

Two newly recorded species of genus *Henricia* (Asteroidea: Spinulosida: Echinasteridae) from the East Sea, Korea

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Contribution to Environmental Biology

- Our findings expanded *Henricia* diversity in the East Sea and highlight the correlation between the marine environment of the East Sea and the habitat expansion of *Henricia* in cold water.

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Abstract: *Henricia* specimens were collected using a dual approach of trimix scuba diving and fishing nets. This inclusive collection encompasses the discovery of two species highlighted in this study and introduces and provides comprehensive descriptions for *Henricia kinkasana* and *Henricia longispina aleutica*. The descriptions offered in this study were derived from the thorough examinations of external morphological characteristics. The documentation provides detailed insight into key traits related to the abactinal and actinal skeletons and spines of these newly recorded species in Korea. This comprehensive examination contributes to our understanding of the distinct morphological characteristics defining each species within the genus *Henricia*.

Keywords: biodiversity, echinoderms, morphology, sea stars, taxonomy

1. INTRODUCTION

Echinoderms are a diverse and widespread group of marine invertebrates that exhibit the ability to inhabit a wide range of environments in oceans worldwide (Hyman 1955; Knott and Wray 2000; Uthicke *et al.* 2009), ranging from dynamic intertidal zones, where they contend with tidal changes and exposure to both land and sea, to the depths of the ocean, showing adaptability and ecological versatility (Karleskint *et al.* 2006). The marine ecosystems surrounding Korea are diverse and rich, playing a crucial role in the overall biodiversity of the East Asia region. Korea is surrounded by three major regions: Yellow Sea to the west, the Korea Strait to the south, and the East Sea. These seas

contribute to the formation of unique marine environments that support a wide variety of species (Rebstock and Kang 2003). Within the family of Echinasteridae Verrill, 1867, the genus *Henricia* Gray, 1840, emerges as an interesting research subject (Ubagan *et al.* 2020). *Henricia* has unique characteristics and intricate ecological adaptations, representing the complexity and diversity of the species in this genus (Fisher 1911; Hayashi 1940). The diversity of *Henricia* species in Korea is increasing, with a total of 21 species documented, including two newly recorded species in this study (Ubagan and Shin 2023).

This study performed comprehensive taxonomic and morphologic examinations of two recently identified species within the genus *Henricia*. Detailed invest-

igations into newly recorded species are needed as the foundations of our understanding of marine ecosystems continue to evolve. This study provided a thorough examination of the taxonomic placement, morphological characteristics, and potential geographical significance of two *Henricia* species recently documented in Korea.

2. MATERIALS AND METHODS

Henricia specimens were collected in an adjacent water of Daejin port in 2016 using fishing nets and trimix SCUBA diving from a depth of 41.5 m on Dokdo Island of Korea in 2023. The collected specimens were preserved in 95% ethyl alcohol solution and deposited in the National Marine Biodiversity Institute of Korea (MABIK). Morphological characteristics, such as the size of the disk, the upper and proximal portions of the arms, the number of abactinal spines, the shape of the abactinal and actinal skeletons, and the number of adambulacral spines, were examined. Morphological features of the whole body of the specimens were photographed using a digital camera (Sony A6100; Sony Co., Tokyo, Japan), a stereomicroscope (Nikon SMZ1000; Nikon Co., Tokyo, Japan) for the detailed parts of the body, and a scanning electron microscope (JSM-6510; JEOL Ltd., Tokyo, Japan) for ossicles. The abbreviations used in the descriptions of *Henricia* were R, which represents the length from the center of the disk to the end of the arm, and r, which represents the length from the center of the disk to the end of the interambulacral area.

3. SYSTEMATIC ACCOUNTS

Phylum Echinodermata Klein, 1778
Class Asteroidea de Blainville, 1830
Order Spinulosida Perrier, 1884
Family Echinasteridae Verrill, 1870
Genus *Henricia* Gray, 1840

Henricia kinkasana Hayashi, 1940

초승달애기불가사리 (신칭) (Fig. 1)

Henricia kinkasana Hayashi, 1940: 144; Mah, 2023a: 369108.

