

Biogeographical Isolation and a Sundaland Relict Cone Shell from Sumbawa Island, Indonesia

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ABSTRACT A new cone species, *Cylinder sumbawaensis* Verbinnen, 2022, was recently described from the Saleh Gulf (Teluk Saleh) of Sumbawa, Nusa Tenggara Islands (Lesser Sunda Islands), Indonesia. The new species is morphologically very similar to *Cylinder bengalensis* (Okutani, 1968) from the Gulf of Bengal and Andaman Sea and represents a geographically-isolated relict of a once widespread Indian Ocean-derived molluscan fauna that extended all along the coast of the Middle Pleistocene Sundaland Peninsula.

KEY WORDS Conidae, *Cylinder*, Indonesia, Lesser Sunda Islands, Sumbawa, Teluk Saleh

INTRODUCTION

A new conid species, *Cylinder sumbawaensis* Verbinnen, 2022, was recently described from the Teluk Saleh of Sumbawa, Nusa Tenggara Islands, Indonesia. (See Verbinnen, 2022) This article opines on the evolution and biogeographical isolation of *C. sumbawaensis* and analyzes its morphology in comparison to its well known sister species *Cylinder bengalensis* which has a wide spread distribution throughout the Gulf of Bengal and Andaman Sea.

The northern Lesser Sunda Islands of Indonesia, extending from Lombok to Wetar Islands, constitute an “evolutionary hot spot” referred to as the Nusa Tenggara Infraprovince (Petuch and Berschauer, 2020: 190-191). This special area of increased speciation and evolution is one of the centers of biodiversity within the Indonesian Subprovince of the Indo-Malayan Molluscan Province and houses a large number of highly-restricted endemic species (Petuch

and Berschauer, 2020: 203). Some of these Nusa Tenggara endemics include the cowry *Erronea vredenburgi* Schilder, 1927, the volute *Cymbiola chrysostoma* (Swainson, 1824), and the cones *Cylinder johnabbasi* Petuch & Berschauer, 2018, *Phasmoconus giorossii* (Bozzetti, 2006), *Graphiconus wittigi* (Walls, 1977), and several closely-knit sibling taxa in the *Eugeniconus victor* (Broderip, 1842) species complex (Parsons *et al.*, 2020). Recently, increased collecting and exploration on Sumbawa Island, at the western end of the archipelago, has resulted in the discovery of an unusual new member of the genus *Cylinder* Montfort, 1810. This distinctive new cone shell, *Cylinder sumbawaensis* Verbinnen, 2022, was recently described as a subspecies of *Cylinder bengalensis* (Okutani, 1968), and as discussed in the following sections the authors consider to be a full species.

The principal geographical feature on Sumbawa Island, the Teluk Saleh (Saleh Gulf), is a large, almost land-locked, engulfment that only

connects to the open Flores Sea through two small, narrow straits on either side of Mojo Island, along its northern end (Figure 1). This small, sheltered gulf provides the perfect environment for extensive coral reef growth and its numerous small islands and shallow coastline support major reef complexes and a very rich fauna of marine mollusks. Teluk Saleh, itself, formed from a series of volcanic eruptions, and their resultant calderas, during the late Pleistocene and is geologically related to the adjacent Tambora Volcano. The entire Lesser Sunda Archipelago dates from the late Pliocene and formed as a series of volcanoes along an accretionary margin related to the Sunda/Sumatra Subduction Zone. Throughout the late Pliocene and Early Pleistocene, the islands expanded in size due to increased volcanism and formed a closely-spaced chain of large islands, separated by narrow, deep channels.



Figure 1. Satellite map of Teluk Saleh, Sumbawa Island. (Google Earth Image, 2019)

The enclosed and sheltered Teluk Saleh of Sumbawa Island has acted as a biogeographical refugium and contains a relict pocket of the Pleistocene Sundalandian marine world,

analogous to the situation in the Caribbean Sea (Petuch, 1982). Here, a remnant of an ancestral eastern Indian Ocean *Cylinder* species complex has managed to survive and evolve into a completely new endemic Sumbawan species.

