

## REDISCOVERY OF THE NEPTUNE'S CUP SPONGE IN SINGAPORE: *CLIONA* OR *POTERION*?

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**ABSTRACT.** — The remarkable *Cliona patera*, or the famous Neptune's Cup Sponge, captured the world's imagination two centuries ago with its peculiar morphology and large size. Measuring more than 1 m in height and diameter, the cup-shaped sponge was also the first sponge species to be described from Singapore in 1820. However, the last record of this iconic sponge from Singapore waters was published in 1908, based on two specimens lodged in the Raffles Museum (collection date unknown). Until recently, *Cliona patera* was widely regarded as extinct due to overfishing until a single specimen was dredged up from the Gulf of Carpentaria (Australia) in 1990. In this paper, we report its presence from Singapore waters, the type locality, once again after more than a century. The generic position of this species in either *Cliona* or *Poterion* is uncertain. There are no records of live characters and little is known about the excavation characteristics of the sponge. This study describes *C. patera* in detail, including *in situ* observations for the first time. New excavation characters observed under the scanning electron microscope revealed that it is well placed in the genus *Cliona*, despite its distinct cup-shape and huge size compared to its congeners.

**KEY WORDS.** — Neptune's Cup Sponge; *Cliona patera*, Singapore, Porifera

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### INTRODUCTION

*Cliona patera* (as *Spongia patera*), the Neptune's Cup sponge, was the first sponge species to be described from Singapore (Hardwicke, 1820; Hardwicke, 1822; Low, 2012). It is arguably one of the most iconic and famous sponge species in the world. It is shaped like a cup or wineglass, growing to over a meter in height and diameter (Fig. 1) and sufficiently large for a child to sit inside (Fig. 2). This remarkable sponge was much sought after by museums and private collectors in the past, and most major natural history museums have at least one specimen of this iconic sponge. The Zoological Museum Amsterdam (ZMA) alone has over twenty specimens and the Natural History Museum in London has some ten specimens.

This sponge was apparently common and abundant in Singapore waters in the early 19<sup>th</sup> century. According to

the second British Resident, Crawfurd (1830: 73): "... those gigantic sponges, which are peculiar to the coast of Singapore, and which Europeans have called Neptunian cups. The natives brought them to us in great numbers." This remarkable sponge continued to fascinate even a hundred years after it was discovered, featuring in a popular series of W. D. and H. O. Wills Cigarette cards titled "Wonders of the Sea" (Fig. 3) produced in 1928. However, *C. patera* was not recorded from Singapore waters since the late 19<sup>th</sup> century. Two specimens were dredged up in Singapore waters by the Eastern Telegraph Company, probably in the 1870s when submarine cables were being laid across Singapore Strait to connect Madras and Darwin. These were lodged in the Raffles Museum (currently Raffles Museum of Biodiversity Research) and reported in Hanitsch (1908). *Cliona patera* has not been recorded from this region since the early 20<sup>th</sup> century. The last record known was off the coast of Bantam in West Java, Indonesia, where two specimens were collected

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in 1907 (Vosmaer, 1908). Subsequently, there were no records of the sponge for a long time, leading biologists to speculate that the species may likely be extinct due to "over-fishing"

(Hooper & van Soest, pers. comm.). It was only till 1990, that one specimen was dredged up in the Australian waters for the first time at the Gulf of Carpentaria (Hooper & Ekins,

