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A southernmost record of the Pacific black scabbardfish *Aphanopus arigato* (Scombriformes, Trichiuridae) from the South China Sea

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Abstract

In this study, a single specimen of Pacific black scabbardfish *Aphanopus arigato* Parin, 1994 was collected at a depth of ~500 m near Dongsha Island in southwestern Taiwan (18°49' to 20°45'N and 112°46' to 116°15'E), on 14 March 2023. This is the southernmost record of *A. arigato*, with a significantly wide range extension from northern Japan, and southern Kuril Islands to the South China Sea. We also provide comparisons of the morphological measurements, first description of sagittae otoliths, and a partial sequence of the cytochrome oxidase subunit I gene for the specimen studied in this study.

Introduction

Fish in the family Trichiuridae are among the most important fisheries' target species worldwide, with a total landing of ~3.5 million tonnes in 2021 (FAO, 2021; He *et al.*, 2022). Trichiuridae species are predominantly found in tropical and temperate areas, including ~46 species and 10 genera (WoRMS Editorial Board, 2024), of which nine species have been recorded around Taiwan (Shen and Wu, 2011).

The deep-sea genus *Aphanopus* Lowe 1839, commonly known as scabbardfish, has been a significant target in commercial fisheries in the northeast Atlantic Ocean since the 17th century, with total landings of 5205 tonnes reported in 2021 (FAO, 2021). Additionally, the fisheries of scabbardfish are considered to be the first recorded commercial deep-sea longline fishing industry (Eduardo *et al.*, 2018). There are seven species in the genus *Aphanopus* (Parin, 1983, 1994; Biscoito *et al.*, 2011). The only *Aphanopus* species found in North Pacific Ocean is the Pacific black scabbardfish, *Aphanopus arigato* Parin, 1994, which was originally described from a specimen collected in the Western North Pacific Ocean (Parin, 1994). The distribution was then found to expand to the northwestern Pacific off southeastern Kamchatka, Russia to North America, south of Hawaiian Islands (Orlov, 1999). All *Aphanopus* species are benthopelagic, and relatively challenging to identify morphologically (Biscoito *et al.*, 2011; Delgado *et al.*, 2013). Alternatively, cytochrome oxidase subunit I gene (*cox1*) sequencing and sagittal otolith morphology are useful tools for species identification within this genus (Stefanni and Knutsen, 2007; Tuset *et al.*, 2010).

The aim of this study was to report the first and the southernmost presence of *A. arigato* in the South China Sea, northwest Pacific Ocean.

Materials and methods

A single specimen was caught via bottom trawl net at ~500 m depth around Dongsha Island, South China Sea, on 14 March 2023 (18°49' to 20°45'N and 112°46' to 116°15'E) (Ng *et al.*, 2024; Mediodia *et al.*, 2024). The measurement and counting methods followed the protocol described in Biscoito *et al.* (2011). Description of otolith followed Lin and Chang (2012) and Tuset *et al.* (2010). The specimen was subsequently preserved at the Biodiversity Research Museum of the Academia Sinica of Taiwan under the registration code ASIZP-0082289. Comparison with the original description and additional references followed Parin (1994) and Orlov (1999).

Genomic DNA was extracted from the muscle tissue of ASIZP-0082289 by a FavorPrep Tissue Genomic DNA Extraction Mini Kit (Favorgen, Pingtung, Taiwan). After DNA extraction, polymerase chain reaction (PCR) amplification of the partial *cox1* gene (~650 bp) using the forward primer, FishF1 + F2 (5'-TCR ACY AAY CAY AAA GAY ATY GGC AC-3') and reverse primers, FishR1 (5'-TAG ACT TCT GGG TGG CCA AAG AAT CA-3') and FishR2 (5'-ACT TCA GGG TGA CCG AAG AAT CAG AA-3') (Chang *et al.*, 2016). The final PCR products were then used for sequencing with the primer FishF1 + F2 (by Genomic Biotech Inc., New Taipei City, Taiwan), and followed the method of Chang *et al.* (2016). The *cox1* sequencing results were submitted to the National Center for Biotechnology Information (NCBI) for nucleoid BLAST analysis (<https://blast.ncbi.nlm.nih.gov/Blast.cgi>) to confirm species identification.

