

The first record of *Porcellanaster ceruleus* (Echinodermata: Porcellanasteridae) in the South China Sea

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Abstract

Porcellanasteridae is a group of starfish that live in the deep ocean around the world. The type species of this family, *Porcellanaster ceruleus* Wyville Thomson, 1878, is cosmopolitan as well as polymorphic. The first record of its occurrence in the South China Sea is reported in this paper. One specimen was caught in the South China Sea on June 6, 2015 by trawl and identified to be a *P. ceruleus*. The morphological characteristics of this specimen are described and detailed pictures are provided. The discovery of this specimen further expands the distribution of *P. ceruleus* in the Pacific Ocean. The world distribution records of *P. ceruleus* and its synonymic species are reviewed in this paper.

Key words: Porcellanasteridae, *Porcellanaster ceruleus*, new record, South China Sea

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1 Introduction

Porcellanasteridae is a group of starfish that live in the deep ocean (Madsen, 1961). The family is composed of 32 species distributed in 11 genera, all characterized by porcellaneous marginal plates (Thomson, 1878) and unique cribriform organ of varied numbers (Sladen, 1883). As the type species of the family, *Porcellanaster ceruleus* was first described in 1878 by Wyville Thomson and recorded 293 times on the mud bottom around the world ocean since then, thus being the most frequently found member in the family. It is mostly recorded in the North Atlantic Ocean. Scattered records also occur in the Pacific, the Indian Ocean and the Antarctic.

2 Materials and methods

During the benthos survey cruise of R/V *Xiangyanghong 10* in the South China Sea, one single specimen of *Porcellanaster ceruleus* was caught by trawl at Sta. C₁₉ (Fig. 1) at 1 400 m depth on June 6, 2015. The specimen was photographed by SLR camera (Canon EOS 7D) immediately after capture and then was fixed with 5% formalin in seawater. It was preserved in 100% alcohol in the laboratory. Detailed photos were taken by stereoscopic microscope (Zeiss Axio Zoom.V16). The specimen (RSIOAS016) is deposited in the sample repository of Second Institute of Oceanography (RSIO), State Oceanic Administration, Hangzhou, Zhejiang Province, China. Identification of the specimen is based on the comprehensive monographic revision of Porcellanasteridae by Madsen (1961) and other taxonomic works (Sladen, 1883; Belyaev, 1969).

3 Taxonomic account

Order Paxillosida Perrier, 1884

Family Porcellanasteridae Sladen, 1883

Diagnosis to Family Porcellanasteridae: Paxillosids with five arms; marginal plates porcellaneous, very conspicuous and delicate; cribriform organ of varied numbers present in each interradius.

Genus *Porcellanaster* Wyville Thomson, 1878

Diagnosis to Genus *Porcellanaster*: Arms broad, round; opposing superomarginals separated on the whole arm-midline; a single lamelliform cribriform organ in each interradius; two mouth plates forming a conspicuous jaw, bearing a single proximal mouth spine; adambulacral plates bearing 1–3 furrow spines on the adoral side; no subambulacral spine or suboral spine.

Porcellanaster ceruleus Wyville Thomson, 1878 (Fig. 2)

Porcellanaster ceruleus: Thomson, 1878: 351–353, Figs 97–98; Sladen, 1883: 218–222; Verrill, 1885: 520, 543, Figs 40–41; Sladen, 1889: 134–138, Pl. 20 (1–7); Wood-Mason and Alcock, 1891b: 433–434; Alcock, 1893: 86; Verrill, 1895: 133; Clark, 1923: 239; Lieberkind, 1935: 5–19, Pl. 2 (1, 7, 8); Madsen, 1951: 74–76, Fig. 1; Madsen, 1961: 126–130, 136–138, Fig. 22; McKnight, 1973: 220, Fig. 1; Sibuet, 1975: 99–100; Gage et al., 1983: 275–276; Clark and Downey, 1992: 100–101, Figs 18 a, c, Pl. 27A–C; Belyaev and Mironov, 1996: 887–892, Figs 1–2; Sumida et al., 2001: 19–21, Fig. 6; Howell et al., 2002: 1 906; Dilman, 2006: 179–180; Dilman, 2008: 137; Dilman, 2013: 568; Dilman, 2014: 29; Alt et al., 2013: 331; Glover et al., 2016: 19–21, Fig. 11;