Main shell morphological features were used during this study to differentiate the new species from its closest congener within the genus *Cylinder*. The terminology used within this description follow Röckel *et al.* (1995), Monnier *et al.* (2018), Monnier *et al.* (2021), and Veldsman (2022). The following abbreviations refer to measurements were taken for each specimen studied:

- SL – maximum shell length (mm)
- MD – maximum diameter (mm)
- H – height (mm)
- AH – aperture height (mm)
- HMD – height of maximum diameter (mm)
- SH – spire height (SL-AH)
- SP – spire percentage of length (SH/SL x 100)
- RD – relative diameter (MD/AH)
- PMD – relative position of the maximum diameter (HMD/AH)
- RSH – relative spire height (SH/SL)
- V – estimated ‘model’ volume (SL x MD x H)
- SR – shell ratio factor (SL/MD x PMD)

A total of 15 adult specimens, along with eight juvenile (not fully developed) specimens of *Cylinder sumbawaensis* Verbinnen, 2022 from Teluk Saleh, Sumbawa Island, Indonesia, were studied, measured, and included in the data tables (Appendix A), along with a total of 16 specimens of *Cylinder bengalensis*.

SYSTEMATICS

Phylum Mollusca
Class Gastropoda

Subclass Sorbeoconcha
 Order Prosobranchia
 Infraorder Neogastropoda
 Superfamily Conoidea
 Family Conidae
 Subfamily Coninae

Genus *Cylinder* Montfort, 1810

Conus textile Linnaeus, 1758 (type by original designation)

Cylinder sumbawaensis Verbinnen, 2022
 (Plate 1, Figures A-F)

Review of Morphology. Shell moderately large to large (57-90 mm), moderately heavy, profile elongate conical, and cylindrical-straight. Body whorl straight, narrowing and angling in at anterior end. High stepped spire, relatively straight in outline. Shallow incised sutures on spire. Shallow, relatively straight sutural ramps with very fine radial striae. Protoconch sharp, pinkish colored. Shoulder sharply angulate, moderately broad profile. Moderately fine spiral striae around the body whorl, the posterior half faint spiral striae visible and the anterior half having stronger spiral striae on the outer part of the whorl towards the lip. Aperture narrow, slightly broad, with a straight lip, highly angled in at the basal part of the columella. Background color off-white, with two very broad bands around the body whorl, one posterior side of the center and the second towards the anterior side, both consisting of a light brown coloration with thin dark brown spiral lines, mostly broken with off-white large tent pattern, and very wavy thick axial dark brown lines. Three spiral bands consisting of tent pattern of large to very large triangles, the first at the posterior end below the shoulder, the second around the center and the last at the anterior end. The sharp side of the shoulder consists of dark brown blotches to thin markings, and off-white tent markings.

Study material. Eighteen specimens in the collection of Stephan G. Veldsman measuring between 83.92 and 39.76 mm in length; two specimens in the collection of Edward J. Petuch measuring 80.47 and 75.48 mm in length; and one specimen in the collection of David P. Berschauer measuring 68.50 mm in length.

Type Locality. 20 m depth off Dangarbesar, Teluk Saleh (Saleh Gulf), Sumbawa Island, West Nusa Tenggara Province, Indonesia.

Distribution. Only known from Teluk Saleh, Sumbawa Island, Indonesia, collected by hookah diver fishing for lobsters at approximately 20 m depth.

DISCUSSION

During the Chibanian Age of the Middle Pleistocene (400,000 years BP), a major worldwide climatic cooling event took place and sea levels dropped as much as 200 m; this resulted in the islands combining into a single fused landmass called "Sundaland" (Petuch and Berschauer, 2020: 190; Zahirovic, *et al.* 2014). In its maximum development, Sundaland extended from the Isthmus of Kra in Thailand and the island of Sumatra in Indonesia eastward all the way to Timor. As a single, fused landmass, the giant peninsula allowed marine ecosystems from the Gulf of Bengal and Andaman Sea to establish themselves along the shoreline, all the way to the present-day Maluku Islands (Moluccas Islands). This ecological continuum allowed for a free interchange of marine organisms and enlarged ranges for many Gulf of Bengal and Indian Ocean species (Figure 2).



Plate 1. *Cylinder sumbawaensis* Verbinnen, 2022. **A, B** = Specimen of *C. sumbawaensis*, measuring 83.92 mm in length, Veldsman Coll.; **C, D** = *C. sumbawaensis* specimen measuring 73.10 mm in length, Veldsman Coll.; **E, F** = *C. sumbawaensis* specimen measuring 68.50 mm in length, Berschauer Coll.