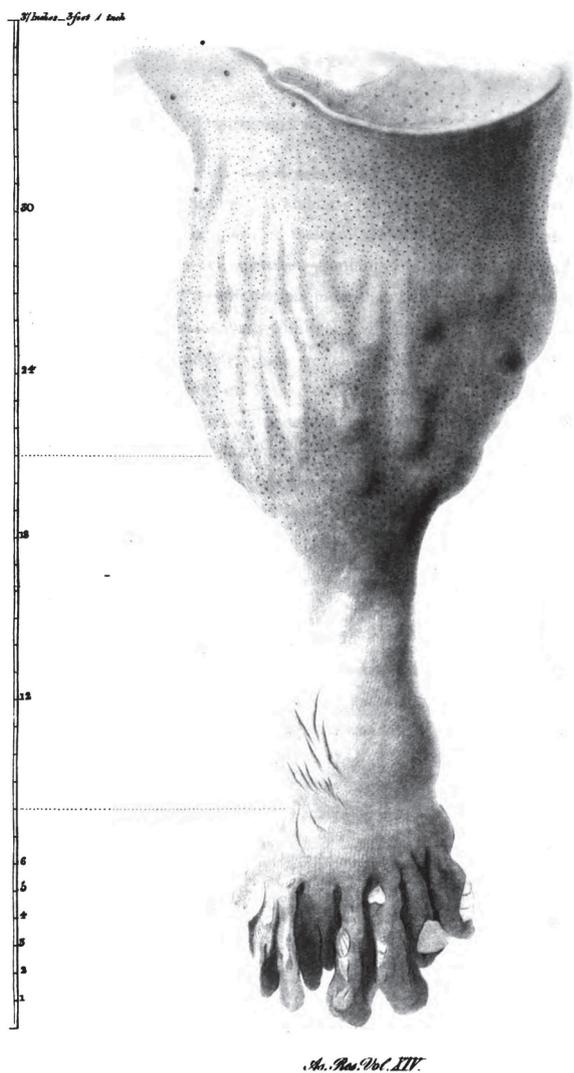


Fig. 1. First drawing of *C. patera* (as *Spongia patera*) in Hardwicke (1822) description (the scale bar on the left is in inches).



Fig. 2. A child bathing in a gigantic *C. patera* dried specimen. This photo was taken in Indonesia, possibly in Sumatera, by F.C. Van Heurn. This sponge is currently lodged in Netherlands Centre for Biodiversity (NCB), Naturalis (RMNH) in Leiden.

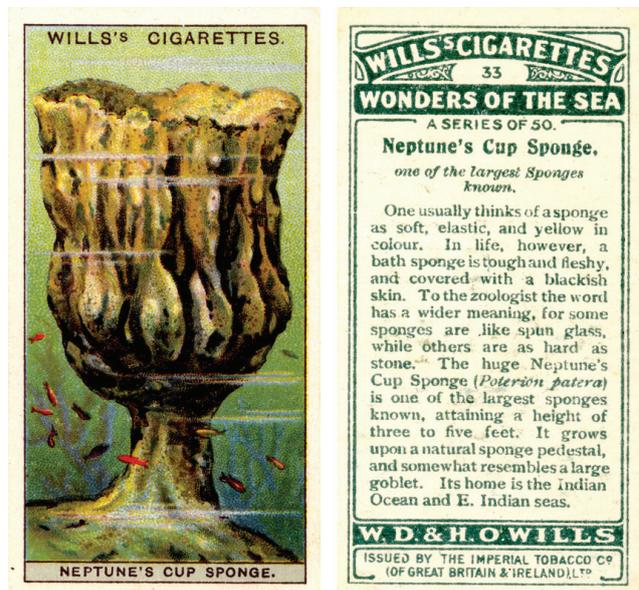


Fig. 3. *Cliona patera* featured in a popular series of W.D. and H.O. Wills Cigarette cards titled "Wonders of the Sea" produced in 1928.

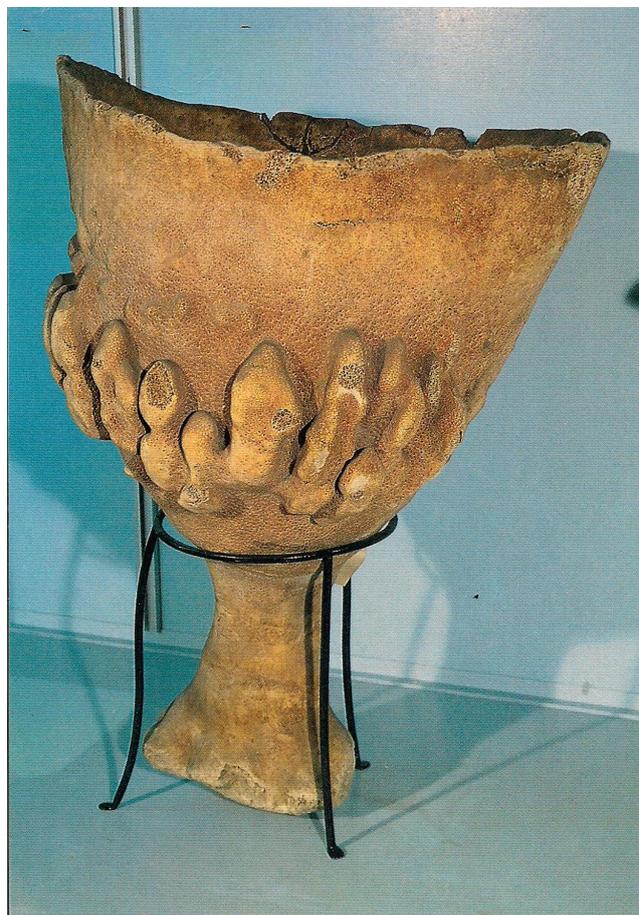


Fig. 4. *Cliona patera* exhibit in Museo Civico Di Storia Naturale (Giacomo Doria), Genoa labeled "*Poterion poseidonis* (Singapore)".

pers. comm.). It must be noted that there has been a number of sponge fauna surveys (Hooper et. al., 2000) in this region but none of these studies recorded *C. patera*.

