

NEW RECORDS OF THE MOLLUSCAN CLASSES CAUDOFOVEATA AND SOLENOGASTRES IN SINGAPORE

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ABSTRACT. — The molluscan classes Caudofoveata and Solenogastres are recorded for the first time in Singapore waters. A total of 25 specimens of Caudofoveata and a single specimen of Solenogastres were obtained from samples collected between 2005 and 2010. The Caudofoveata specimens were determined to be members of the genus *Falcidens*, but the Solenogastres specimen was not identified to a lower taxonomic level. General descriptions and figures of the Caudofoveata and Solenogastres specimens are provided herein, with relevant details and remarks added for information.

KEY WORDS. — Caudofoveata, Solenogastres, Singapore, Mollusca, benthic, new records

INTRODUCTION

Aplacophoran molluscs are worm-like animals with a worldwide distribution (Salvini-Plawen, 1999; Salvini-Plawen & Öztürk, 2006; Scheltema & Ivanov, 2009; Salvini-Plawen & Schawbe, 2012). They are exclusively marine benthic and epibenthic animals found at depths ranging from 1 m to 9000 m (Salvini-Plawen & Öztürk, 2006). In addition to their worm-like body, they have a small, reduced posterior mantle cavity and an epidermal cuticle covered by aragonitic spicules, and their foot is reduced or lost completely. The aplacophorans are generally regarded to be basal members of the phylum Mollusca, their calcareous spicules and internal anatomy being reflective of the primitive molluscan state (Scheltema, 1993; Scheltema & Schander, 2000). Hence they are regarded as a phylogenetically important basal group, possessing morphological characteristics that are essential for the reconstruction of the evolution of the Mollusca (Scheltema, 1993; Haszprunar, 2000; Salvini-Plawen, 2003b).

Over a century has passed since the first aplacophoran was reported as an echinoderm by Lovén (1844), but relatively little is known about the aplacophorans despite the Mollusca being one of the most studied phyla. Studies on aplacophorans were primarily focused on European taxa although some researches were carried out in Australia, America, and Japan (see Salvini-Plawen, 1997; García-Álvarez & Salvini-Plawen, 2007, and references cited therein). Most of these studies were concentrated on taxonomy, while only a much smaller number were on anatomy, physiology, behaviour, and larval development.

Two groups of aplacophorans, Caudofoveata (Chaetodermomorpha) and Solenogastres, are universally recognised but their current classification is still contentious with two different systems in use (e.g., Salvini-Plawen, 1972; Scheltema, 1978). One system treats Caudofoveata and Solenogastres as subclasses of a class Aplacophora, which is accepted to be monophyletic with a common neomenioid-like ancestor (e.g., Scheltema, 1978, 1993; Scheltema & Schander, 2000). Proponents of the other system consider Solenogastres and Caudofoveata to be paraphyletic (e.g., Salvini-Plawen, 1969, 1972, 1978, 1980, 2008; Haszprunar, 2000; Glaubrecht et al., 2005). The latter view is largely corroborated by studies comparing morphological characteristics and molecular analyses (e.g., Salvini-Plawen, 1980; Haszprunar, 2000; Glaubrecht et al., 2005), but the interrelationship between the two remains ambiguous with recent studies supporting either of the classification systems (e.g., Kocot et al., 2011, Vinther et al., 2011, Faller et al., 2012). The classification recognising Caudofoveata and Solenogastres as separate classes is adopted here. The two classes are however still known collectively as aplacophorans.

To date, about 130 species of Caudofoveata and approximately 263 species of Solenogastres have been described (Salvini-Plawen, 1997; Salvini-Plawen & Öztürk, 2006; Ivanov et al., 2009; Salvini-Plawen, 2009; Salvini-Plawen & Schwabe, 2012). The first descriptions of aplacophorans from the East-Indian Archipelago were by Thiele in 1898, of two Australian forms from the Torres Straits and North West coast of Australia (Nierstrasz, 1902). During the Siboga Expedition, 10 species of Solenogastres and two Caudofoveata were described from Indonesian waters from depths

ranging from 18–1633 m (Nierstrasz, 1902). Since then, the aplacophoran diversity around the Southeast Asia region is mostly unexplored.

Thus far the only reports of aplacophorans from the Sunda Shelf are from the Java Sea (Nierstrasz, 1902), and these molluscs have never been previously reported from Singapore or its adjacent areas. A provisional representation of the malacofauna diversity in Singapore by Tan & Woo (2010) included some 875 Gastropoda, 351 Bivalvia, 10 Scaphopoda, three Polyplacophora, and 25 Cephalopoda species, but neither Caudofoveata nor Solenogastres was mentioned. Sub-tidal collections made in recent years have however revealed the presence of aplacophorans in Singapore waters. The discovery of these two molluscan classes (Caudofoveata and Solenogastres) in Singapore is thus both surprising and significant. The finds are herein reported and figured for the first time.

