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Short communication

A Newly Recorded Sea Star, *Aquilonastra doranae* (Asteroidea: Asterinidae), from Jejudo Island, South Korea

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ABSTRACT

Aquilonastra doranae, a newly recorded sea star, was collected from the southern coast of Jejudo Island by a trimix SCUBA diving survey in May 2021. The newly collected specimen is distinguished from a previously known *Aquilonastra* species in South Korea by having a fissiparous body form with six arms. Results of pairwise genetic distance analysis showed that the new specimen was identical or close to *A. anomala* from Hawaii (0.0%), Australia (3.1%), and Samoa (3.3%). However, morphological characteristics of the Korean *Aquilonastra* specimen corresponded with the original description of *A. doranae*, not that of *A. anomala*, including the number of inferomarginal spines, the absence of pedicellariae, and the inhabit locality. Thus, this study agrees with the original morphological study of *A. doranae* and presents this specimen as the first record of *A. doranae* in South Korea.

Keywords: Echinodermata, asteroids, taxonomy, morphology, *COI*

INTRODUCTION

Genus *Aquilonastra* was erected by O'Loughlin in O'Loughlin and Waters (2004) based on a molecular and morphological revision about genera of family Asterinidae Gray, 1840, and this genus initially contained 13 species of genus *Asterina* Nardo, 1834 (O'Loughlin and Waters, 2004). Among them, *Aquilonastra heteractis* was synonymized to *Ailsastra heteractis* (H.L. Clark, 1938) when genus *Ailsastra* O'Loughlin and Rowe, 2005 was erected based on morphological study (O'Loughlin and Rowe, 2005). Since then, 20 species of genus *Aquilonastra* have been added. This genus now contains 32 extant species (Mah, 2023). Among them, two species have been reported in South Korea (Shin, 2010): *A. batheri* (Goto, 1914) and *A. minor* (Hayashi, 1974). These two species were typically distributed in adjacent waters of Jejudo Island and the Korean Strait. Common characteristics of these species include a regular body form with five arms and flattened plane of oral side (Shin, 2010). In May 2021, a unique *Aquilonastra* specimen was collected from the southern coast of Jejudo Island. The aim of the present study was to identify this sea star based on morphology and molecular analysis with a DNA barcoding sequence.

The sea star was collected by trimix SCUBA diving from Seopseom Island located on the southern coast of Jejudo Island, Korea (Fig. 1). It was picked from the surface of Porifera and immediately preserved in ethyl alcohol solution (>95%). The sample was deposited at the Honam National Institute of Biological Resources (HNIBR). Observation of major morphological characteristics and measurement of body part for sea star such as length of an arm were performed following the method of Shin (2010). Abbreviations of morphology also followed the method of Shin (2010). Specimen observation and photography for figures were performed using a Nikon SMZ1000 stereomicroscope (Nikon, Tokyo, Japan), a DP22 digital camera (Olympus, Tokyo, Japan), and a Helicon Focus 7.7.5 (Helicon Soft Ltd., Oakland, CA, USA) for combinations of images with varying focus.

Total genomic DNA was extracted from tube feet using a DNeasy Blood & Tissue kit (Qiagen, Hilden, Germany) following the manufacturer's protocol. DNA product quality was assessed with a NanoDrop ONE-C (Thermo Scientific, Waltham, MA, USA). A partial sequence of mitochondrial cytochrome c oxidase subunit I (*COI*) was amplified using

