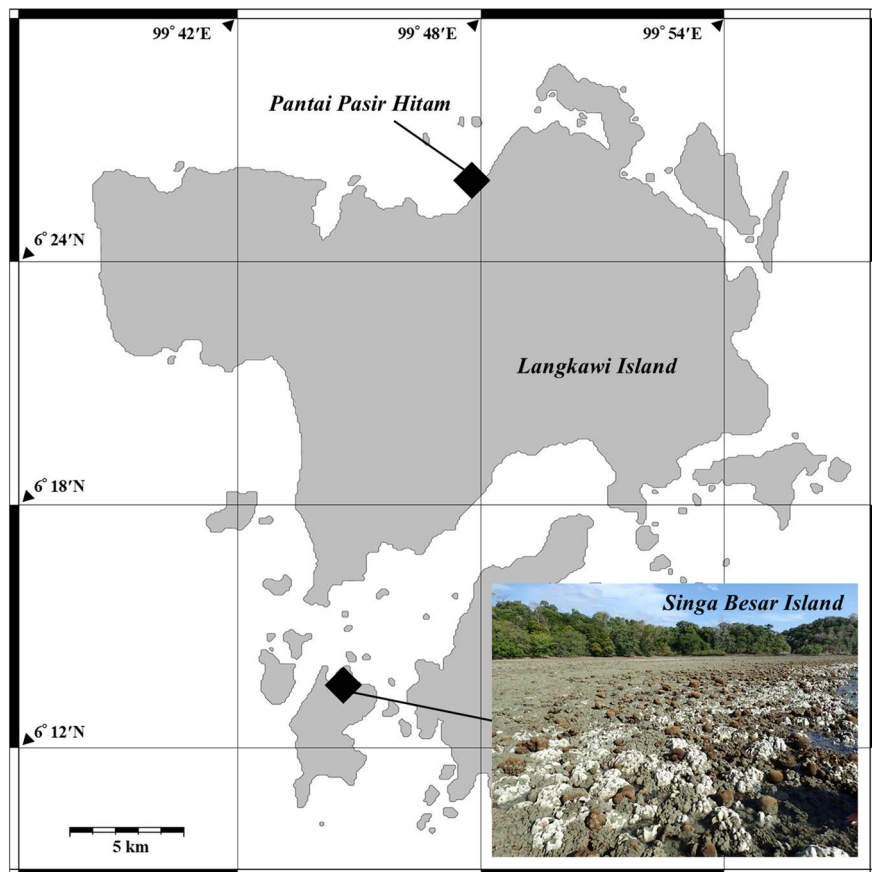


Fig. 1. Sampling site of *Aquilonastra aileenae* n. sp. (indicated by solid diamonds).

Actinal plates round to ovoid, arranged in five regular longitudinal series (Fig. 2H). Actinal series extend over half arm length, longest in first series, gradually shortening toward fifth series. Each actinal plate bearing 2–5 actinal spines (Fig. 2I). Actinal spines 0.12–0.15 mm in length, curved, sacciform, conical, distally serrated (Figs 2I, 3E).

Adambulacral plates transversely elongated, longitudinally constricted at median section of each plate (Fig. 2H). Each adambulacral plate bears 3–7 furrow spines on adradial part of plate and 1–5 subambulacral spines on abradial

section (Fig. 2I). Furrow and subambulacral spines each arranged in one curved series, similar shape, 0.19–0.23 mm in length, straight, spatulate, blunt tip (Figs 2I, 3F).

Ambulacral plates transversely elongated, medially narrowed (Fig. 2J). Adradial triangle part of plate projects proximally, overlapping preceding plate. Superambulacral and superactinal plates bridge corresponding ambulacral/actinal, and actinal/abactinal plates internally. Tube feet with suckered disks, arranged biserially.

Pedicellariae absent.