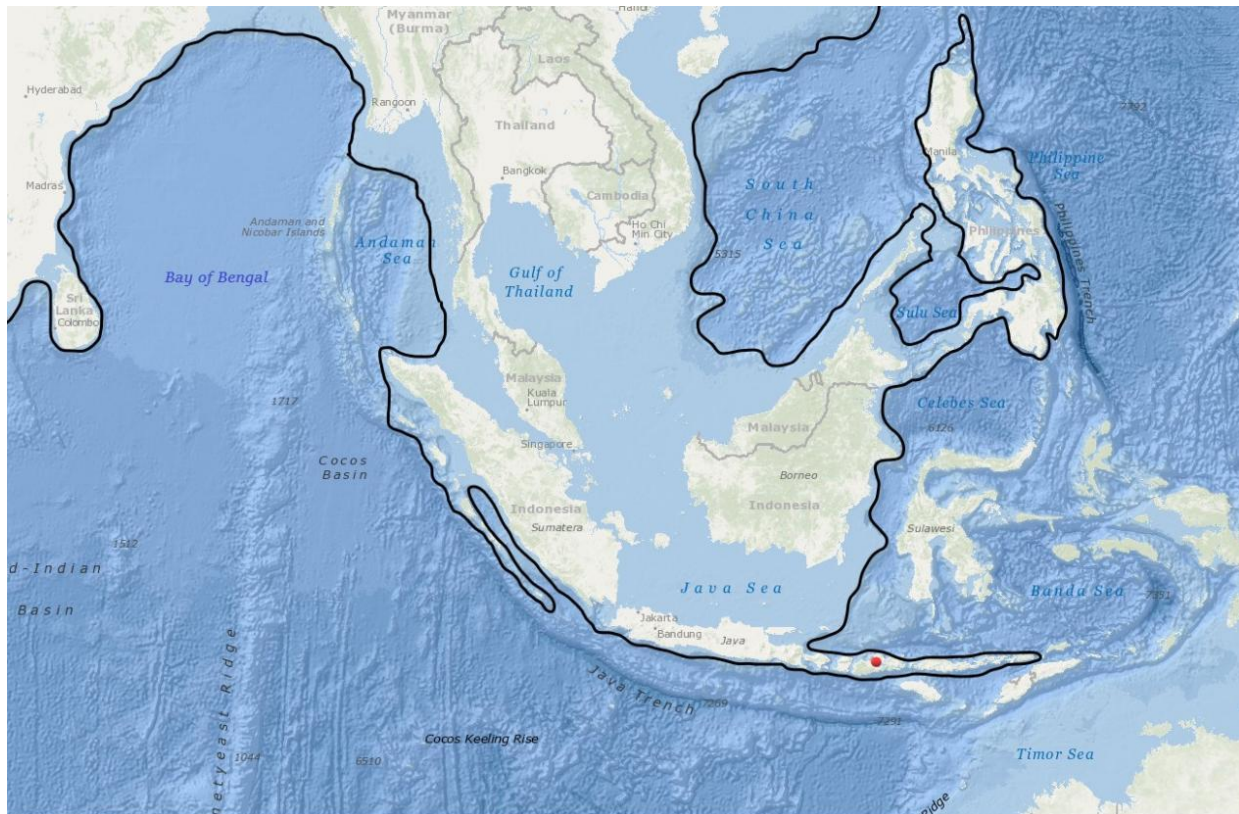


Figure 2. Middle Pleistocene coastlines of Sundaland compared to present day. (Adapted from Wisnu-Aji, 2016, and Zahirovic, *et al.* 2014.) The red dot shows the modern day location of Teluk Saleh, Sumbawa Island, Indonesia

During the Late Pleistocene (Tarantian Age), sea level rose rapidly and flooded many of the lower-relief Sundaland areas that previously had been channels between individual islands. Once these channels had re-developed, and the Java and Banda Seas had inundated northern Sundaland, the once-continuous ranges of the resident marine mollusks became separated into geographically-smaller areas due to the newly-created ecological barriers. Being genetically-isolated, these small populations either became extinct or underwent genetic drift and have evolved into two sibling species before the Holocene, *Cylinder bengalensis* in the north and *C. sumbawaensis* in the south.