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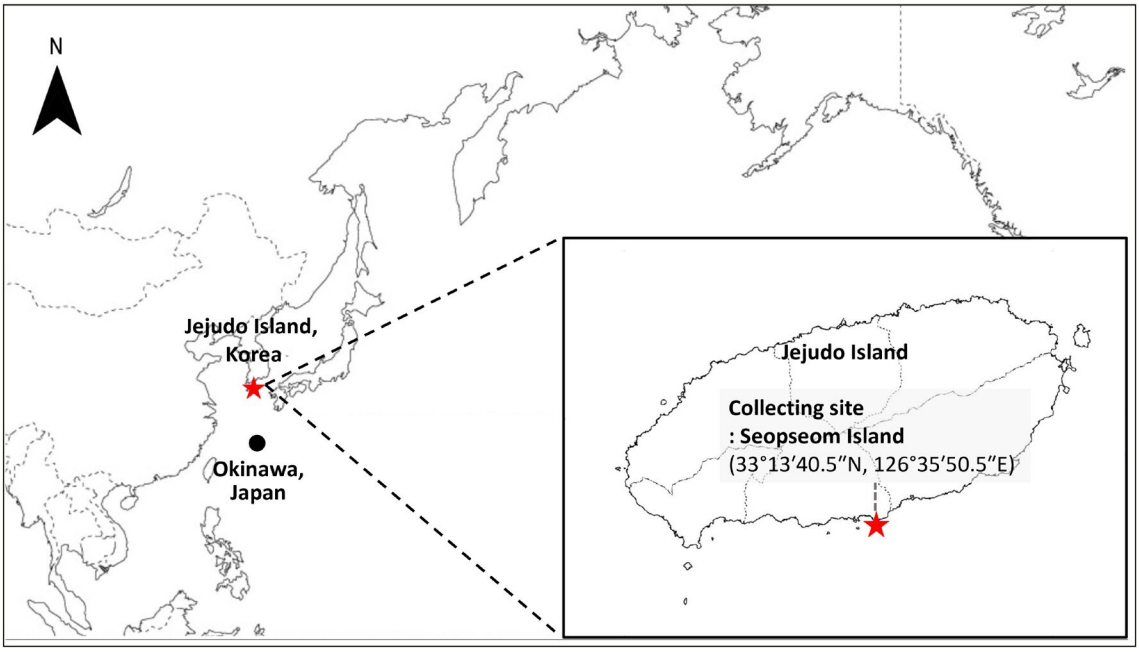

Fig. 1. Distribution of *Aquilonastra doranae* O'Loughlin and Rowe, 2006. The type locality is marked by '●'. The collecting locality in this study is marked by '★' on the map.

primers of LCOech1aF1 (Layton et al., 2016) and HCO2198 (Folmer et al., 1994). Polymerase chain reaction (PCR) was performed with a total reaction volume of 20.0 μL including 1.0 μL of each primer (10 mM) and 0.5 μL of DNA template (> 50 ng/μL) using an AccuPower PCR PreMix & Master Mix (Bioneer, Seoul, Korea). PCR cycling conditions were as follows: denaturation at 94°C for 3 min; 35 cycles of 95°C for 30 s, 50°C for 45 s, and 72°C for 60 s; followed by a final elongation step at 72°C for 5 min. PCR products were sequenced using ABI BigDye Terminator kits (Applied Biosystems, Foster City, CA, USA) on an ABI 3730XL DNA Analyzer. Pairwise genetic distance (*p*-distance) was calculated using the Kimura 2-parameter model (K2P) (Kimura, 1980) in MEGA11 (Tamura et al., 2021).

SYSTEMATIC ACCOUNTS

Phylum Echinodermata Klein, 1778
Class Asteroidea de Blainville, 1830
Order Valvatida Perrier, 1884
Family Asterinidae Gray, 1840
Genus *Aquilonastra* O'Loughlin in O'Loughlin and Waters, 2004

Key to the species of genus *Aquilonastra* from South Korea

1. Arms more than five, fissiparous body form·····*A. doranae*
– Arms typically five, not fissiparous body form····· 2
2. Gonopore presented at actinal side·····*A. minor*
– Gonopore presented at abactinal side·····*A. batheri*

[1]**Aquilonastra doranae* O'Loughlin and Rowe, 2006 (Fig. 2)**

Aquilonastra doranae O'Loughlin and Rowe, 2006: 274, figs. 1, 3a, 8e; O'Loughlin and Bribiesca-Contreras, 2015: 29.

Material examined. One specimen, Seopseom Island, Seogwipo-si, Jeju-do, Korea (33°13′40.5″N, 126°35′50.5″E), 24 May 2021, Lee T., 53.7 m depth, 17°C water temp., collected by trimix SCUBA diving, deposited in HNIBR (HNIBR IV1434) (Fig. 1).