Material examined. One specimen, Daejin: Goseong-gun: Gangwon-do: Korea (38°30'09.9"N, 128°27'06.5"E), 1 December 2016, Ubagan M., a depth of 70.0 m, collected by fishing nets, deposited in the National Marine Biodiversity Institute of Korea (MABIK; MABIK_IV00173333).

Description. Arms five, short, gradually tapering to tips (Fig. 1A, B). Abactinal paxillae clustered, bearing seven to 16 spinelets (Fig. 1C). Denuded abactinal spine stout tip with uneven apical thorns (Fig. 1J). Abactinal skeleton closely meshed, characterized by small crescentic, elongated cross, and lobe shapes of nearly uniform sizes, larger than papular areas (Fig. 1D). Papular areas narrow, containing one or two papulae in an area (Fig. 1E). Madreporite small, circular in form, slightly sunken, bearing spines similar to adjacent spines (Fig. 1F). Actinal plate series distinguishable, with superomarginal plates gradually bending upward near base of arm, almost same size as adjacent plates. Intermarginal plates consist of elongated cross, lobe shape, and crescentic shape, reaching near one-half length of arm. Inferomarginal plates elongated cross-shaped, bearing 15 to 22 spines, reaching one-half length of arm. Ventrolateral plates rounded cross shape, smaller size compared to adjacent plates, reaching nearly arm tip. Actinal papular areas bearing a single papula (Fig. 1G). Adambulacral plates semi-rounded shape, bearing 11 to 14 spines, with three longer spines near the furrow edge and shorter spines near ventrolateral spines, and arranged in two transverse series (Fig. 1G, H, K). Furrow spine single. Oral part bearing two stubby oral spines, three marginal spines, and six sub-oral spines (Fig. 1I).

Size. R = 32 mm, r = 7 mm, R/r = 4.5.

Distribution. Korea (Daejin: Goseong-gun: Gangwon-do), Japan (Off Kinkasan).

Remarks. The morphological characteristics of *Henricia kinkasana* Hayashi, 1940, were compared to its congeners, including *H. anomala* Hayashi, 1973, *H. elachys* Clark and Jewett, 2010, *H. nipponica* Uchida, 1928, and *H. tumida* Verrill, 1909. The variations in features, such as arm morphology, abactinal papulae, spines, and plates, highlighted the similarities and differences in each related species within the genus (Table 1). Major distinctions emerged from the analysis of the morphological traits, particularly skeletal shape and the number of adambulacral spines. The detailed morphological analysis suggested that they are different species