MATERIAL AND METHODS

Numerous benthic surveys were made between 2005 and 2010 along the Singapore Strait. Specimens were obtained from muddy and sandy-mud bottom using a Van Veen grab and naturalist' dredge (gape size of 50 × 20 cm and a 50 cm cod end of ½" polyethylene mesh) samplers at depth between 5 m and 38 m. The collected sediment samples were fixed in the field with 4–10% buffered formaldehyde solution. After a minimum fixation period of three days, the samples were sorted using a series of stacked sieves of 2 mm and 1 mm steel mesh. Samples collected off the 1 mm sieves were further sorted under a stereo-dissecting microscope at 10–40× magnification. Specimens were then transferred to 70% ethanol for long term preservation.

Identification of the specimens was based on external morphology using keys extracted from Jones & Baxter (1987), and Salvini-Plawen (1968). Specimens were processed according to methods described in Scheltema (1989) to obtain key taxonomic features, but the single Solenogastres specimen collected was not dissected, and only whole animal photographs were taken. The specimens will be deposited in the ZRC (Zoological Reference Collection) of the Raffles Museum of Biodiversity Research (RMBR), National University of Singapore after further taxonomic studies are concluded.

DETAILS OF RECORDS

CLASS CAUDOFOVEATA

Family Chaetodermatidae

Genus *Falcidens* Salvini-Plawen, 1968

Falcidens sp. (Figs. 1, 2)

Material examined. — 1 ex., Changi/Pulau Tekong, 01°20.020'N, 104°05.121'E, mud, 17 m, 20 Jan.2005; 2 ex., Changi, 01°17.396'N, 104°02.822'E, sandy clay, 30 m, 15 Nov.2006; 1 ex., East Coast/Bedok, 01°17.944'N, 103°56.521'E, mud, 18 m, 23 Jun.2005; 3 ex., East Coast/Bedok, 01°17.944'N, 103°56.521'E, mud, 18 m, 25 May 2006; 4 ex., Kusu Island, 01°13.708'N, 103°51.505'E, mud, 25 m, 17 Nov.2010; 5 ex., East Coast, 01°17.655'N, 103°53.947'E, mud, 5 m, 6 Feb.2006; 2 ex., East Coast, 01°17.655'N, 103°53.947'E, mud, 5 m, 8 May 2006; 2 ex., East Coast, 01°17.655'N, 103°53.947'E, mud, 5 m, 16 Aug.2006; 2 ex., East Coast, 01°17.428'N, 103°53.624'E, muddy sand, 3 m, 6 Feb.2006; 1 ex., East Coast, 01°17.428'N, 103°53.624'E, muddy sand, 3 m, 16 Aug.2006; 1 ex., East Coast, 01°17.110'N, 103°53.104'E, mud, 5 m, 8 May 2006.

Description. — Body size ranging from 3.55–8.1 mm, with distinct anterior constriction between neck and anterior trunk (see Fig. 1). Posterior trunk is usually more swollen than the other parts of the animal and the posterium ends with a sometimes orange colour pallial 'tassel' (Fig. 1B). Body translucent, appearing pale cream to light brown, with darker colour at the posterior trunk mainly owing to the translucent epidermis (internal structure is visible as a darker shade). Oral shield small, horseshoe-shaped, not fully divided (Fig. 2A). Radula teeth sickle-like and attached to a cone (Fig. 2B).

Remarks. — A total of 24 specimens were collected from the Singapore Straits (see Material examined). The specimens were recovered from substratum that generally has a higher proportion of fine sediment, and found in shallow water 10–40 m in depth. All samples collected appear superficially similar and are herein provisionally regarded as conspecific, although some specimens have orange pallial 'tassel' and the others have posterium with the same cream colour (see Fig. 1).



Fig. 1. *Falcidens* species: A, specimens without orange pallial 'tassel'; B, specimen with orange pallial 'tassel'. Scale bars = 1 mm. (Photographs by: Ang Hwee Peng).

The class Caudofoveata is characterised by a lack of ventral furrow and foot, presence of oral shield, and spicule types that are varied at different parts of the body, changing gradually from anterior to posterior region (see Fig. 2). It has a slender, worm-like body shape with a tail-like posterior which ends with a terminal knob or tassel. The mouth and anal chamber is terminal in position.