Description. Body rather small (R = 5.70 mm, and r = 3.27 mm), fissiparous form. Arms six in number with three recovering arms, broad at basal side, mostly rounded at blunt tip (Fig. 2A, B). Body flattened on actinal side, abactinal side inflated. Three madreporites situated slightly off from center of disk, inconspicuous, surrounded by spinelets. Pedicellariae absent on abactinal side. Abactinal plates rather large, imbricated

Korean name: [1]*도란물별불가사리 (신칭)

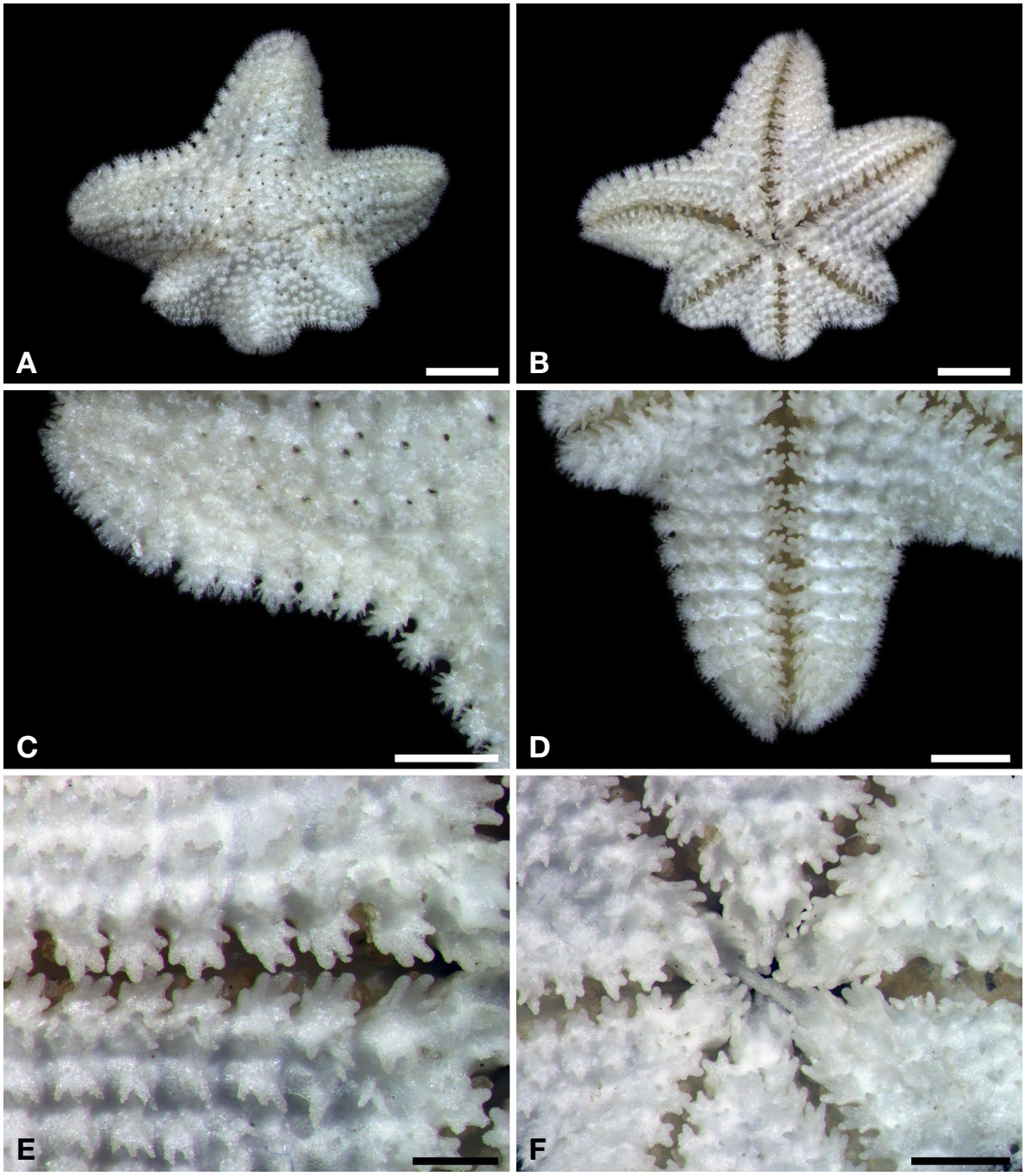

Fig. 2. *Aquilonastra doranae* O'Loughlin and Rowe, 2006 (voucher number: HNIBRIV1434). A, Abactinal side; B, Actinal side; C, Abactinal side of arm; D, Actinal side of arm; E, Adamburacral spines and interradii; F, Oral part. Scale bars: A, B=2 mm, C, D=1 mm, E, F=500 μm.

with each other, slightly concave on popular side with one papula, arranged with two irregular series from basal to tip, each plate containing 10 or 11 spinelets. Spinelets of abactinal plates conical or digit shape, thorns at tip. Superomarginal plate with six spinelets. Inferomarginal plates not imbricated with each other, long and splay-pointed, 11 to 12 spinelets on each plate (Fig. 2C). Interradial actinal plates contain three or four spines (predominantly three), adamburacral plate contains three, amburacral plate contains four (three in recovering part), oral plate contains five (Fig. 2D–F).

Distribution. Korea (Seopseom Island: Jejudo Island), Japan (Okinawa: type locality) (Fig. 1).

Habitat. This specimen inhabits the rocky area of rather deep and warm water in Seopseom Island (depth of 53.7 m and water temperature of 17°C).

Size. R = 5.70 mm and r = 3.27 mm in a regular body part. R = 1.74r.

Color. This specimen was dark green with some dark or reddish-brown spots on the abactinal side and greenish gray on the actinal side during life.