Synonyms: *Porcellanaster caulifer*: Sladen, 1883: 222–223; Sladen, 1889: 138–140, Pls 21(5–10), 27 (9–12); Koehler, 1909a: 33–34, Pls 11(5), 13(1); *Porcellanaster tuberosus*: Sladen, 1883: 223–225; Sladen, 1889: 140–141, Pls 23 (1–4), 27 (13–16); *Porcella-*

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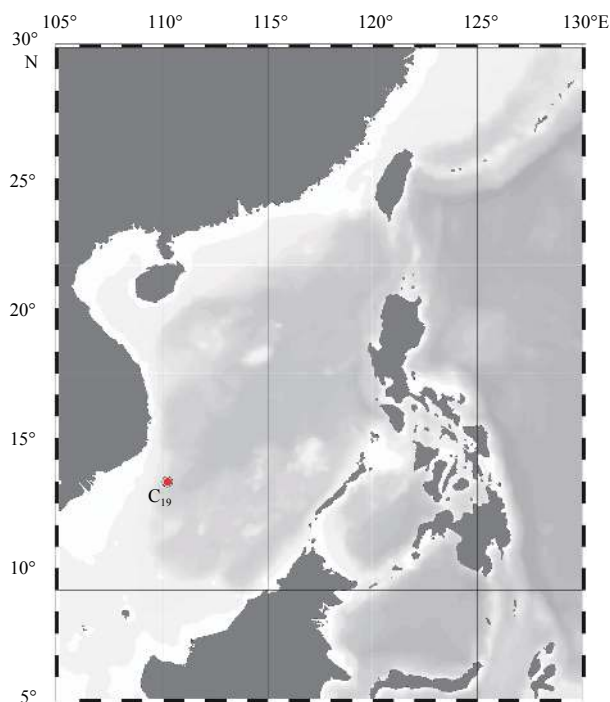


Fig. 1. Location of the sampling site (C₁₉) during the benthos survey cruise of R/V *Xiangyanghong 10* in the South China Sea.

naster inermis: Perrier, 1885: 50–53; Perrier, 1894: 212–215, Pl. 15 (2, 2a, 2c); *Porcellanaster granulosus*: Perrier, 1885: 53–55; Perri-

er, 1894: 216–218, Pl. 17 (1a–c); *Porcellanaster eremicus*: Sladen, 1889: 145–149; Belyaev and Mironov, 1996: 896–898, Fig. 5; *Porcellanaster fragilis*: Döderlein, 1921: 15–16, Pl. 3 (1–1g); *Porcellanaster irregularis*: Lieberkind, 1932: 272–276, Figs 1–4, Pls 1 (1–2), 3 (1–3), 7 (5–6); *Albatrossia semimarginalis*: Ludwig, 1905: 97–100, Pl. 6 (30–31); *Albatrossaster nudus*: Ludwig, 1907: 318–319; Clark, 1920: 81, Pl. 2 (5–6); *Albatrossaster richardi*: Koehler, 1909b: 25–28, Pl. 19 (7–9); *Caulaster sladeni*: Perrier, 1885: 47–50; Perrier, 1894: 208–210, Pl. 15(2b); *Caulaster pedunculatus*: Perrier, 1882: 1379–1381; Perrier, 1885: 45–47; Perrier, 1894: 204–208, Pl. 15 (1); Belyaev and Mironov, 1996: 892–896, Fig. 3; Dilman, 2006: 179; Dilman, 2008: 135–136; Dilman, 2013: 567; Dilman, 2014: 28; *Caulaster dubius*: Koehler, 1909a: 34–36, Pls 1 (5), 5 (8), 11 (4); Dilman, 2008.

