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Research Article

Commercial sea cucumbers from east Kalimantan, Indonesia: How to identify the dried products?

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Abstract

Certain species of sea cucumbers in Indonesia are valuable marine commodities, commonly traded globally in dried form (*trepang*). The diversity of *trepang* species with similar colors and patterns has led to confusion about the names of the species in the coastal areas. As part of ongoing efforts to mitigate false and conserve stock biodiversity, accurate identification of *trepang* is essential. This study aims to document *trepang* traded from East Kalimantan, based on their external morphology as well as ossicle shapes and composition. The observation of 24 specimens revealed fifteen species from the family *Holothuriidae* and five species from the family *Stichopodidae*. This study recorded dried *Bohadschia marmorata*, *B. subrubra*, and *Stichopus quadrifasciatus* for the first time in East Kalimantan. Understanding these newly recorded commercial species in this region will help the local management authority compile species-specific trading data. Ossicles observation provides an effective method for identifying *trepang*, particularly in coastal areas where access to advanced laboratory facilities is limited. Therefore, we recommend ossicle examination as an important addition to the species identification of dried sea cucumbers, which are difficult to identify morphologically. This will support regulatory controls and clearance processes, as part of efforts to conserve biodiversity stocks for the sustainable use of sea cucumber species-specific.

Introduction

Trepang refers to certain species of valuable dried sea cucumber commodities. *Trepang* is traded globally in its dried form as delicacy, especially in East Asian countries. Different countries have various local names for dried sea cucumbers, such as *bêche-de-mer* in France, *ikiro* in Japanese, *haisom* in Chinese and *trepang* or *teripang* in Malaysia and Indonesia (Arianto *et al*., 2023). Consuming *trepang* has traditionally been believed to offer health benefits, and scientific evidence now supports these claims (Wen *et al*., 2010). Consequently, international demand for sea cucumber products has been steadily increasing.

The key sea cucumber hotspots worldwide range from the central and northwestern parts of South America, the east coast of Africa and the Red Sea, to the West Indian Ocean Island countries, the Western Pacific, and Asia, including Indonesia (Bruckner, 2006). Sea cucumbers from the eastern coast of Borneo (Kalimantan, Indonesia), including South, West, and East Kalimantan, have been exploited since the 19th century (Atsushi, 2010). Previous studies have documented fresh or live sea cucumber species from Derawan Island, East Kalimantan (Setyastuti *et al*., 2019) and Melahing waters, East Kalimantan (Ritonga, 2010). However, reports on the *trepang* from East Kalimantan remain limited.

In Indonesia, *trepang* fisheries are extensive due to the high demand from international markets (Wirawati *et al*., 2021). In 2014, Hong Kong imported up to 4000 tons of *trepang* from various countries, with Indonesia serving as the second largest importer (Conand, 2017). However, the lack of comprehensive and accurate data is a long-standing issue in Indonesia, such as information on the species-specific list in export data (Setyastuti and Purwati, 2015). One of the contributing factors is the limited information on species correctly identified in trade (Setyastuti, 2014; Setyastuti *et al*., 2018, 2019). Based on field observations by the Coastal and Marine Resources Management Center (CMRMC) for Pontianak, it was noted that *trepang* traders in the East Kalimantan region name their products solely based on colors and patterns, such as *bintik, cera merah,* or *cera hitam*. These local names can mislead species identification and negatively impact conservation efforts for species-specific protection.

The species diversity and local names of *trepang* in Indonesia require meticulous and integrative efforts to resolve naming confusion in sea cucumber trading. Recently, the Ministry of Marine Affairs and Fisheries (MMAF), Indonesia has commenced an initiative to establish national commercial names for widely traded-*trepangs* in Indonesia. This initiative requires support through accurate species identification to ensure traceability and sustainability, particularly for species with declining stocks (Bruckner, 2006), and to mitigate trading frauds (Patantis *et al*., 2019).