Cylinder bengalensis (Okutani, 1968) is a well-known species from the Gulf of Bengal and Andaman Sea. The species has been recorded off southern India, Maldives, Sri Lanka,

Myanmar and Thailand, and is trawled from 45 to 300 m depth. *Cylinder bengalensis* was originally described from the Gulf of Bengal from a depth of 50 m (Okutani, 1968). *Cylinder sumbawaensis* is a smaller cone species that shares several shell morphological features in common with *C. bengalensis* was discovered in Teluk Saleh, Sumbawa Island, Indonesia. The two localities of the two populations are biogeographically far from each other with no direct link in-between (Plate 2, and Figure 3).

The morphometric parameters for the adult specimens of *C. sumbawaensis*, and *C. bengalensis* are summarized in Tables 1 and 2, whereas the detailed information is tabled in Appendix A. Most of the morphometric parameters are very similar and overlapping, and are characteristic of the *Cylinder* genus.



Plate 2. Comparison between *Cylinder bengalensis* and *C. sumbawaensis*. **A, B** = *C. bengalensis* measuring 103.92 mm in length, from Gulf of Bengal, India, Berschauer Coll.; **C, D** = *C. bengalensis* measuring 95.49 mm in length, from Phuket, Thailand, Berschauer Coll.; **E, F** = *C. sumbawaensis* specimen measuring 68.50 mm in length, Berschauer Coll.

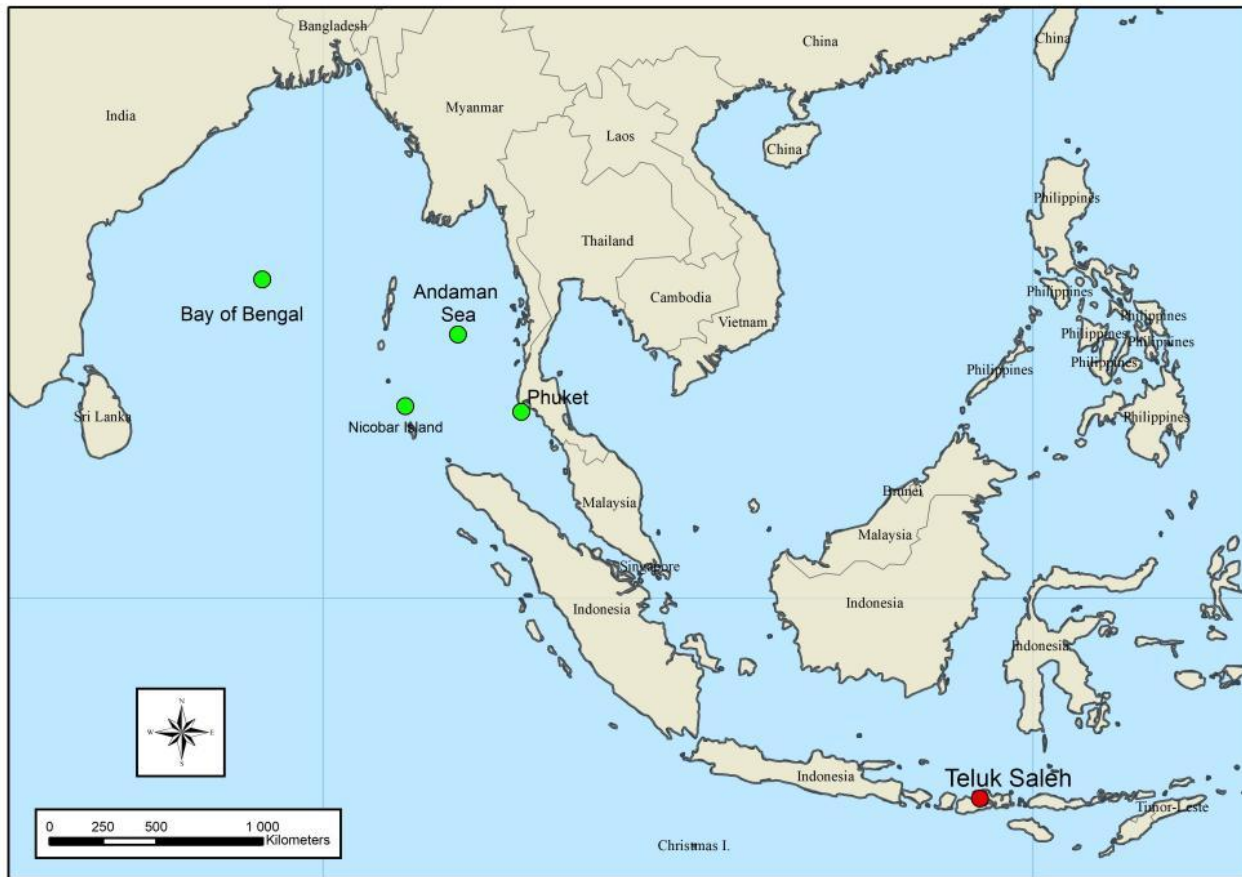


Figure 3. Relative distributions of *Cylinder bengalensis* (green dots), and *C. sumbawaensis* (red dot). Map compiled by S.G. Veldsman (2022).