DNA barcoding analysis. This study obtained partial sequence of mitochondrial *COI* with a length of 621 bp. The obtained sequence was deposited in GenBank (accession number: OP498326). Pairwise genetic distances (*p*-distance) were calculated based on 402 bp sequences of *COI*. The dataset consisted of 10 species of *Aquilonastra*, including *A. doranae* (Table 1). The *p*-distances within species of genus *Aquilonastra* in this study showed a distinct gap between each species except for *A. anomala* - *A. doranae*. The mean interspecific *p*-distance in *Aquilonastra* was 21.3%, ranging from 0.0% (*A. doranae*: Korea - *A. anomala*: Hawaii) to 23.5% (*A. coronata* - *Aquilonastra* sp. 1) (Table 1). The *p*-distances within *A. doranae* and *A. anomala* exhibited a quite close relationship with each other. The *p*-distances of Korean *A. doranae* and *A. anomala* from Australia and Samoa were 3.1% and 3.3%, respectively. Sequences of Korean *A. doranae* and Hawaiian *A. anomala* were the same (Table 1).

Remarks. This species was reported from Okinawa, Japan with only one specimen in the original description (O'Loughlin and Rowe, 2006). This species was recorded as a new species based on geographical isolation and morphological distinctions from other *Aquilonastra*: short arms (R = 5 mm, r = 3.5 mm), shape of spine on the abactinal side (thin digitiform or conical shape), and the number of actinal interradial spines (up to 5) (O'Loughlin and Rowe, 2006). In this study, only one specimen of *Aquilonastra* was collected from southern Jejudo Island. It was distinctly different from other *Aquilonastra* in Korea, showing a fissiparous body form. In morphology, this specimen was the same as the original description of *A. doranae* in O'Loughlin and Rowe (2006). It also fitted into a morphological key to the species of *Aquilonastra* from O'Loughlin and Bribiesca-Contreras (2015).