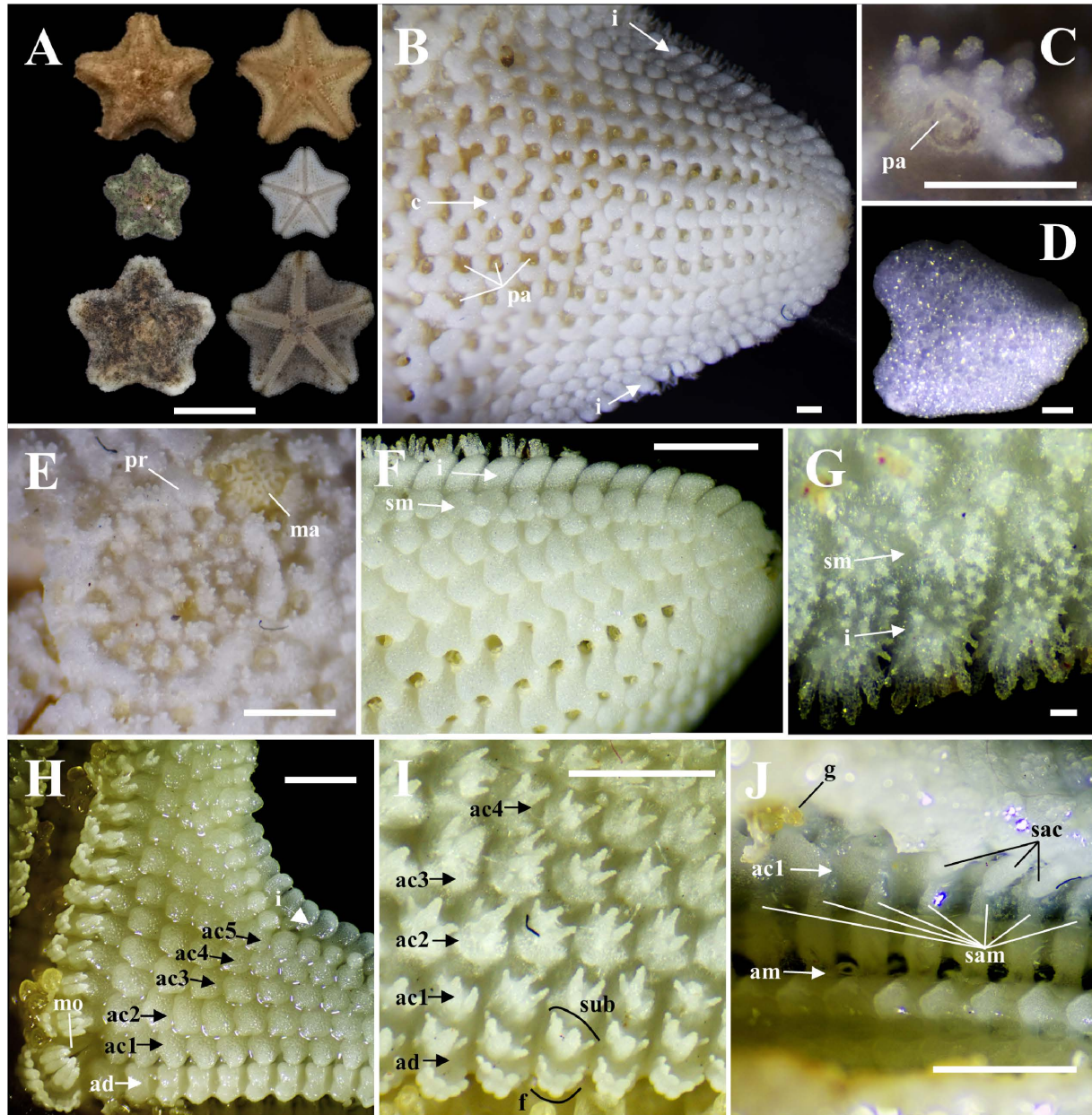


Fig. 2. *Aquilonastra aileenae* n. sp., holotype, USMCRC-Echi 0031 (B–J), paratypes, USMCRC-Echi 0033 (A, top), 0037 (A, middle), and 0036 (A, bottom). A, Whole body, abactinal (left) and actinal (right) side; B, denuded abactinal surface of arm; C, abactinal surface of proximal portion of arm; D, detached abactinal plate on middle portion of arm; E, center of abactinal side of disk; F, denuded abactino-lateral portion of arm; G, abactino-lateral portion of arm; H, denuded actinal surface of proximal portion of arm; I, actinal surface of proximal portion of arm; J, abactinal view of inside of proximal to middle portion of arm. Abbreviations: ac, actinal series; ad, adambulacral series; am, ambulacral series; c, carinal abactinal series; f, furrow spines; g, gonads; i, inferomarginal series; ma, madreporite; mo, mouth plate; pa, papulae; pr, primary radial plates; sac, superactinal plate; sam, superambulacral plate; sm, superomarginal series; sub, subambulacral spines. Arabic numerals one to five after “ac” indicate the first to fifth actinal series, respectively. Scale bars: A, 10 mm; B, C, E, F, H–J, 1 mm; D, G, 0.1 mm.