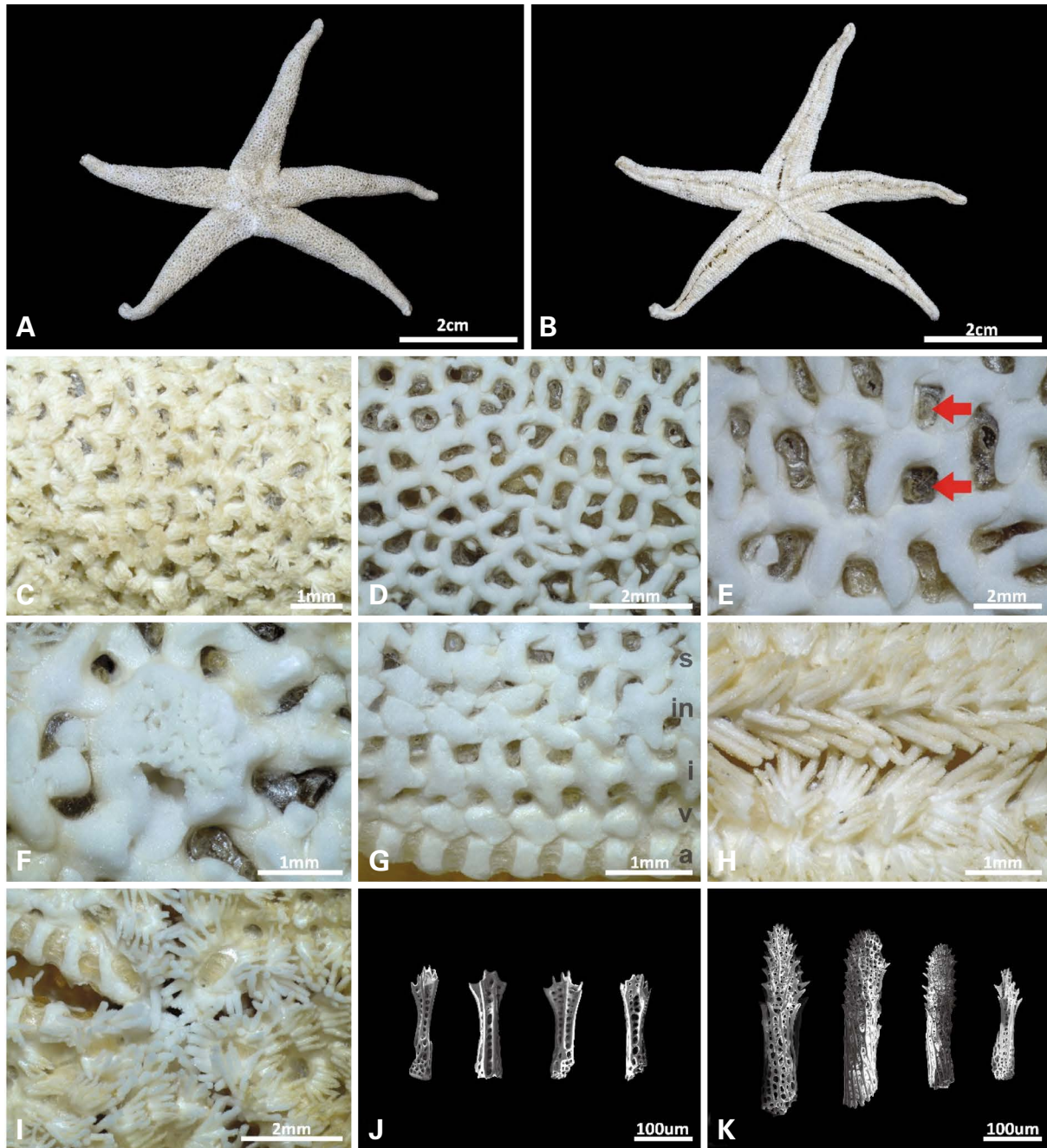


Fig. 1. *Henricia kinkasana* Hayashi, 1940. A, abactinal side; B, actinal side; C, abactinal paxillae; D, abactinal skeleton; E, papulae (arrows); F, madreporite; G, actinal skeleton. H, K, adambulacral spines; I, oral part and interradia of the actinal side; and J, abactinal spines. Abbreviations: a, adambulacral plates; i, inferomarginal plates; in, intermarginal plates; s, superomarginal plates; v, ventrolateral plates.

based on major morphological characteristics, such as skeletal shape (our specimen possessed a crescentic, lobed, and elongated cross shape), which is the major difference in closely related species. The number of adambulacral spines (our specimen had 11–14) was

closer to that of *H. elachys*. However, it was distinctly separated by the shape of the abactinal plates and the inferomarginal area (Table 1). Morphological analysis of Korean *H. kinkasana* showed some slight morphological variation compared to the holotype specimen

Table 1. Comparison of the morphological characteristics of *Henricia kinkasana* with analogous *Henricia* species