Members of the Caudofoveata family Chaetodermatidae have an undivided oral shield. The radula membrane forms a strongly developed basal cone or basal plate, with only one or two pairs of true teeth on top, midgut with cuticular stomach shield.

Chaetodermatid species assigned to the genus *Falcidens* has a radula represented by a pair of sickle-shaped teeth which proximally are in contact or possess a symphysis, and a unitary oral shield. *Falcidens* is distributed worldwide except the Polar Regions, and occur from the subtidal to abyssal depths (3 to >4000 m; Schander et al., 2006), but most

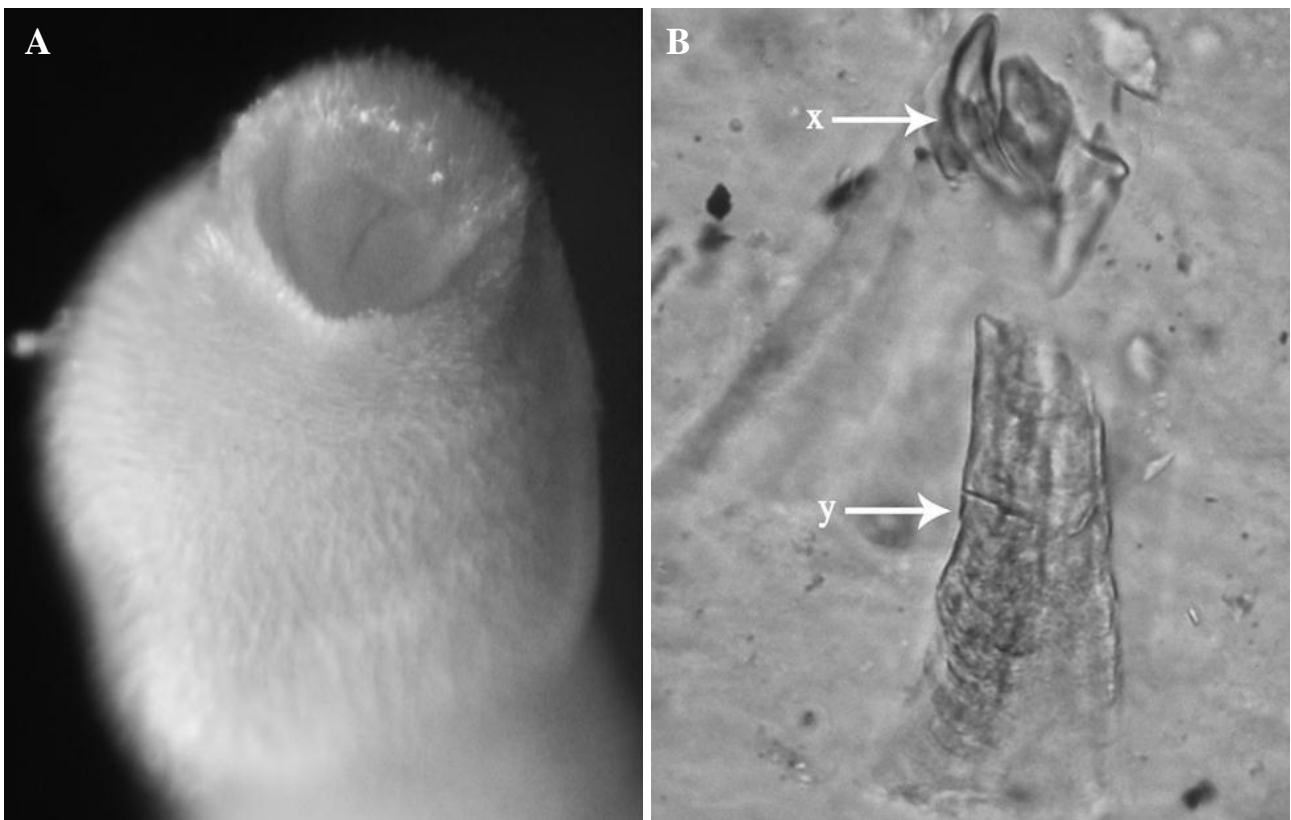


Fig. 2. *Falcidens* species: A, oral shield; B, radula apparatus showing sickle-shaped teeth (x) and radula cone (y). (Photographs by: Ang Hwee Peng).

species appear to be restricted to well-defined, non-overlapping geographic regions (Salvini-Plawen, 1997). Only one species, *Falcidens loveni* (Nierstrasz, 1902) collected from a depth of 1,310 m in the Bali Sea, Indonesia, during the Siboga Expedition (1899–1900), has hitherto been recorded from Southeast Asia (Nierstrasz, 1902). Thus the *Falcidens* species collected from Singapore waters are likely to represent one or more yet undescribed species. A taxonomic study is still on-going.