In DNA barcoding analysis, *p*-distance within *A. doranae* and *A. anomala* showed that these two species were the same or quite close to each other (0.0−3.3%). The typical interspecific *p*-distance of *Aquilonastra* exceeds 10.0%, with a mean of 26.2% (Waters et al., 2004). However, *A. batheri* and *A. burtoni* showed a closed *p*-distance value of 3.1% (Waters et al., 2004). Hawaiian *A. anomala* was found to be the same as Korean *A. doranae*, but not identical to *A. anomala* from Australia or Samoa. Therefore, Hawaiian *A. anomala* should be con-

Table 1. Pairwise genetic distances (%) within 10 species of *Aquilonastra* from South Korea and GenBank based on the Kimura 2-parameter model

	Species	Locality	1	2	3	4	5	6	7	8	9	10	11	12	GenBank accession No.	References
1	*Aquilonastra doranae*	South Korea													OP498326	This study
2	*Aquilonastra anomala*	Hawaii	0.0												MW277928	Unpublished
3	*Aquilonastra anomala*	Samoa	3.3	3.3											AY370753	Waters et al. (2004)
4	*Aquilonastra anomala*	Australia	3.1	3.1	0.2										AY370754	Waters et al. (2004)
5	*Aquilonastra batheri*	South Korea	17.7	17.7	19.1	18.8									MG970141	Lee and Shin (2018)
6	*Aquilonastra coronata*	Japan	14.0	14.0	14.3	14.0	16.5								AY370747	Waters et al. (2004)
7	*Aquilonastra minor*	Japan	12.6	12.6	13.3	12.9	15.9	13.1							AY370746	Waters et al. (2004)
8	*Aquilonastra scobinata*	Australia	16.4	16.4	17.3	17.0	15.2	16.0	16.7						AY370755	Waters et al. (2004)
9	*Aquilonastra watersi*	Iran	17.1	17.1	18.1	17.8	5.7	14.5	17.4	15.8					MT375420	Adeli et al. (2020)
10	*Aquilonastra yairi*	Israel	18.3	18.3	19.4	19.0	7.4	14.8	17.0	15.8	4.4				AY370752	Waters et al. (2004)
11	*Aquilonastra* sp. 1	Indian Ocean	17.0	17.0	17.9	17.6	20.2	23.5	20.5	17.3	11.6	10.7			GU480547	Hoareau and Boissin (2010)
12	*Aquilonastra* sp. 2	Indian Ocean	16.4	16.4	17.3	17.0	11.6	14.5	15.5	17.6	19.8	19.2	20.8		GU480548	Hoareau and Boissin (2010)

firmed in a further study through morphological comparison with *A. doranae* and *A. anomala* from Australia and Samoa.

In this study, results of morphology and molecular identification were not corresponding to each other. O'Loughlin and Rowe (2006) have indicated that species of *Aquilonastra* have local geographical ranges. Thus, when *A. doranae* erected a new species, O'Loughlin and Rowe (2006) pointed out that this species was geographically isolated from other similar *Aquilonastra* species. *Aquilonastra anomala* is distributed in central West Pacific including northern and northeastern Australia, Papua New Guinea, Palau, Caroline Islands, and Marshall Islands (Marsh, 1974; Clark, 1993; Rowe and Gates, 1995; O'Loughlin and Rowe, 2006), whereas *A. doranae* is distributed in northwestern Pacific, including southern Korea (this study) and Japan (O'Loughlin and Rowe, 2006). Moreover, *A. doranae* has some major morphological differences from *A. anomala* (O'Loughlin and Rowe, 2006): (1) a number of spines in abactinal, superomarginal, inferomarginal plate, and actinal interradii (*A. anomala*: up to 20, 8, 16, and 8, respectively; *A. doranae*: up to 10, 6, 12, and 5, respectively); (2) shape of abactinal spines (*A. anomala*: splay-pointed at tip; *A. doranae*: solid pointed at tip). Accordingly, Hawaiian *A. anomala* from NCBI should be reconfirmed through species identification.

In conclusion, characteristics of Korean *A. doranae* are consistent with morphological analyses of former studies of *A. doranae* (O'Loughlin and Rowe, 2006; O'Loughlin and Bribiesca-Contreras, 2015). This study presents that this specimen is the first record of *A. doranae* in South Korea.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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