Two living specimens of *C. patera* were recently discovered off the southern coast of Singapore, the Singapore Strait (Tun & Goh, 2011). This is especially amazing as almost the entire southern coastline of Singapore and many of the 50-odd islands in Singapore Strait were reclaimed and transformed in the past 50 years (Koninck et. al., 2008). *Cliona patera* is iconic but it is also one of the least known sponge species. There were doubts as to whether it should be placed in the genus *Cliona* (van Soest, pers. comm.; see also Topsent, 1909) as it has a unique cup-shaped top or wineglass like growth form like no other *Cliona* species. Most *Cliona* exist in the alpha and beta form, only a few exhibits the gamma form and become massive. However, these are amorphous or irregular in shape, unlike *C. patera*, which has an upright stalk with rooting processes extending into the substratum. A distinct cup forms the main body of the sponge and is supported underneath by a stalk. Its excavating ability is poorly documented, and only Vosmaer (1908) and Annandale (1915) reported their observations from dried material.

A detailed description of *C. patera* from its type locality (Singapore), together with new *in situ* and fresh excavation characters are described in detail for the first time since the last account by Annandale (1915). The contentious issue of the genus placement of this species is also discussed in the light of these new characters.

#### MATERIAL AND METHODS

Thick sections of freshly collected material were made with a surgical blade, soaked in Xylene-Phenol (1:1) solution before mounting on glass slides in DPX® and examined under the light microscope at 100–400 X magnification. Dissociated spicule suspensions were obtained by boiling in concentrated nitric acid (siliceous spicules) and subsequently mounted on brass stubs for examination under a JEOL scanning electron microscope (SEM). Residues of the spicule suspensions were also mounted on glass slides in DPX® measurements of spicule dimensions under the light microscope.

Spicule size data are given as minimum–average–maximum based on a minimum of 25 measurements for each spicule type. Images of specimens, sections and SEM preparations were obtained digitally. Systematic and the order of treatment of the families and genera follow the Systema Porifera (Hooper & van Soest, 2002) and the World Porifera Database (van Soest et al., 2012).

#### TAXONOMY

##### CLIONAIDAE d'Orbigny, 1851

##### *Cliona* Grant, 1826

##### *Cliona patera* (Hardwicke, 1820) (Figs. 5–8)

**Material examined.** — ZRC.POR. 0272. Singapore, Singapore Strait, Kias on 23 March 2011, 12m; ZRC.POR. 0273. Singapore, Singapore Strait, Kias on 18 April 2011, 10m.

Studied for comparison: ZMA.POR.15267. Australia, Gulf of Carpentaria, W. of Kirk Reef. 31 November 1991; BMNH 10.10.24.1. Indonesia, Java Sea, off Batavia (now Jakarta). Collection date unknown.

**Description.** — Sponge in gamma stage and free-living, comprising an oval, shallow, concave disk supported by a stalk with a height of 26 cm (Fig. 5A). The stalk extends some 20 cm into substrate after which it branches into 4-6 rooting processes that extend a further 20 cm in depth into the substratum (Fig. 5B). Colour of living sponge was white to yellow. The upper part of the disk is mostly white, becoming more yellowish towards the exterior and the undersides of the disk and a more intense yellow towards the base of the stalk. The consistency of the sponge is tough, particularly at