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Figure 1. Whole specimen of *Aphanopus arigato* (ASIZP-0082289) caught around Dongsha Atolls, South China Sea. Scale bar = 20 mm.

Results

Family TRICHIURIDAE
Aphanopus arigato Parin, 1994
 (Figures 1–4)

Specimen: one specimen. ASIZP-0082289, 438 mm SL, from Dongsha Atolls, South China Sea, ca. 500 m depth, 14 March 2023, collected by Chien-Hsiang Lin.

Description of ASIZP-0082289: The morphometric and meristic data are presented in Table 1.

Body extremely elongated, the highest body depth situated at the first anal-fin spine, corresponding to 6.8% standard length (SL); body depth narrows posteriorly, reaching 0.4% SL at the end of the caudal peduncle. Anus positioned about mid-point

of body, with pre-anus length 52.7% SL. First anal fin spine rudimental; second anal fin spine sharp, sword-shaped, positioned posteriorly to the anus; pre-anal length 60.2% SL (Figure 3). Caudal fin very small, with slender caudal peduncle. Entire body without scales; with very thin skin; lateral line very distinct and straight.

Head large, head length (HL) 18.4% SL; eye large and slightly oval, eye diameter is 17.6% of HL, situated laterally; interorbital width 13.3% HL. Snout long and large; snout length 7.8% SL; posterior end of upper jaw reaches the middle of the eye; lower jaw projected anteriorly to upper jaw (Figure 2). Teeth sharp and strong, triangular shaped, in a uniserial arrangement on upper and lower jaws (Figure 2). Mouth large, gently curved; maxillary length 50% of HL.



Figure 2. Details of the head profile, snout, and teeth of *A. arigato* (ASIZP-0082289). The red arrow indicates the posterior end of the upper jaw.



Figure 3. Details of the anal spine of *A. arigato* (ASIZP-0082289). The yellow arrow indicates the position of the anus; the red arrow indicates the rudimental first anal spine.



Figure 4. Right sagittal otolith of *A. arigato* (ASIZP-0082289). Top: ventral view; bottom: proximal view. Scale bar = 1 mm.

Dorsal-fin origin right behind the operculum; pectoral fin short; pelvic fin absent. First dorsal-fin base slightly shorter than second dorsal-fin base; with first dorsal-fin base 37.7% SL and second dorsal fin base 45.8% SL; prepectoral length 20.8% SL.

Coloration: Body black to whitish (maybe caused by scrubbing in the bottom trawl net), separated from the blackish peritoneum. Dense black inside the mouth and gill cavities. All fins translucent.

Otolith morphology: Sagittae otoliths are fusiform (right sagittae in Figure 4). Otolith thin, spindle-shaped, with pointed anterior rim and blunt, truncated posterior rim. Dorsal rim flat to gently curved, slightly elevated anteriorly. Ventral rim gently curved. Sulcus narrow, spindle-shaped, not well-divided into ostium and cauda. Ostium triangular, opens anteriorly, deeper and wider just anteriorly to the collum. Cauda very shallow and narrow. Cristae thick, ridge-like, but become indeterminate at posterior end.

Distribution: Adults (SL > 385 mm) mainly recorded in temperate North Pacific Ocean from northern Japan to southeastern Kamchatka, Russia (Parin, 1994; Orlov, 1999); and northern California (Lauth, 1997). Juveniles were found in subtropic and tropic central northern Pacific Ocean, most often off Hawaii (Evseyenko *et al.*, 1994; Orlov, 1999). Specimen caught in Dongsha Island, South China Sea, northwest Pacific Ocean (present study) represents a significant range expansion to the southwest Pacific Ocean, and also the southernmost record of the *Aphanopus arigato*. Mainly inhabiting depths between 400 and 800 m (Parin, 1994; Orlov, 1999).