Identifying *trepang* can be challenging because they often lose their natural color and shape during processing (Purcell *et al*., 2023). Another taxonomically validated method for identifying sea cucumbers is

through the observation of ossicle shape and composition (Setyastuti and Purwati, 2015; Setyastuti *et al*., 2019; Wirawati *et al*., 2019; Keipour *et al*., 2023). Ossicle shapes and compositions are unique to each sea cucumber species, providing essential tools for accurate identification. These distinctive features may even lead to the discovery of a new species (Teoh and Woo, 2022; Setyastuti *et al*., 2024a; Yamana and Hirabayashi, 2024). Despite the possibility of damage during processing, ossicles are more resistant compared to other body structures, and sufficient ossicle remnants are typically preserved for reliable species identification. Therefore, identifying *trepang* through ossicle observation is essential, adding the morphological characteristic that should be considered by the local management authority. Through detailed observations of *trepang* appearance and ossicle features, this study aims to document the species of *trepang* traded in East Kalimantan, Indonesia.

Materials and methods

Sampling

A total of 24 dried specimens (*trepangs*) were collected from local suppliers in East Kalimantan by the Coastal and Marine Resources Management Center (CMRMC) for Pontianak, under the Ministry of Marine Affairs and Fisheries (MMAF) of Indonesia. Each morphologically distinct dried specimen was collected, regardless of its local name. The specimens represented the average sizes available from the suppliers. Each specimen was weighed and measured for length using a digital scale with an accuracy ±0.01 g and a stiff plastic ruler with precision ±1 mm, following Ram *et al*. (2014). The local names of the *trepangs* were also recorded. According to the local suppliers and collectors from whom the specimens were obtained, the *trepangs* were fished from Balikpapan, Bontang, Balikukup, Derawan, and Maratua (Fig. 1).

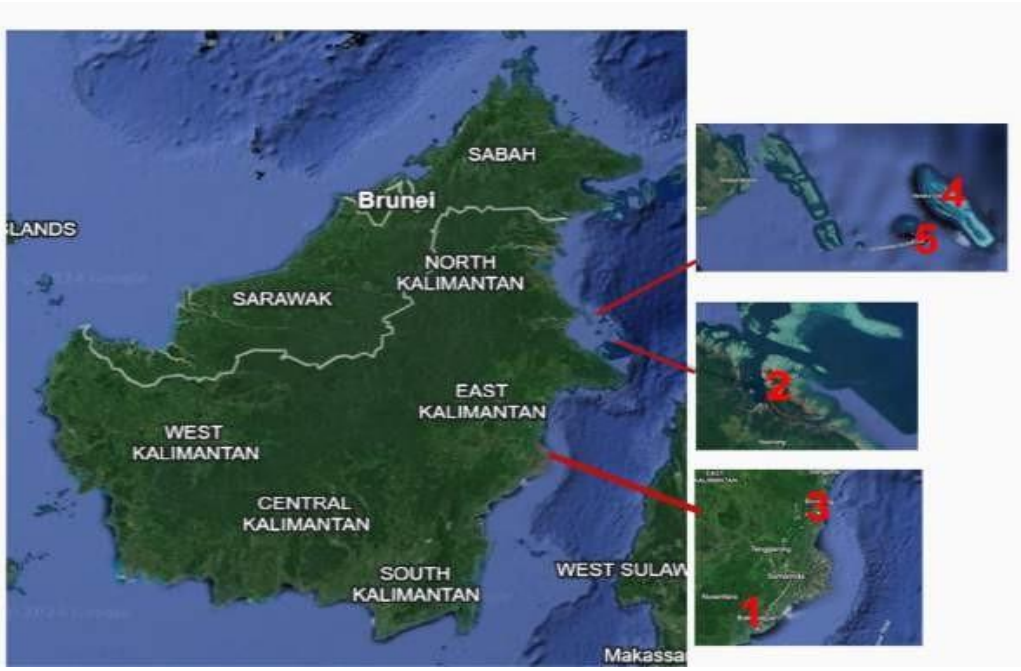

Figure 1: Sea cucumbers origin (1) Balikpapan waters; (2) Balikukup waters; (3) Bontang waters; (4) Maratua island waters; (5) Derawan island waters (Map source: Google Earth).

External morphology identification

The external morphology of each specimen was observed and documented by examining the body patterns and shapes following Purcell *et al*. (2023) and Di Simone *et al*. (2023). Measurements of body length and weight of the dried specimenswere carried out at the CMRMC for Pontianak in Balikpapan. Afterwards, the specimens were photographed and subsequently sent to the National Research and Innovation Agency in Cibinong, Bogor, for ossicle analysis.