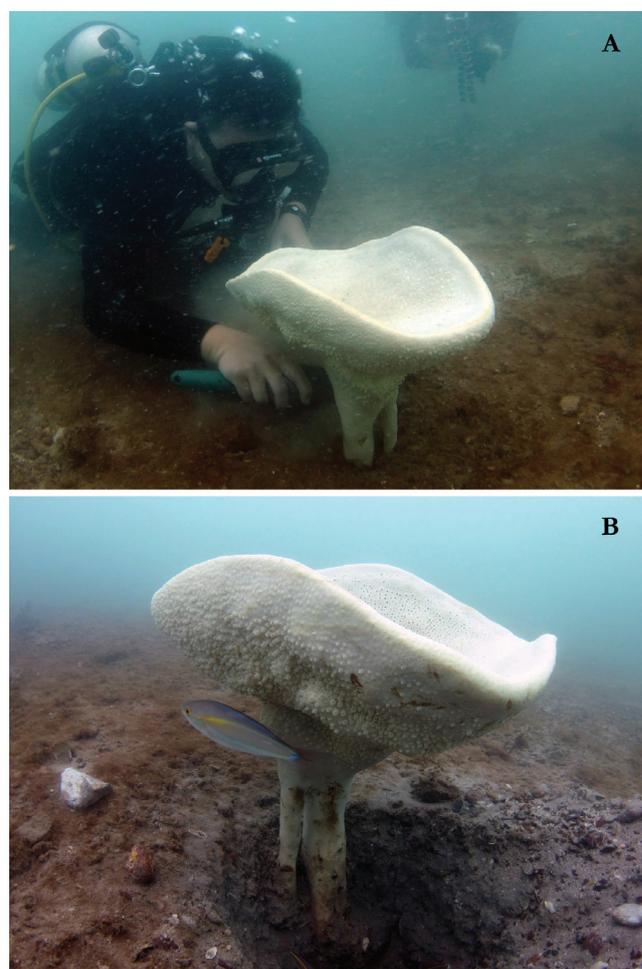


Fig. 5. *Cliona patera*. (A) in Singapore waters observed in March 2011; (B) Stalk and rooting processes in substratum exposed.

the base of the stalk. The oval disk has a diameter of 38 cm on the long side and 28 cm on the short side, with a depth of 5 cm. Rim of disk is not level (Fig. 5). Thickness of disk is approximately 1.5 cm at the rim, becoming gradually thicker towards the center. Surface of disk is covered with papillae. Only oscular papillae are present on the upper surface of the disk, and most papillae are 1-2 mm apart from each other. These oscular papillae are circular in outline with a diameter ranging between 1-3 mm and are typically 0.1 mm in height (Fig. 6A). Ostial papillae are found only on the underside of the disk and cover the entire undersurface of the disk. These ostial papillae are typically 1-2 mm apart from each other, and they extend downward to the upper part of the stalk. The ostial papillae are 3-5 mm in diameter and 2-3 mm in height (Fig. 6B). The stalk is 13 cm in height, cylindrical in shape, with a diameter of 4 cm at the middle of the stalk. The rooting processes are about 1 cm in diameter, and these are filled with materials from the surrounding substratum, consisting mainly of sand, mollusc shells, coral rubble and foraminifera.

**Skeleton.** — Consists of a thick cortical skeleton, 2.2 mm in width, with numerous thick branching and anastomosing spicule tracts (1-1.5 mm) (Fig. 7A). The ectosomal skeleton comprises of dense tylostyle palisade supported by dense

tylostyles lying tangentially beneath (Fig. 7B). The cortical skeleton is an extension of the tylostyle tracts from the choanosomal skeleton. In the choanosomal skeleton, vague pauspicular tracts, loose spicules and collagen surrounded the thick and widely spaced tylostyle tracts (Fig. 7C).

**Spicules.** — Tylostyle megascleres are long, slim and sometimes bent. Subterminal swellings are observed in some tylostyles (Fig. 7D). Tylostyles in: 1) disk, 300–420.7–490  $\mu\text{m}$  x 6–10.1–13  $\mu\text{m}$ ; 2) stalk, 205–377.4–480  $\mu\text{m}$  x 8–11.5–13  $\mu\text{m}$ ; 3) rooting process, 210–358.4–480  $\mu\text{m}$  x 7.5–10.3–13  $\mu\text{m}$ . Microscleres absent.

**Ecology.** — The two *Cliona patera* in this study were found at 10-12 m depth, about 10 m apart from each other, and were in an area subjected to strong tidal currents of up to 3 knots. The sponge stands upright with the disk facing up, supported by a stalk. The main body was firmly anchored by rooting processes and basal part of the stalk was buried in the substratum.

The rooting processes contain a high composition of the surrounding substratum, bound together firmly by sponge materials, typically 0.5–1 mm in width, in between or enveloping the substratum materials. The substrata comprised of intact and broken mollusc shells, coral rubble, sand, and foraminifera. All calcareous material extracted from one piece of rooting process at the basal end, about 10 × 1 × 1 cm in size, were examined under a microscope but none exhibited the typical three dimensional network of excavation chambers below the substrate surface associated with *Cliona* species in the alpha and beta stage (Rützler, 2002). However, these calcareous materials were not large, ranging from 2–20 mm in width. Ten pieces of these smaller calcareous materials were randomly selected for examination under the SEM (Fig. 8). Seven pieces exhibited fresh excavated marks and slits on the surface (Fig. 8A & B). Excavated chip marks were irregularly circular, their diameters ranging between 15 and 30  $\mu\text{m}$ . The slits were approximately 2  $\mu\text{m}$  in diameter (Fig. 8C) and varied widely in length. Processes from etching cells (Rützler & Rieger, 1973; Pomponi, 1979; Schonberg, 2008) were observed in the slits (Fig. 8C).