Material examined. RSIOAS016. South China Sea, Sta. C₁₉, 10.15°N, 110.03°E, at 1 400 m depth, collected via a trawl net on June 6, 2015

Description. Rays five. $R=11$ mm; $r=6$ mm; $R/r\approx 1.83$.

Disk tumid with full stomach. Arms short, tapering to the end. Aboral surface of the disk covered with minute plates, each bearing a short blunt spinelet. A triangle area of naked plates at arm base. A large apical appendage (≈ 4.5 mm) present at the disk center (Figs 2a and 3e). One conspicuous semicircular madreporite in close proximity with a cribriform organ (Fig. 2a).

Superomarginal plates rectangular, 4–5 in number, the proximal ones are armed with a short conical spinelet (Fig. 2a). Superomarginals of either side of arm separate through the whole arm length. Superomarginals and inferomarginals corresponding in number and length (Fig. 3b). Inferomarginal plates bearing no spine.

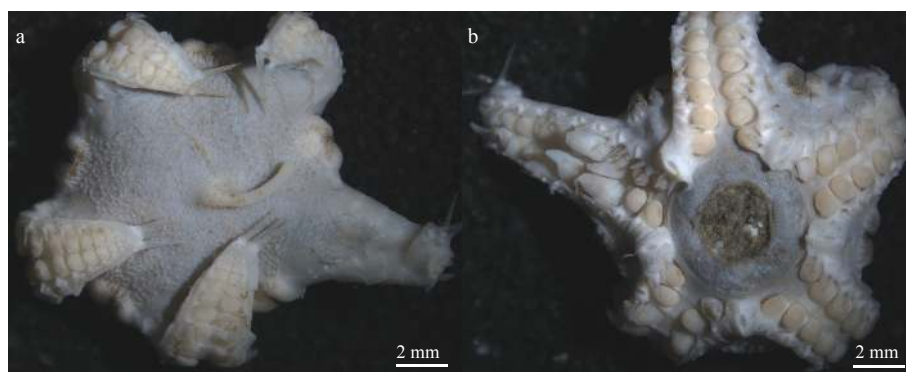


Fig. 2. *Porcellanaster ceruleus* Wyville Thomson, 1878. a. Aboral surface and b. oral surface.

One broad lamelliform cribriform organ in each arm interradius, almost covers the whole interradius (Figs 3a, b). The cribriform organ is separated to two parts by a deep groove in the middle; each half consists of 7–8 parallel rows of thin lamellar papillae. The cribriform organ each bears 6 flattened spinelets on the oral side.

Terminal plates rather tubercular, with three long transparent terminal spines (≈ 1.5 mm) (Fig. 3b).

Ventrolateral area triangular, covered by 3–4 tangential rows of naked plates (Fig. 3c).

Adambulacral plates conspicuous, each bearing two transparent, conical furrow spines on the adoral side. No subambulacral armature (Figs 2b, 3c–f). The furrow is broad and tube feet relatively large. Tube feet appear in pairs, covered with spirals, conical (Fig. 3c). Two mouth plates form a conspicuous jaw, with one common mouth spine pointing to the mouth. Each mouth plate bears

two marginal spines, parallel with furrow spines (Figs 2b and 3d).

Coloration. Color in life greyish white.

Ecology. Marine, benthic, mud bottom.

Distribution. Atlantic Ocean: from Iceland southward to South Africa; Pacific Ocean: eastern tropical Pacific, New Zealand and Australian sea, Malay Archipelago, Japan and South China Sea; Indian Ocean: northern Indian Ocean, Sri Lanka; Antarctic Ocean. Depth: 1 158–6 040 m.