Characters	<i>H. kinkasana</i> Hayashi, 1940	<i>H. anomala</i> Hayashi, 1973	<i>H. elachys</i> Clark and Jewett, 2010	<i>H. nipponica</i> Uchida, 1928	<i>H. tumida</i> Verrill, 1909
Range of R/r (Max R)	4.5	4.0	3.2-3.9	3.1-3.6	2.0-3.0
Arms	short, tapering to the tip	short, tapering to the tip	short, tapering to the tip	short, tapering to the tip	short, tapering to the tip
Number of abactinal papulae	1 or 2	1 or 2	2-5	1	1
Shape of abactinal papular areas	narrow	narrow	narrow	narrow	narrow
Number of abactinal spines	7-16	2-5	3-14	7-15	3-10
Shape of abactinal spines	slender	pointed	pointed	pointed	pointed
Shape of abactinal plates	crescentic, lobe, elongated cross	sub-triangular, rod-like, or lobed	rounded cross	rod-like or lobed	roundish, lobed
Shape of inferomarginal plates	elongated cross	rounded cross	rounded cross	elongated cross	elongated cross
Number of adambulacral spines	11-14	5-7	10-14	6-9	4-5
Pattern of adambulacral furrow + near ventrolateral plate	1-3 slender + 4-14 shorter, pointed tip	1 short, stout + 2-7 shorter, pointed tip	1-3 bluntly pointed + 4-14 shorter, pointed tip	1-3 bluntly pointed + 4-9 shorter, pointed tip	1 bluntly pointed + 2-5 shorter, pointed tip

such as abactinal spines (our specimen: 7-16; holotype: 5-18), and the adambulacral spines (our specimen: 11-14; holotype: 8-12). However, these slight morphological variation in the number of abactinal spines and adambulacral spines does not render the specimens distinct from each other. Therefore, we consider that the Korean *H. kinkasana* is the same species as the holotype specimen.

Henricia longispina aleutica Fisher, 1911

알루샬긴가시애기불가사리 (신칭) (Fig. 2)

Henricia longispina aleutica Fisher, 1911: 122; Mah, 2023b: 369124.

Material examined. One specimen, Dokdo Island: Ulleung-gun: Gyeongsangbuk-do: Korea (37°24'95.1"N, 131°86'70.2"E), 23 August 2023, Lee T., a depth of 41.5 m, a temperature of 16°C, collected by trimix SCUBA diving, deposited in the National Marine Biodiversity Institute of Korea (MABIK; MABIK_IV001 73452).

Description. Arms five, long, slender, small disk, gradually tapering to tips (Fig. 2A, B). Clustered abactinal paxillae, bearing four to 18 spinelets, not densely packed (Fig. 2C). Denuded abactinal spines slender with uneven apical thorns (Fig. 2J). Paxillae on lateral side of arms similar to abactinal paxillae. Abactinal skeleton open-meshed and comprised of lobed and elongated shapes united into a rhomboid coarse meshwork of different sizes. Abactinal plates smaller than papular areas (Fig. 2D). Papular areas wide, containing numerous six to 13 papulae in an area (Fig. 2E). Small ossicles with spinelets present in some papular areas. Madreporite circular in form and slightly elevated, bearing spines similar to adjacent spines (Fig. 2F). Three regular series of plates adjacent to adambulacral (superomarginal, inferomarginal, and ventrolateral) plates well-defined. Superomarginal plates rounded cross-shape, reaching tip of arm. Intermarginal plates rounded cross and lobed-shaped, smaller size than adjacent plates, reaching half of arm. Inferomarginal plates elongated, cruciform-shaped, larger than adjacent plates, bearing 12 to 30 spines, reaching tip of arm. Ventrolateral plates rounded cross-shape, slightly smaller than inferomarginal plates, bearing four to 15 spines, reaching three-fourths length of arm. Actinal papular areas bearing one to six papulae (Fig. 2G). Adambulacral plates semi-rounded shape, bearing