**Distribution.** — Only two *Cliona patera* individuals were recorded in this study. Historical records have shown, since the publication of *C. patera* species, that they occurred in the Malacca Strait (off Sumatra), South China Sea (from Gulf of Thailand, Singapore Strait, Java Sea off Java) and Gulf of Carpentaria, off Australia (Hardwicke, 1820; Schlegel, 1867; Harting, 1870; Vosmaer, 1908; Sawangwong et al., 2008; van Soest et al., 2012). However, many specimens lodged in natural history museums around the world do not have locality information and collection date (Harting, 1870). For example, the former Zoological Museum Amsterdam (ZMA, now merged with the National Centre for Biodiversity (NBC), Naturalis) in the Netherlands, has some 20 whole dried specimens, and the Natural History Museum (NHM) in London with some ten whole specimens, but most of them lack locality and collection information. Interestingly, a *C. patera* labeled "*Poterion poseidonis* (Singapore)" is being

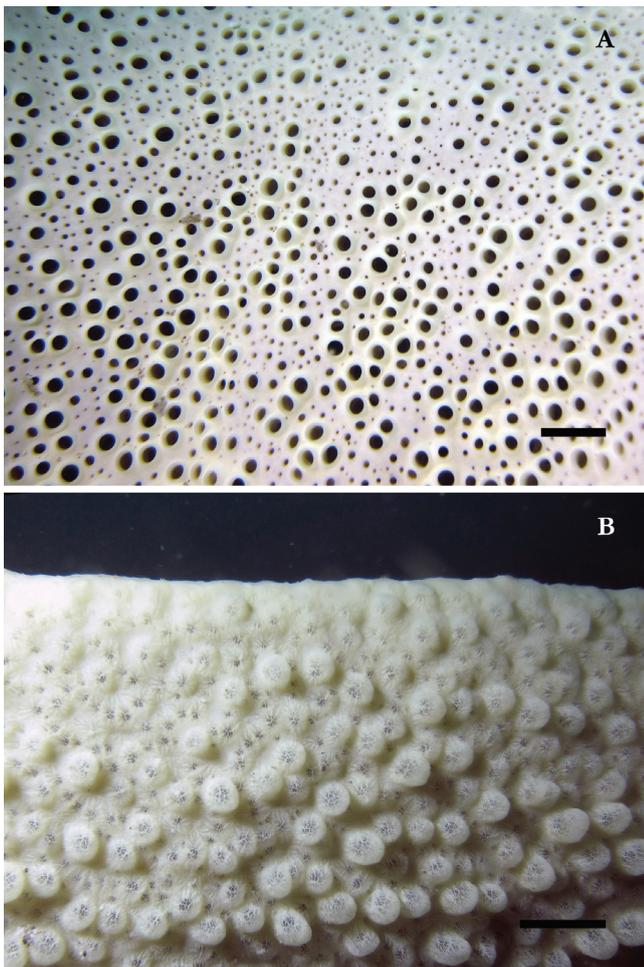


Fig. 6. *Cliona patera*. (A) Oscular papillae on the top surface of disk. . Scale bar = 1 cm; (B) Ostial papillae on the under side surface of disk. Scale bar = 1 cm.

exhibited in Museo Civico Di Storia Naturale (Giacomo Doria) in Genoa but no information of collection date and specific locality (Fig. 4).

In 1974–76, surveys of fishes in Java and South China Sea by Pauly et al. (1996) revealed large mushroom-shaped sponges (tentatively identified as *Poterion nautilus*) in almost every haul. The *P. nautilus* looks very much like *C. patera* from a photo (Fig. 9) taken by Pauly. However, there is no way to verify the identity of *P. nautilus* as no specimen was collected during that survey.

**Remarks.** — The rediscovery of the *Cliona patera* in Singapore after more than a century is especially significant considering the extensive modification of its coastline. Singapore has developed rapidly since its founding by Sir Stamford Raffles in 1819, transforming the quiet island to a busy port in a few years. Now, Singapore is a highly developed and urbanized city country, and have one of the busiest ports in the world. The coast where *C. patera* used to be found in abundance (Hardwicke, 1822; Crawford, 1830) has been greatly transformed. Almost the entire south coastline of mainland Singapore and the 50-odd islands have been reclaimed and developed in the past 50 years

(Koninck et al., 2008). All previous marine biodiversity surveys carried out in the past did not report the presence of *C. patera* despite its large size (Chuang, 1961, 1973, 1977; Chou and Wong, 1985; Hooper et al., 2000; Lim et al., 2008; De Voogd & Cleary, 2009; Lim et al., 2012). The discovery and the presence of two young *C. patera* reported in this study may be indicative that more could present within the area, but more importantly, points to the possibility of adult populations present within Singapore's coastal waters. It alludes to the presence of pockets of favorable habitats with suitable environmental conditions that can serve as refugia for the continued recruitment and survival of this rare sponge species.