	Maximum length (SL) - mm	Maximum diameter (MD) - mm	Height (H) - mm	Aperture height (AH) - mm	Height of maximum diameter (HMD) - mm	Relative Diameter (RD)
<i>C. sumbawaensis</i> (15 specimens)						
Range	57.65 – 85.20	19.37 – 31.75	17.66 – 28.62	42.12 – 67.86	39.38 – 64.59	0.44 - 0.50
Mean	70.88	24.86	22.49	53.35	50.60	0.47
<i>C. bengalensis</i> (16 specimens)						
Range	92.04 – 110.90	28.02 – 35.98	25.45 – 31.75	67.82 – 80.78	64.40 – 77.06	0.39 - 0.45
Mean	99.86	31.78	28.59	76.44	72.12	0.42

Table 1. Morphometric parameters including SL, MD, H, AH, HMD, and RD for the adult specimens of *C. sumbawaensis*, and *C. bengalensis*.

Cylinder sumbawaensis is on average smaller than *C. bengalensis*, with a proportionately wider shoulder to spire length, the relative diameter of *C. sumbawaensis* being higher (mean RD of 0.47) than *C. bengalensis* (mean RD of 0.42) (Table 1).

Cylinder sumbawaensis has on average a slightly higher spire percentage to shell length (mean of 24.87%) than *C. bengalensis* (mean of 23.40%). The most significant parameter is the shell ratio factor, *C. sumbawaensis* has a mean of 2.71 and *C. bengalensis* a mean of 2.97 (Table 2).

	Relative position of the maximum diameter (PMD)	Spire Height (SH) - mm	Relative Spire height (RSH)	Estimated 'model' volume (V)	Spire % of length (SP)	Shell ratio factor (SR)
<i>C. sumbawaensis</i> (15 specimens)						
Range	0.93 - 0.97	13.46 – 21.78	0.20 - 0.28	19.72 – 77.42	20.35 – 27.65	2.55 – 2.84
Mean	0.95	17.53	0.25	42.01	24.87	2.71
<i>C. bengalensis</i> (16 specimens)						
Range	0.90 - 0.97	19.04 – 31.32	0.19 - 0.28	65.63 – 119.33	19.15 – 28.24	2.77 – 3.14
Mean	0.94	23.42	0.23	91.51	23.40	2.97

Table 2. Morphometric parameters including PMD, SH, RSH, V, SP, and the shell ratio factor (SR) for the adult specimens of *C. sumbawaensis* and *C. bengalensis*.

The relative diameter in relation to the relative position of the maximum diameter *C. sumbawaensis* fills a different plot area with a very different trend (Figure 4) than *C. bengalensis*.

The shell ratio factor in relation to the spire percentage to shell length, *C. sumbawaensis* fills a very different plot area with a very different trend (Figure 5) than *C. bengalensis*.

Cylinder sumbawaensis has, on average, a smaller shell with a slightly broader shoulder in relation to shell length. *Cylinder bengalensis* has very fine spiral striae around the outer whorl, the posterior half becoming smooth on the last whorl, the anterior half exhibiting faint fine spiral striae, whereas *C. sumbawaensis* has

moderately fine spiral striae around the outer whorl, the posterior half faint spiral striae visible and the anterior half having stronger spiral striae on the outer whorl. *Cylinder sumbawaensis* has a straight body whorl whereas *C. bengalensis* is relatively straight, but slightly concave in the center. The spire of *C. bengalensis* is moderately stepped with a moderately straight outline, whereas *C. sumbawaensis* is much more stepped and has a straight outline. The shoulder of *C. sumbawaensis* is sharply angulate with a moderately broad profile, whereas *C. bengalensis* has a sub-angulate to angulate shoulder with a narrow profile. The color of the two species is very similar with regards to the banding, and *C. bengalensis* has a finer tent pattern, whereas *C. sumbawaensis* has a large tented pattern.