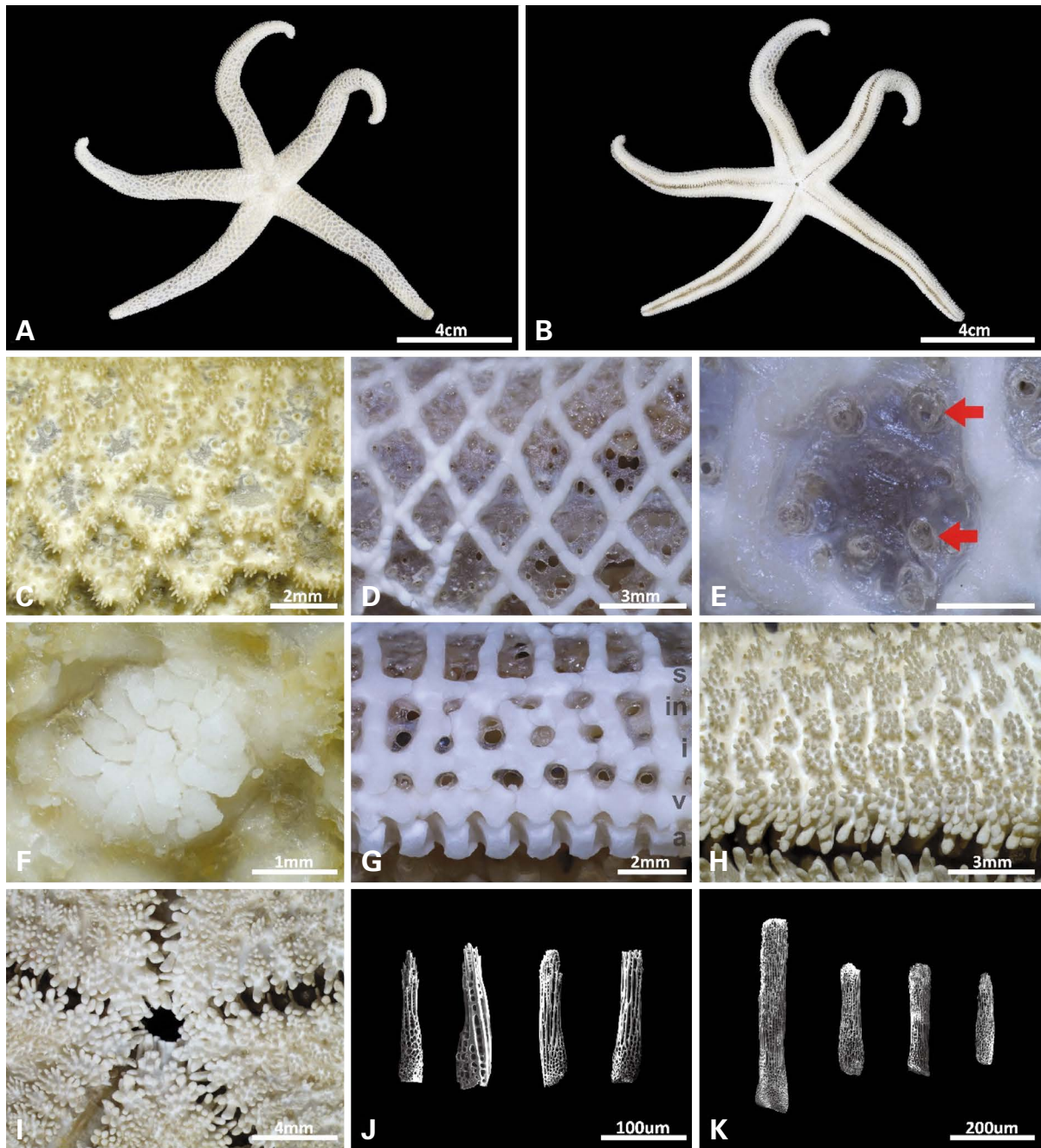


Fig. 2. *Henricia longispina aleutica* Fisher, 1911. A, abactinal side; B, actinal side; C, abactinal paxillae; D, abactinal skeleton; E, papulae (arrows); F, madreporite; G, actinal skeleton; H, K, adambulacral spines; I, oral part and interradial spines; J, abactinal spines. Abbreviations: a, adambulacral plates; i, inferomarginal plates; in, intermarginal plates; s, superomarginal plates; v, ventrolateral plates.