The two *C. patera* in this study, unlike all those documented in the past (Hardwicke, 1822; Crawford, 1830; Schlegel, 1858; Harting, 1870; Vosmaer, 1908; Topsent, 1909) did not possess the cup or wineglass shaped main body characteristic of this species. They are probably the smallest and youngest specimens documented although there is no doubt that the two specimens are indeed *C. patera*. They have similar spiculation and skeletal structure as *C. patera* as indicated in the literature (Harting, 1870) and material from both ZMA and NHM show the distinct stalk and basal rooting processes

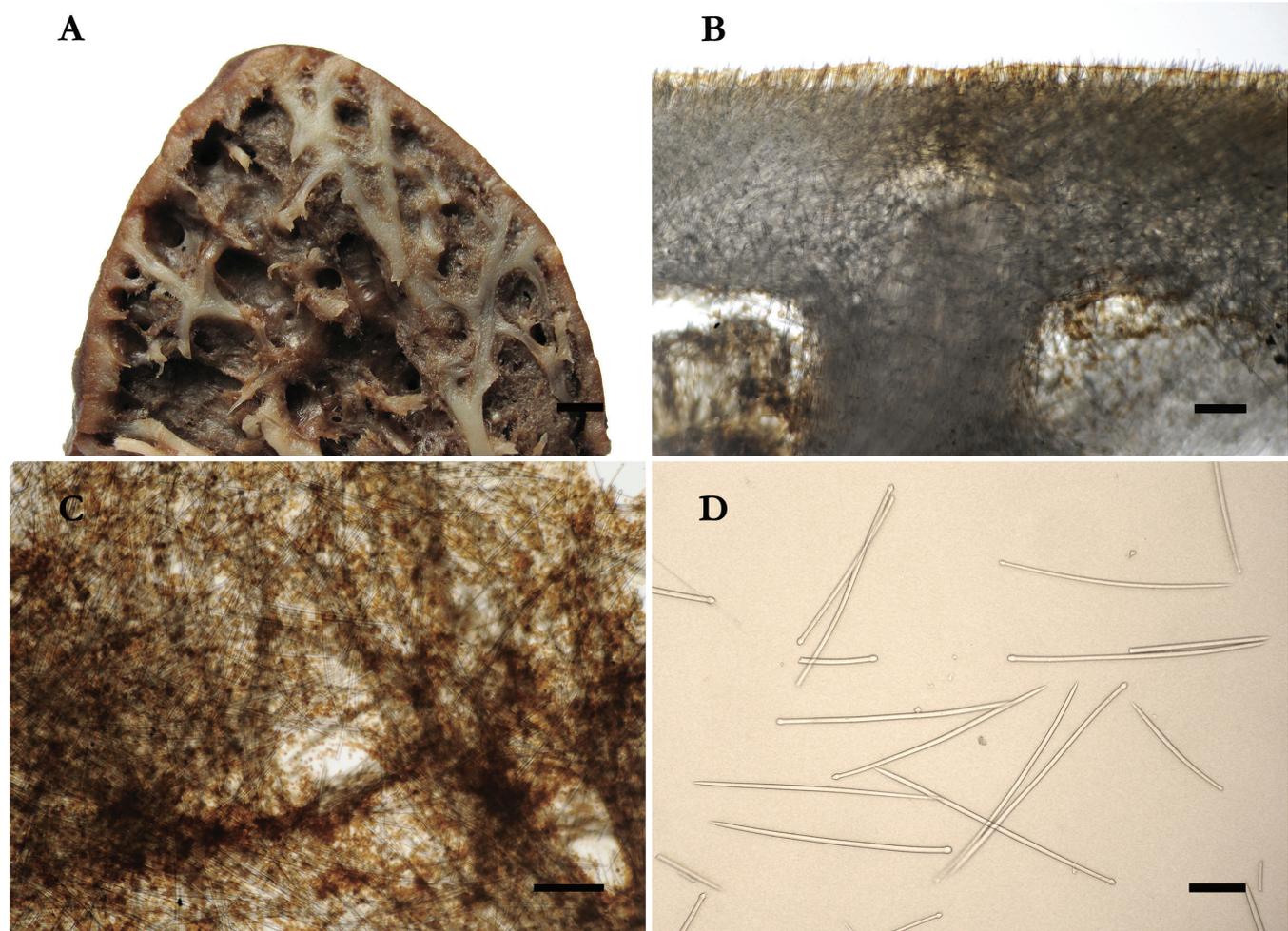


Fig. 7. *Cliona patera*. A. Skeletal cross-section of disk. Scale bar = 3 mm; B. Tylostyle tract extending to the cortex. At the surface is a palisade of tylostyles with the needle end of tylostyle facing out. Scale bar = 200 µm; C. Vague paucispicular tylostyle tracts in space between the thick spicule tracts. Scale bar = 200 µm; D. Tylostyles. Scale bar = 100 µm.

of *C. patera* that are also present in the specimens examined. The most closely related species, *C. celata*, do not exhibit stalk and rooting processes (Rützler, 2002; Rosell & Uriz, 2002; Schönberg et al., 2006).

*Cliona patera* has the most advanced gamma form amongst all clionoids in having a cup or wineglass shaped main body supported by a stalk with rooting processes anchoring the

sponge in the substratum. Only a few clionoids have been reported in gamma stage, e.g., *Cliona celata* Grant, 1826, *C. viridis* and *C. californiana* de Laubenfels, 1932. They are just massive (reaching one meter in width) and amorphous but nothing remotely as structured as *C. patera*. Beside their distinct form, *C. patera* can be distinguished from most of the 81 valid *Cliona* species worldwide (van Soest et al., 2012) in having only tylostyles megascleres and the absence of microscleres. Only 16 species have been reported to contain only tylostyles (Schönberg et al., 2006), and only three species of these exhibit gamma form, namely *C. arenosa* (Schmidt, 1870), *C. californiana* and *C. celata*. *Cliona patera* can be distinguished from them in having larger tylostyles and thicker tylostyle tract (750–1000  $\mu\text{m}$ ), in addition to the unique gamma form.

Vosmaer (1908) was the first to report that *C. patera* (as *Poterion patera*) was a boring sponge based on a *Voluta* (neogastropod) shell with numerous holes “found between the roots”, “dried sponge substance in the interior of *Voluta* proved that the spiculation closely resembles that of the *Poterion*”. Annandale (1915) reported “...at least one gastropod shell, which was extracted from the centre of the basal portion of large specimen, is wholly permeated and nearly destroyed