Remarks. One lamelliform cribriform organ in each interradius, one shared mouth spine and opposite superomarginals separated in arm midline confirm the belonging of this specimen to *Porcellanaster*. The genus *Porcellanaster* consists of two species, *P. ceruleus* and *P. ivanovi* Belyaev, 1969. *Porcellanaster ivanovi* is distinguished from *P. ceruleus* for (1) lack of an apical appendage; (2) adambulacral and mouth plates each bears one spine instead of two or three in *P. ceruleus*; (3) much smaller inferomar-

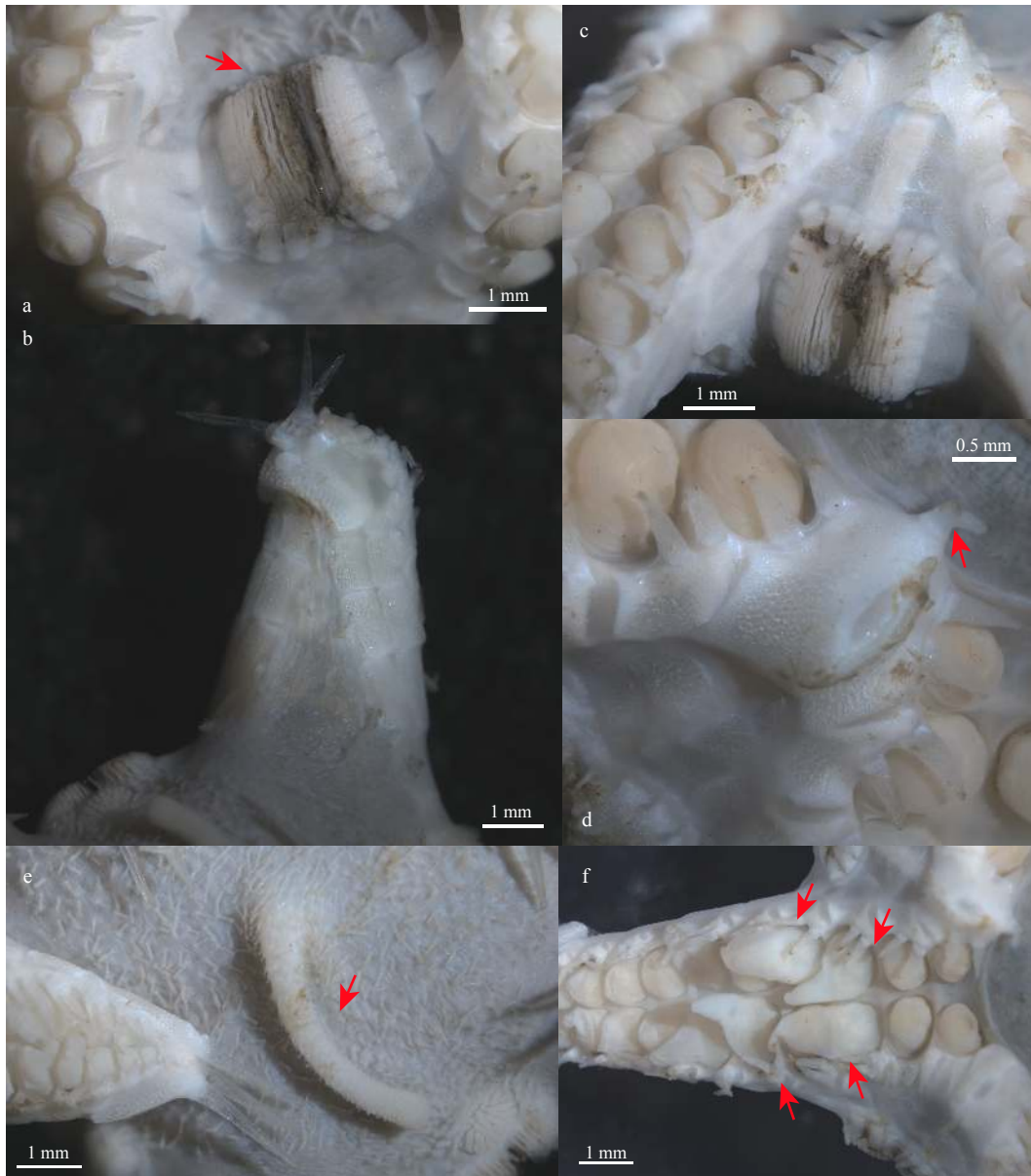


Fig. 3. *Porcellanaster ceruleus* Wyville Thomson, 1878. a. Cribriform organ (pointed by the red arrow); b. aboral side of arm; c. ventrolateral area; d. mouth plates with a common mouth spine (pointed by the red arrow); e. apical appendage (pointed by the red arrow); and f. oral side of arm, red arrows pointing the tumid tube feet (suspected to be an individual characteristic).

ginal plates, which do not correspond to the supermarginal plates in number and location; and (4) larger number of supermarginal plates comparing with *P. ceruleus* of equal size (Belyaev, 1969).