Table 1. Morphological variations in the examined specimens of *Aquilonastra aileenae* n. sp.

Characters	Holotype	Paratypes						
		USMCRC-Echi 0032	USMCRC-Echi 0033	USMCRC-Echi 0034	USMCRC-Echi 0035	USMCRC-Echi 0036	USMCRC-Echi 0037	USMCRC-Echi 0038
R (mm)	8.2	9.1	7.7	6.4	5.5	8.7	5.6	3.3
r (mm)	5.8	6.4	4.6	4.5	3.6	6.5	4.1	2.9
Number of arms	5	4	5	5	5	5	5	5
Number of actinal series	5	6	6	5	6	6	6	4
Number of abactinal spinelets	6–14	3–12	4–12	1–12	4–13	2–13	3–15	1–7
Number of superomarginal spinelets	7–13	6–15	9–15	3–7	7–13	3–11	10–14	5–6
Number of inferomarginal spinelets and spines	24–43	23–32	26–30	15–23	26–30	17–22	19–29	16–22
Number of actinal spines	2–5	3–6	2–7	2–4	2–4	2–5	2–4	1
Number of subambulacral spines	1–5	2–6	3–4	3–7	2–4	2–5	3–4	1–2
Number of furrow spines	3–7	3–6	3–6	3–5	3–5	4–5	3–6	2–3

Gonads attached on abactinal body wall (Fig. 2J). Gonopores unobservable.

Body color mottled brown or olive (Fig. 2A).

Variations in paratypes. Shown in Table 1.

Distribution. *Aquilonastra aileenae* is documented solely from Pantai Pasir Hitam, Langkawi Island, Malaysia, and Singa Besar Island, Malaysia, under locks in the intertidal zone with living and dead corals.

Etymology. The specific name is dedicated to the honor of Professor Dato' Dr. Aileen Tan Shau Hwai (CEMACS, Universiti Sains Malaysia) who has contributed significantly to the study of marine invertebrate biodiversity in Malaysia.

Remarks. Eight examined *Aquilonastra aileenae* specimens exhibit a flat and stellate body, regularly arranged abactinal and actinal plates, a distinct carinal series, glassy convexities on the abactinal plates, and superambulacral and superactinal plates (Figs 2, 3), aligning closely with the diagnosis of the genus *Aquilonastra* by O'Loughlin and Waters (2004). Out of 33 recognized *Aquilonastra* species, *A. aileenae* is most closely related to three western Indian Ocean species, namely *A. lorioli* (Koehler, 1910), *A. marshae* O'Loughlin and Rowe, 2006, and *A. samyni* O'Loughlin and Rowe, 2006, sharing five arms, a single madreporite, gonads attached to the abactinal body wall, and distinctive domed to short conical abactinal spinelets (O'Loughlin and Rowe 2006). However, the present specimens lacked secondary abactinal plates (Fig. 2B), distinguishing them from the three related species, which possess secondary abactinal plates (O'Loughlin and Rowe 2006). Additionally, *A. aileenae* possesses 15–43 superomarginal spinelets and 2–5 actinal spines on each plate (Table 1), whereas *A. lorioli* and *A. marshae* have fewer than 11 superomarginal spinelets and *A. samyni* has 8–14 actinal spines (O'Loughlin and Rowe 2006).

All eight *A. aileenae* specimens possess either five arms or (exceptionally) four arms, a single madreporite, and gonads attached to the abactinal body wall (Fig. 2A, E, J). These morphological characters suggest that this new species is not fissiparous and have pelagic development (refer to Byrne 2006; O'Loughlin and Rowe 2006), distinguishing

it from the 11 fissiparous and 3 benthic development species within the genus *Aquilonastra* (O'Loughlin and Rowe 2006; O'Loughlin and Bribiesca-Contreras 2015).

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Authors Contributions

Itaru Kobayashi: Conceptualization; Resources; Investigation; Data curation; Visualization; Writing – original draft. Masaki Yamamoto: Conceptualization; Resources; Investigation; Data curation; Visualization; Writing – original draft. Mikihiro Arai: Conceptualization; Resources; Investigation; Data curation; Visualization; Writing – original draft. Sau Pinn Woo: Conceptualization; Resources; Writing – review & editing; Funding acquisition. Toshihiko Fujita: Conceptualization; Supervision; Resources; Writing – original draft; Writing – review & editing; Project administration; Funding acquisition.