CLASS SOLENOGASTRES

Solenogastres species

(Fig. 3)

Material examined. — 1 ex., Changi, 01°17.396'N, 104°02.822'E, sandy clay, 30 m, 16 Nov.2010.

Description. — Preserved specimen pale cream colour, almost white, with small red spots scattered over the entire body; approximately 1.85 mm in length. Anterior end rounder and slightly wider with a distinct opening of the atriobuccal cavity; posterior end is more tapered and rounded terminally. Ventral surface has a distinct pedal groove. Sclerites are adpressed on the entire animal. The distinct pedal groove runs along the entire length of the whole animal (see Fig. 3).

Remarks. — Only one Solenogastres specimen was thus far located among the samples, but was unable to identify it to a lower taxonomic level (i.e., family, genus). The Solenogastres are characterised by a median longitudinal groove (the pedal groove) on its ventral surface. An oral shield is absent. A mouth and anal chamber is present, but the radula is lost in some species. Diagnosis of the Solenogastres is rather complex (compared to Caudofoveata), and require serial sections of the animal for accurate identification. The unique specimen was however not dissected since there is no comparative material available for any further work to justify the risk of damage to the precious specimen.

DISCUSSION

It is not difficult to understand why the molluscan classes Caudofoveata and Solenogastres were not previously reported from Singapore. The worm-like animals are easily overlooked, as they are usually very small and live predominantly in marine offshore habitats below 50 m (Scheltema, 1995; Salvini-Plawen, 2003a). Evidently, these animals can be very sparsely distributed, making them a rare representative of the overall benthic community in samples. Out of the total of 225 grab and dredge samplings made during the surveyed period, only 15 (about 6%) yielded aplacophoran specimens—24 Caudofoveata and a single specimen of Solenogastres.

Far more species of the class Solenogastres have been described to date compared to the Caudofoveata. This is perhaps reflective of the more diverse habitats in which they occur. The Solenogastres are known to be epizoic, free living on benthic substratum and even as burrowers (Glaubrecht et al., 2005; Salvini-Plawen, 2008), while the Caudofoveata are exclusively burrowers (Jones & Baxter, 1987). Specimens collected in the Singapore Strait were dominated by members of the Caudofoveata, but this could be an artefact of the sampling methodology employed as grab sampling can sample burrowing organisms much more effectively.

A taxonomic study on the aplacophoran material collected is still on-going, and may take years to conclude. Nevertheless, the discovery of two hitherto unrecorded classes of molluscs in Singapore is remarkable enough to warrant an antecedent note. Notably, this report brings the number of molluscan classes recorded in Singapore from five to seven, which is all of the extant classes except one, the Monoplacophora. This article also contributes to the scarce amount of information available for the two classes in this region.

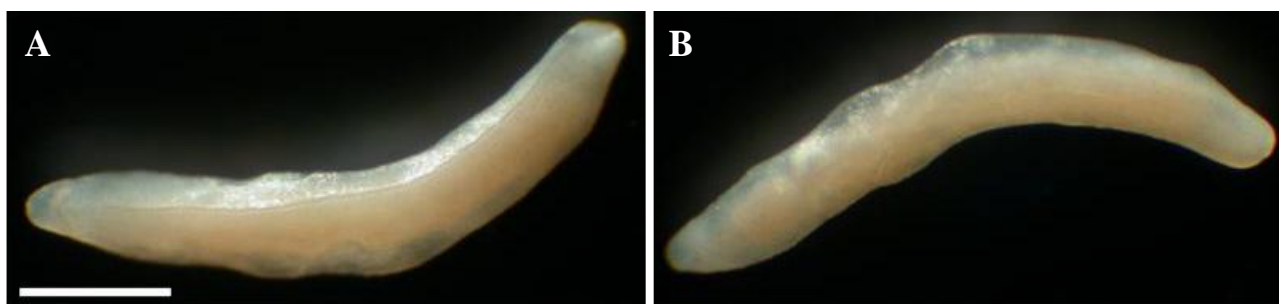


Fig. 3. Solenogastres species: A, ventral view showing the ventral groove; B, dorsal view. Scale bar = 0.5 mm. (Photographs by: Ang Hwee Peng).

In this age of rapid habitat loss, it is comforting that new records, new species, and rediscoveries are still being regularly reported (e.g., Benayahu & van Ofwegen, 2011; Lim et al., 2012; Low & Tan, 2012). Increased effort to document discoveries and the accompanying knowledge gained would eventually help advance conservation causes and understanding of our existing marine biodiversity.

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