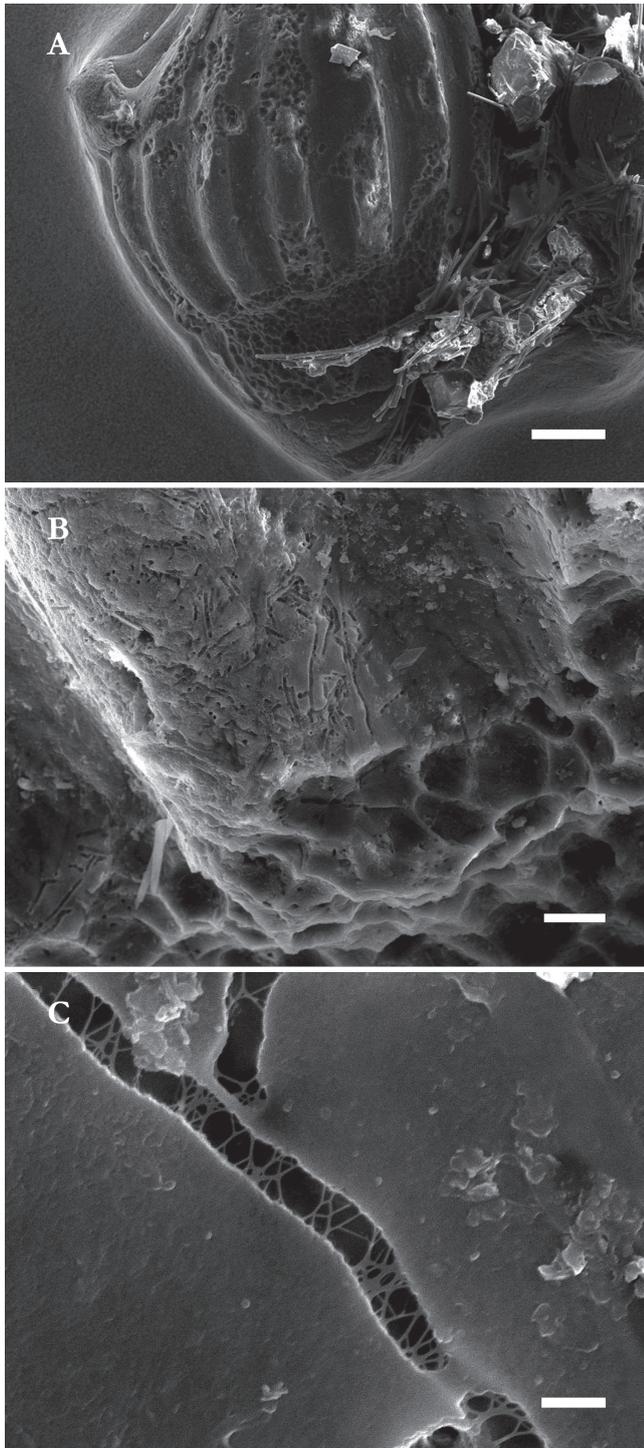


Fig. 8. Etch marks made by *Cliona patera* on gastropod shells. (A) Gastropod shell with etch marks made by rooting process of sponge. Scale bar = 200  $\mu\text{m}$ ; (B) Etch marks and slits on a gastropod shell. Scale bar = 20  $\mu\text{m}$ ; (C) Processes of etching cells in slit. Scale bar = 2.5  $\mu\text{m}$ .



Fig. 9. A “*Poterion nautilus*” (at the top right) trawled up from one of Mutiara surveys in Java and Southern South China Sea between 1974-1976. Specific collection date and locality not recorded. Photo used with permission from Gustav Pauly.

by excavations filled with sponge substance". Both of them observed the typical cavities made by clionoids in alpha and beta stages, which are visible to the naked eye. However, such cavities were not observed in all calcareous material (over 100 pieces, ranging from 2-20 mm in width) extracted from a piece of basal rooting process (10×1×1 cm in size) from the Singapore material. Instead, freshly etch marks (15–30 µm), slits and etching cells processes in the slits (Rützler & Rieger, 1973; Pomponi, 1979) are reported for the first time in *C. patera*. All the seven etch calcareous material examined under SEM showed extensive chipped marks on the surface but no cavity. Fragments of gamma stage *C. celata* have been shown to be capable to etch and excavate holes on calcareous materials within two months (Hartman, 1958). *Cliona patera* is observed to be able to etch calcareous materials but more studies are required to prove that *C. patera* really excavates and make cavities like a typical clionoid. There are no reports of alpha and beta stage excavation characters of *C. patera*. Interestingly, it might be difficult to distinguish the alpha stage of *C. celata* from *C. patera* as both have similar spiculation and skeletal structure.