This specimen agrees largely with the type specimen of *Porcellanaster ceruleus* (Thomson, 1878), with variations only in size (R/r 11/6 to 22/10.5) and the number of marginal plates (4–5 to 6–8). On one arm of the specimen, the third pair of tube feet, along with one in the fourth pair and one in the fifth pair of tube feet, are conspicuously tumid comparing to the others (Fig. 3f). This characteristic is not found in the other four arms, nor described in previous literatures (Sladen, 1889; Madsen, 1961). It is taken to be an individual characteristic, till further evidences are found in other specimens in the future.

4 Discussion

Porcellanaster ceruleus is cosmopolitan as well as polymorph-

ic, with infraspecific variations from location to location and juveniles to adults. Fifteen previously established species are now accepted as *P. ceruleus* according to the World Asteroidea database (Mah, 2018). Previously established genera *Caulaster* Perrier 1882 and *Albatrossia* Ludwig 1905 are also regarded as juvenile stages of *Porcellanaster* in later taxonomic revisions (Ludwig, 1907; Madsen, 1961). *Porcellanaster ceruleus*, as well as all these synonymic species, is found in the world ocean during numerous cruises and research (Table 1). It is reported to be of high abundance in deep-sea, with the largest population found at Rockall Trough (Sta. ES 6: 55°03'N, 12°29'W, ca. 2 900 m) including 835 individuals (Gage et al., 1983).

The closest record to the Chinese specimen in this paper was reported by Sladen in 1883 under the name *P. caulifer* n. sp., which was found during the H. M. S. “Challenger” expedition at Sta. 191 (5°41'S, 134°04'E, 1 463 m) in the Malay Archipelago. In the same report, Sladen claimed another new species, *P.*