Ossicles Identification of dried sea cucumber

Ossicle isolation was performed following Setyastuti *et al*. (2024a). Dorsal, ventral, and tentacle tissues of specimens were cut into pieces (5-10 mm^2) using a dissecting set and then placed on a microscope slide. The tissue was bleached using 5.25% sodium hypochlorite (Bayclin ®) for a maximum of 20 minutes to dissolve the ossicles. The ossicles were then rinsed three times with distilled water and preserved in 70% ethanol. Ossicles were observed and photographed using a compound microscope (Olympus BX-53) at 200-400x magnification andidentified based on existing literature.

Results

Twenty species were identified from 24 *trepang* specimens, comprising fifteen species from the family *Holothuriidae* and five species from the family *Stichopodidae* . Three species not previously reported scientifically in East Kalimantan were discovered: *Bohadschia marmorata*, *B. subrubra*, and *Stichopus quadrifasciatus.* Detailed identification of the specimens is described below:

Actinopyga echinites Jaeger, 1833

Material - BLP 7 and BLP 20

Dried appearance - Specimens 50 mm, 10 g and 85 mm, 50 g, respectively, both samples exhibited rusty-brown color dorsally and ventrally with wrinkled body wall, visible tentacle surrounding the mouth (Fig. 2A). Ossicles - Rosettes and rosette-rods on both dorsal and ventral surfaces. The rosettes are categorized into two types: small rosettes, which measure between 28.46 and 41.30 µm across, and large rosettes, which measure between 42.32 and 57.10 µm. Moreover, the size of the rosette-rods ranges from 18.68 to 83.32 µm. The tentacles are either straight or slightly arched and spiny, with a broad range of sizes (38.65 - 324.45 µm) (Fig. 3A).

Remarks - The appearance and ossicle characteristics of both samples were consistent with those of *A. echinites* (Massin, 1996; Purcell *et al*., 2023; Khatulistiani *et al*., 2024).

Actinopyga lecanora Jaeger, 1833

Material - BLP 10

Dried appearance - Specimen 70 mm, 50 g, body wall smooth and no wrinkles, color dark brown with a lighter spot through its body to the anterior ends, specific beige color around its anus, and unobservable anal teeth. Ossicles - Rosettes of various sizes at the dorsal and ventral surfaces. BLP 10 showed a notable absence of rod-rosettes typically found in other *Actinopyga* species. In addition, isolation of tentacle ossicles from BLP 10 was quite

challenging, resulting in incomplete characterization of its ossicles (Fig. 3B).

Remarks - Based on external appearance and ossicle observation, this specimen is indeed *A. lecanora* (Massin, 1996; Purcell *et al*., 2023; Khatulistiani *et al*., 2024).