Table 1. Morphometrics and meristics data for *Aphanopus arigato* caught around Dongsha Island, South China Sea, compared with original description and previous research by Parin (1994) and Orlov (1999)

	This study; ASIZP-0082289	Orlov (1999); IMBV-uc	Holotype; HUMZ-78109	Paratype, <i>n</i> = 2; additional material, <i>n</i> = 3 ZIL 50587-88; OSUO 2352-54
Standard length (SL, mm)	438	710	651	385–540 (5)
Measurements in % of SL				
Head length	18.4	19.1	18.5	18.2–20.0 (5)
Pre-anus length	52.7	54.9	53.7	52.3–54.4 (5)
Pre-anal length	60.2	–	–	–
Pre-first anal-spine length	56.2	–	–	–
Prepectoral length	20.8	–	–	–
Pre-dorsal length	17.5	–	–	–
Pre-first dorsal soft ray length	55.2	–	–	–
Body depth	6.8	8.9	8.7	5.6–8.4 (5)
Least depth of caudal peduncle	0.4	–	–	–
Caudal-peduncle length	2.5	–	–	–
Head length (HL, mm)	80.6	136	120	72.8–107 (5)
Measurements in % of HL				
Preopercular length	81.1	–	–	–
Snout length	42.3	43.3	–	–
Eye diameter	17.6	16.8	17.4	15.5–18.1 (5)
Interorbital width	13.3	16.3	12.5	9.0–13.0 (5)
Maxillary length	46.0	43.7	46.7	43.3–45.5
Head height	35.1	–	–	–
Dorsal-fin spines	41	39	42	39–43
Dorsal-fin soft rays	58	58	57	54–58
Total dorsal-fin elements	99	97	99	95–99
Anal-fin rays	49	50	50	47–50

Measurement data from the holotype and five paratypes from Parin (1994).

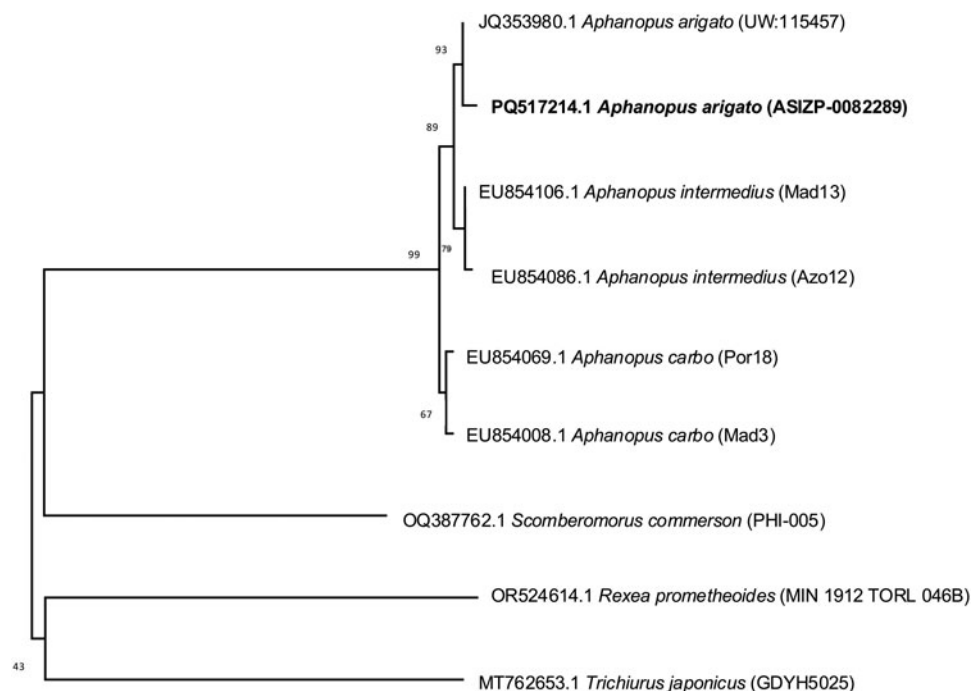


Figure 5. Neighbour-joining tree based on *cox1* sequences of the specimens in the present study (ASIZP-0082289; NCBI accession: PQ517214.1) and congeners from NCBI.

Remarks: The morphological characteristics of ASIZP-0082289 mostly fall within the range described by Parin (1994) and previous research by Orlov (1999). As ASIZP-0082289 is relatively small (438 mm SL), it shows a slightly lower body depth compared to larger individuals in previous studies: 6.8% SL vs 8.7% in the holotype HUMZ-78109 (651 mm SL) and 8.9% in IMBV-uc (710 mm SL) (Table 1) (Parin, 1994; Orlov, 1999). However, the body depth of ASIZP-0082289 is consistent with paratypes of similar size, which have body depths of 6.6% SL in ZIL-50587 (504 mm SL) and 5.6% SL in ZIL-50588 (385 mm SL) (Parin, 1994).