Table 1. World distribution of *P. ceruleus* and its synonymic species

Geographical distribution		Species name and author	Depth/m	Maximum abundance	Reference
Atlantic	North Atlantic	<i>Porcellanaster ceruleus</i> Wyville Thomson, 1878	1 160–6 040	835	Thomson (1878), Sladen (1883, 1889), Verrill (1885, 1895), Lieberkind (1935), Gage et al. (1983), Clark (1989), Clark and Downey (1992), Belyaev and Mironov (1996), Sumida et al. (2001), Howell et al. (2002), Dilman (2006, 2008, 2013, 2014), Alt et al. (2013), NMNH: Antarctic Invertebrates
		* <i>Caulaster pedunculatus</i> Perrier, 1882	1 505–3 076	204	Perrier (1882, 1885), Belyaev and Mironov (1996), Dilman (2006, 2008, 2013, 2014)
		* <i>P. inermis</i> Perrier, 1885	2 995–3 200	3	Perrier (1885)
		* <i>C. dubius</i> Koehler, 1909	2 350	1	Dilman (2008)
		* <i>P. granulatus</i> Perrier, 1885	2 324	1	Perrier (1885)
	Mid Atlantic	* <i>P. granulatus</i> Perrier, 1885	2 320–3 200	3	Perrier (1885)
		<i>P. ceruleus</i>	1 520–5 610	10	Madsen (1951, 1961), Belyaev and Mironov (1996)
		* <i>Albatrossaster richardi</i> Koehler, 1909	6 035	1	Koehler (1909b)
		* <i>P. irregularis</i> Lieberkind, 1932	2 492	3	Lieberkind (1932)
	South Atlantic	* <i>C. sladeni</i> Perrier, 1885	1 435–1 900	2	Perrier (1885, 1894)
		<i>P. ceruleus</i>	1 460–4 335	80	Clark (1923), Madsen (1961), Sibuet (1975), Belyaev and Mironov (1996), NMNH: Antarctic Invertebrates
		* <i>P. eremicus</i> Sladen, 1889	4 664–5 120	67	Sladen (1889), Belyaev and Mironov (1996)
Pacific	Southeast Pacific	* <i>P. eremicus</i>	4 540	3	Belyaev and Mironov (1996)
	New Zealand and Australia	<i>P. ceruleus</i>	1 222–4 868	5	Madsen (1961), McKnight (1973), NMNH: Antarctic Invertebrates
	Eastern tropical Pacific	<i>P. ceruleus</i>	4 054–4 500	2	Glover et al. (2016)
		* <i>A. semimarginalis</i> Ludwig, 1905	1 408–2 149	2	Ludwig (1905)
		* <i>A. nudus</i> , Ludwig, 1907	3 667	1	Ludwig (1907), Clark (1920)
	Japan	* <i>P. tuberosus</i> Sladen, 1883	3 429	1	Sladen (1883, 1889)
	Malay Archipelago	* <i>P. caulifer</i> Sladen, 1883	1 463–3 044	1	Sladen (1883, 1889), Koehler (1909a)
		* <i>P. fragilis</i> Döderlein, 1921	1 158–1 914	3	Döderlein (1921)
	China	<i>P. ceruleus</i>	1 400	1	this study
<i>P. ceruleus</i>		1 249–4 040	numerous	Wood-Mason and Alcock (1891a, b), Alcock (1893) Koehler (1909a, b), Madsen (1961)	
* <i>C. dubius</i>		3 197	1	Koehler (1909a)	
Indian Ocean					
Antarctic		<i>P. ceruleus</i>	3 737–5 060	3	NMNH: Antarctic Invertebrates

Note: * Synonymic species to *P. ceruleus*.

tuberosus n. sp. according to a single specimen from Japanese waters (Sta. 237: 34°37'N, 140°32'E, 3 429 m). Both species are later accepted as synonyms to *P. ceruleus* by Madsen in 1961. These early findings of West Pacific specimens share similar morphological characteristics with the Chinese specimen to a large degree, but both the Malay and Japanese records have higher *R/r* ratio (21/6.5 and 18.5/6 respectively), whereas in the Chinese specimen this ratio is only 11/6. In addition, the Malay specimen has more superomarginal and inferomarginal plates (7 in number) comparing with the Japanese and Chinese specimens (4–5 in number). Due to the polymorphic nature of *P. ceruleus*, these variations are likely to be of no taxonomic value but owing to individual difference.

In addition, the family Porcellanasteridae is rarely recorded in China seas in previous studies, and the few existed records are doubtful. Wyville Thomson (1878) notes that "there is an allied species of the same genus somewhat more ornate, and of an orange instead of a blue color, in the China Sea". Madsen (1961) suggests that this statement may indicate a *Hyphalaster intermis* Sladen, 1883, which is another porcellanasterid species. Li (1986) records two porcellanasterids: Porcellanasteridae Gen. sp. and

Porcellanaster sp. in China seas. In the monograph *Marine Species and their Distribution in China* (Huang, 2008), three porcellanasterid species are recorded in the South China Sea: *Abyssaster planus* Sladen, 1883, *Eremicaster crassus* Sladen, 1883 and *Thoracaster cylindratus* Sladen, 1883. However, none of these records are provided with detailed illustrations or descriptions. Meanwhile, Porcellanasteridae is not recorded in China seas in several journals and monographs (Liao and Clark, 1995; Liu, 2008; Liao and Xiao, 2011). Overall, the distribution of Porcellanasteridae in China seas seems to be underestimated. This paper reveals the existence of *P. ceruleus* in China seas and provides detailed pictures and descriptions of the specimen. The record of this specimen further expands the distribution of *P. ceruleus* in the Pacific Ocean, but its disperse pathway and relationship with the closest records in Malay Archipelago and Japan are yet to be found.

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