eight to 22 spines, with flat-tip spines near furrow edge and stout spines near ventrolateral spines, arranged in two transverse series (Fig. 2G, H, K). Furrow spine single. Oral part bearing two stubby oral spines, three marginal spines, and four or five sub-oral spines (Fig.

2I).

Size. R = 82 mm, r = 11 mm, R/r = 7.4.

Distribution. Korea (Dokdo Island: Ulleung-gun; Gyeongsangbuk-do); Alaska (Aleutian Islands).

Remarks. As indicated in the morphological analysis,

Table 2. Comparison of the morphological characteristics of *Henricia longispina aleutica* with analogous *Henricia* species

Characters	<i>H. longispina aleutica</i> Fisher, 1911	<i>H. aspera</i> Fisher, 1906	<i>H. longispina longispina</i> Fisher, 1911	<i>Henricia pacifica</i> Hayashi, 1940
Range of R/r (Max R)	7.4	4.1	4.5–5.2	6.9–8.4
Arms	long, slender tapering to the tip	slightly swollen basally, tapering to the tip	cylindrical, tapering to the tip	long, slender tapering to the tip
Number of abactinal papulae	6–13	2–9	5 or 6	1–5
Shape of abactinal papular areas	wide	wide	wide	narrow
Number of abactinal spines	4–18	3–7	2–9	5–19
Shape of abactinal spines	slender	barrel	pointed	pointed
Shape of abactinal plates	rod-like	sub-triangular, rod-like, or lobed	quadrate or roundish	rod-like
Shape of inferomarginal plates	elongated cross, rounded cross	elongated cross	rounded cross, rod-like	elongated cross
Number of adambulacral spines	7–22	4–8	6 or 7	10–15
Size of actinal interradial areas	larger	smaller	smaller	smaller
Pattern of adambulacral furrow + near ventrolateral plate	1–3 slender + 4–22 shorter	1 short with a flat tip and 2–3 stout + 4–8 shorter	1–3 long, bluntly pointed + 4–7 shorter	1–3 long, pointed + 4–15 shorter

this species has numerous points of close similarity, particularly to *H. longispina longispina* Fisher, 1911. However, the most prominent distinctions between the two forms lie in the wide-meshed skeleton of *H. longispina aleutica* and larger actinal interradial areas. These traits represent the most significant separation, highlighting variations in the skeletal structure. In our examination of Korean *H. longispina aleutica*, a thorough comparison was conducted with closely related *Henricia* species in Korea, such as *H. aspera* Fisher, 1906, and *H. pacifica* Hayashi, 1940. The findings of our specimen align with Fisher's 1911 identification, emphasizing the significance of the distinctions observed, particularly in relation to the wide-meshed skeleton and the larger actinal interradial areas of *H. longispina aleutica*, as shown in Table 2. This focused analysis enhances our understanding of the unique morphological characteristics that distinguish *H. longispina aleutica* from closely related species. The comparison of our specimen to the holotype described by Fisher (1911) demonstrated similarities in most traits, affirming its identification as the same species. While close resemblance was noted, minor variations were observed, particularly in the number of abactinal spines (our specimen: 4–18; holotype: 3–5). However, this difference alone was deemed insubstantial and did not justify the recognition of a distinct species. Therefore, we consider that our specimen is the same species as that described by Fisher (1911).

CRedit authorship contribution statement

MD Ubagan: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original article, Writing - Review and editing. **J Lee:** Investigation. **T Lee:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - Review and editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare no conflicts of interest.

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