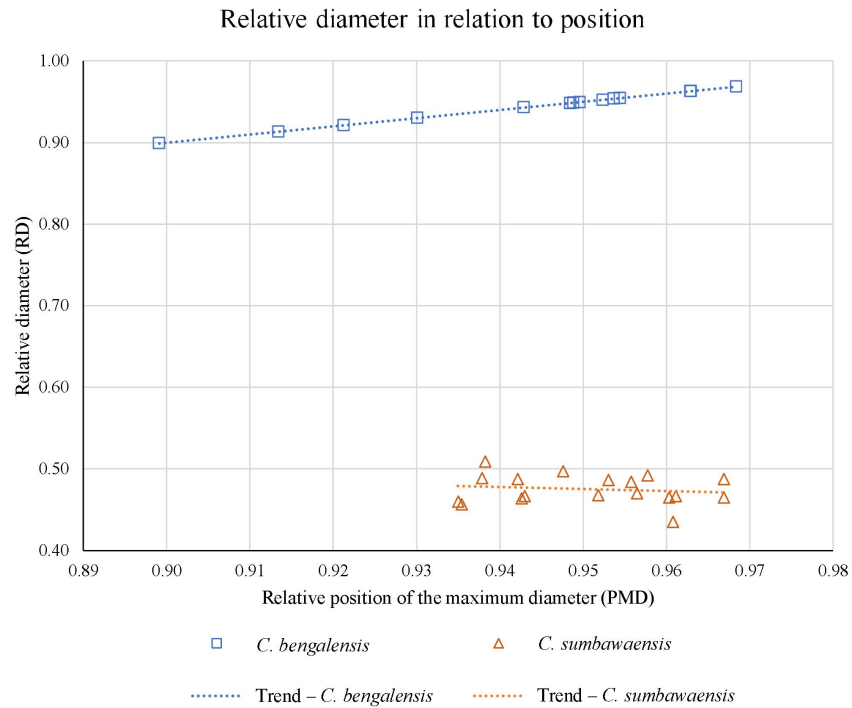


Figure 4. Plots of the relative diameter (RD) of the shell in relation to the relative position of the maximum diameter (PMD) for the adult specimens of *C. sumbawaensis*, and *C. bengalensis*.

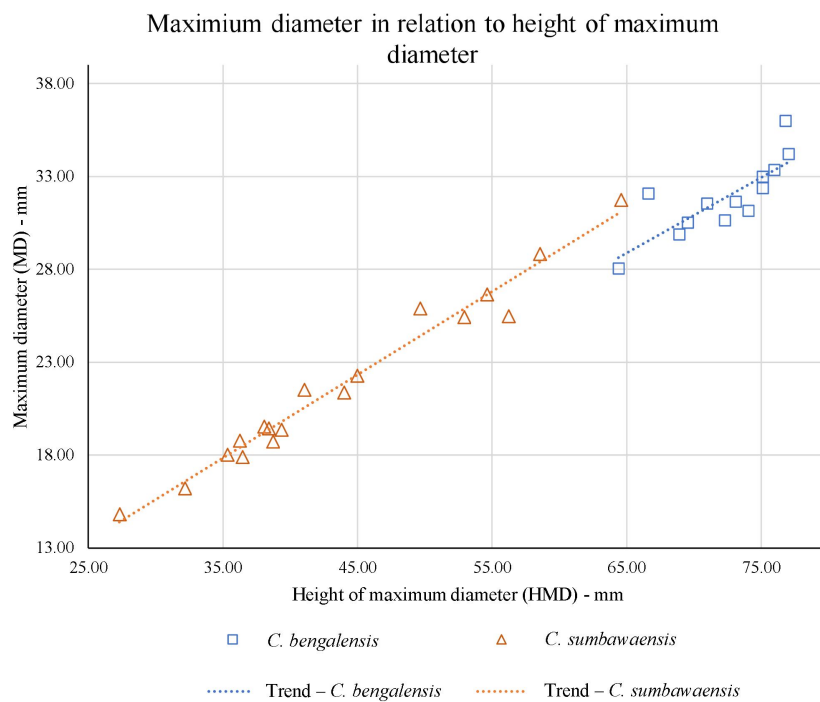


Figure 5. Plots of the shell ratio factor (SR) of the shell in relation to the spire as a percentage of shell length for the adult specimens of *C. sumbawaensis*, and *C. bengalensis*.

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