*Cliona patera* was placed the genus *Spongia* when first described by Hardwicke (1820). *Spongia* was diagnosed by Linnaeus in 1759 and used for the archetypal Greek bath sponge, *Spongia officialis*, in his classification. Over the following 100 years or so, authors assigned almost all sponge species to *Spongia* (Cook & Bergquist, 2002). Thirty-eight years later, Schlegel (1858) used the name *Spongia (Poterion) Neptuni*, probably with no knowledge of Hardwicke (1820 & 1822), for a sponge universally considered to be identical to Hardwicke's *Spongia patera*. *Poterion* refers to a cup or drinking vessel, and derived from "πιδων", a Greek word meaning, "to drink". Nine years later, Gray (1867) transferred Hardwicke's *Spongia patera* to the genus *Rhaphiophora*, giving the definition as "Sponge cup-shaped, friable, with a harder external case, pores minute. Spicules pin-shaped, fasciculated." without reference to Schlegel (1858). Topsent (1909) proposed the transfer of *P. patera* to the genus *Cliona* after Vosmaer (1908) reported that *C. patera* is a boring sponge. He argued that the distinct cup-shaped top of *C. patera* does not warrant a separate genus. However, Vosmaer (1911) did not agree with Topsent (1909) and preferred to retain *Poterion* as a genus. He also said "there are sufficient anatomical grounds to keep *Poterion* and *Cliona* apart" but did not provide supporting evidence. However, Rützler (2002) supported Topsent's decision, and *Cliona patera* fitted well in the definition of the family Clionidae and the genus *Cliona* in Rützler's revision. This decision is supported by the fresh excavation marks and characteristic clionoid ostial and oscular papillae observed in situ in this study. We also feel that the sole character of form, though unique in a spectacular fashion in the case of *C. patera*, is not sufficiently strong justification to erect a separate genus. Genetic data will shed more light on the placement of *C. patera* in relation to other genera in the Clionidae and other *Cliona* species, especially *C. celata*. Until then, *C. patera* seems well placed in the genus *Cliona*.

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