The specimen is clearly identified as *A. arigato* with the morphometric characters mentioned above. The total dorsal-fin elements (Table 1) and the sword-shaped, long second dorsal spine (Figure 3) also showed distinct differences with the congeners.

The body coloration of ASIZP-0082289 is whitish, which is slightly different compared to previous descriptions (Parin, 1994; Parin and Nakamura, 2016). However, the dense black coloration in the peritoneum and head is still observable. The white coloration could be due to the thin skin of *A. arigato* being rubbed off when caught by the bottom trawl net. Additionally, colour fading during the defrosting process with running water is also one major possibility (Jiang and Lee, 2004).

Molecular: The partial *cox1* sequence of ASIZP-0082289 has been submitted to NCBI under accession number PQ517214.1. The best BLAST match identified ASIZP-0082289 as *A. arigato* with a per cent identity exceeding 99% (NCBI accession: JQ353980.1). Furthermore, the neighbour-joining tree results also showed a high bootstrap value (93%) in the same monophyletic group of *A. arigato* (Figure 5). Both morphological and molecular findings consistently point to the identification of the specimen ASIZP-0082289 as *A. arigato*.

Discussion and conclusion

The initial taxonomic review of the genus *Aphanopus* in 1994 by Parin restricted the distribution of *Aphanopus intermedius*

exclusively to the tropical and temperate Atlantic Ocean, and reclassified *A. intermedius* recorded in the North Pacific Ocean as *Aphanopus arigato* (Parin, 1994). As a single specimen was recorded from southeastern Kamchatka, Russia, there have been no updates on the distribution of *A. arigato* (Orlov, 1999). Apart from adults, larvae and juveniles of *A. arigato* have been discovered in the mesopelagic zone (200–500 m depth) in the northeastern region of the Hawaiian Islands (Parin, 1994; Orlov, 1999).

The spawning area of the Pacific black scabbardfish has been reported in the temperate waters of the North Pacific Ocean (northern Japan, southern Russia coastal areas, and northern California), with eggs and larvae being transported by deep-sea currents to subtropical and tropical (present study) waters for further growth (Orlov, 1999; Kawabe *et al.*, 2003). In this study, a single specimen of *A. arigato* was collected using a bottom trawl net at ~500 m depth, which is consistent with the depth range previously described for juveniles and small individuals of this species (Parin, 1994). Furthermore, the specimen recorded in this study has a total length within the adult size range (TL > 385 mm) of *A. arigato* (Parin, 1994; Orlov, 1999). This is the first recorded occurrence of *A. arigato* in the South China Sea, suggesting the possibility of a wider distribution area for the Pacific black scabbardfish. The specimen may also alternatively be a wanderer that drifted during its planktonic life and settled and survived in this region, of which there are some similar cases of fish species in the Mediterranean's Lessepsian migration (Corsini *et al.*, 2005). Therefore, we recommend further research to comprehensively assess the distribution of *A. arigato* in the Pacific Ocean.

In conclusion, this study reports the southernmost distribution of the Pacific black scabbardfish, *A. arigato*, and provides a partial sequence of the *cox1* gene and the otolith morphology description.

Data availability. All data supporting the findings of this study are included in the main text. The *Aphanopus arigato* specimen described in this study is

housed at the Biodiversity Research Museum, Academia Sinica, Taiwan, under the registration code ASIZP-0082289 and the partial *cox1* sequence is available on NCBI under accession number PQ517214.1.

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Author contributions. Yen-Ting Lin mainly conducted the experiments, analysed the results, and wrote the manuscript. Chien-Hsiang Lin obtained and described the otolith. Chien-Hsiang Lin and Yu-San Han designed and supervised the experiments. All authors participated in manuscript writing and interpretation of results. All authors read and approved the final manuscript.

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Competing interests. None.

Ethical standards. The material utilized in this study was acquired by us from local fisherman (Chengbin Fishing Port, Keelung). It is important to note that the specimen was deceased at the time of acquisition, hence no living animals were involved in current research.

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