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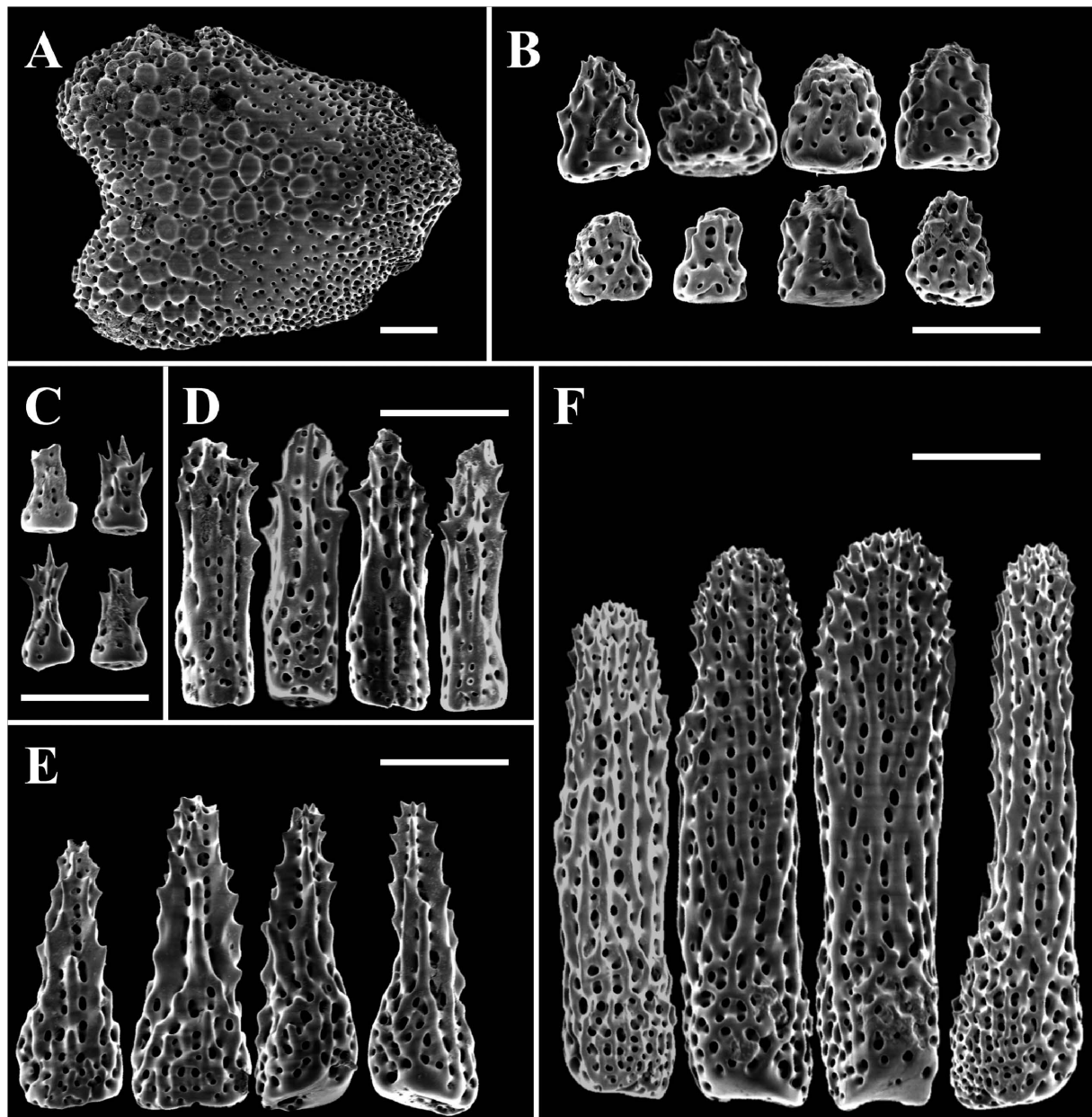


Fig. 3. SEM images of ossicles of *Aquilonastra aileenae* n. sp., holotype, USMCRC-Echi 0031. A, Abactinal plate on the proximal portion of the arm; B, abactinal spinelets on the disc; C, superomarginal spinelets on the proximal portion of arms; D, inferomarginal spines on the proximal portion of the arm; E, actinal spines on the proximal portion of the arm; F, furrow spines on the proximal portion of arms. Scale bars: 0.1 mm.

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Declarations

Competing interests. The authors declare no conflicts of interest.

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