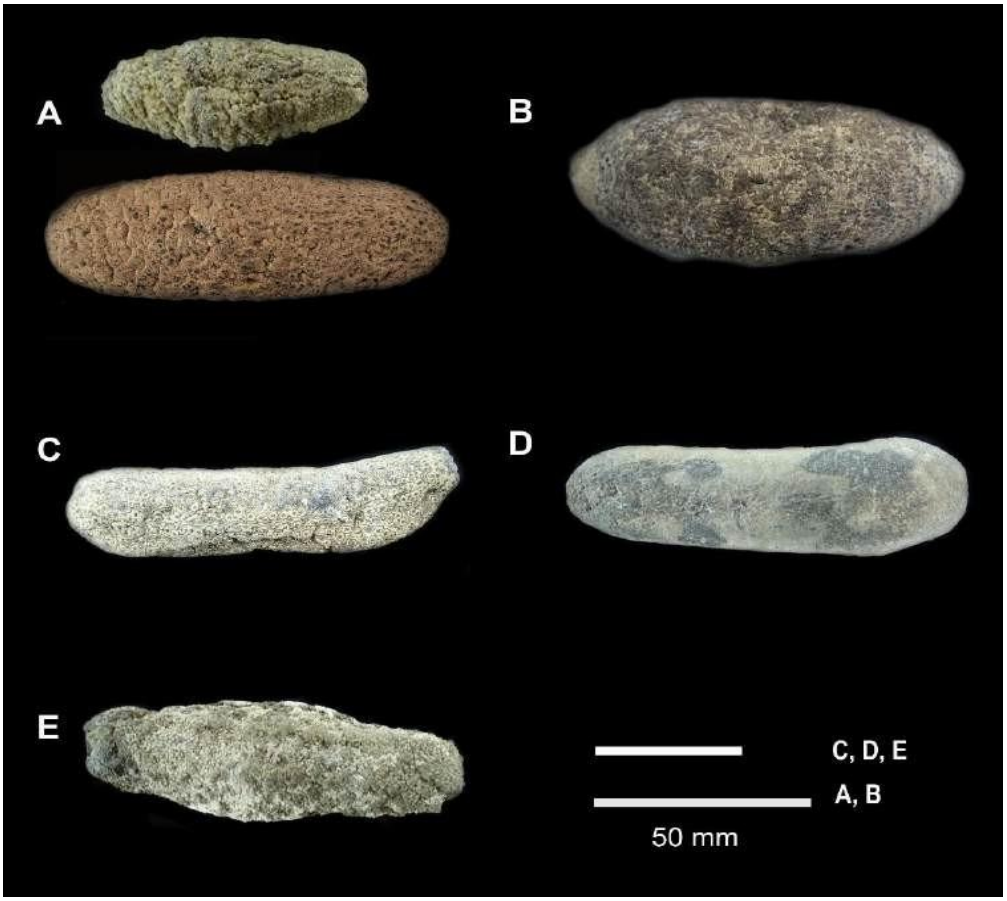

Figure 2: (A) *Actinopyga echinites*; (B) *A. lecanora*; (C) *Bohadschia argus*; (D) *B. marmorata*; (E) *B. Subrubra*.

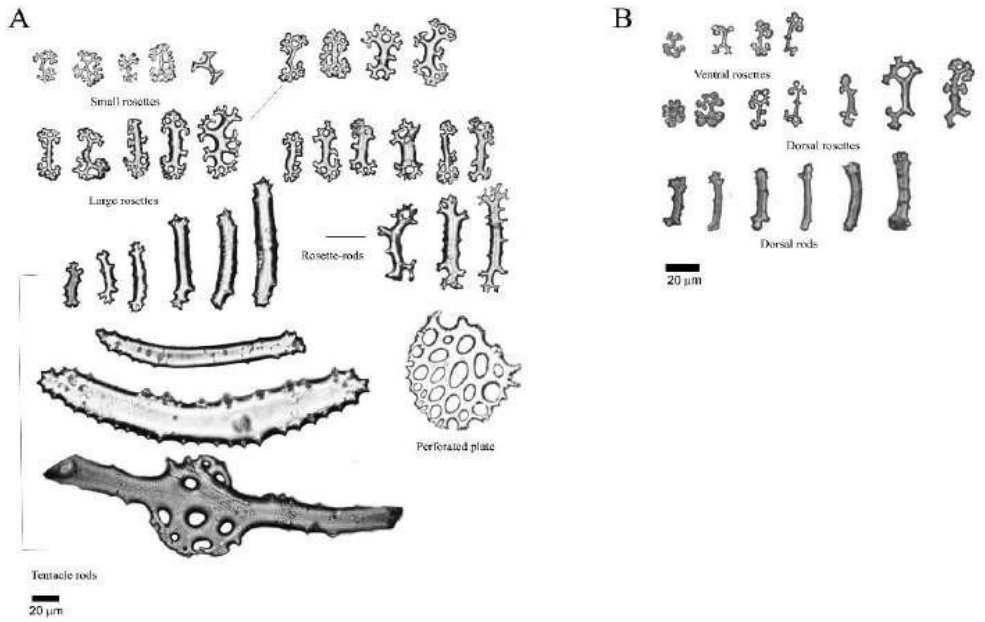

Figure 3: Ossicle of (A) *Actinopyga echinites* and (B) *A. lecanora*.

Bohadschia argus Jaeger, 1833
Material - BLP 12
Dried appearance - Specimen 130 mm, 100 g, cylindrical body shape, rounded at both the anterior and posterior ends. Dorsal to lateral covered by beige blotches (2-6 mm across) with a black spot and a regular shape. The ventral surface was dark-colored and flattened (Fig. 2C).
Ossicles - Small, simple rosettes (8.60 - 20.37 µm), grains and perforated grains (10.85 - 18.62 µm) at the dorsal and ventral. Rods ranging from 13.99 to 42.68 µm at the ventral. A fraction of large, spiny rods in tentacles (size could not be observed) (Fig. 4A).

Remarks - In this study, the appearance and ossicles of the specimen were consistent with those of *B. argus* (Kim *et al*., 2013; Sese and Wirawati, 2018; Wirawati *et al*., 2019).

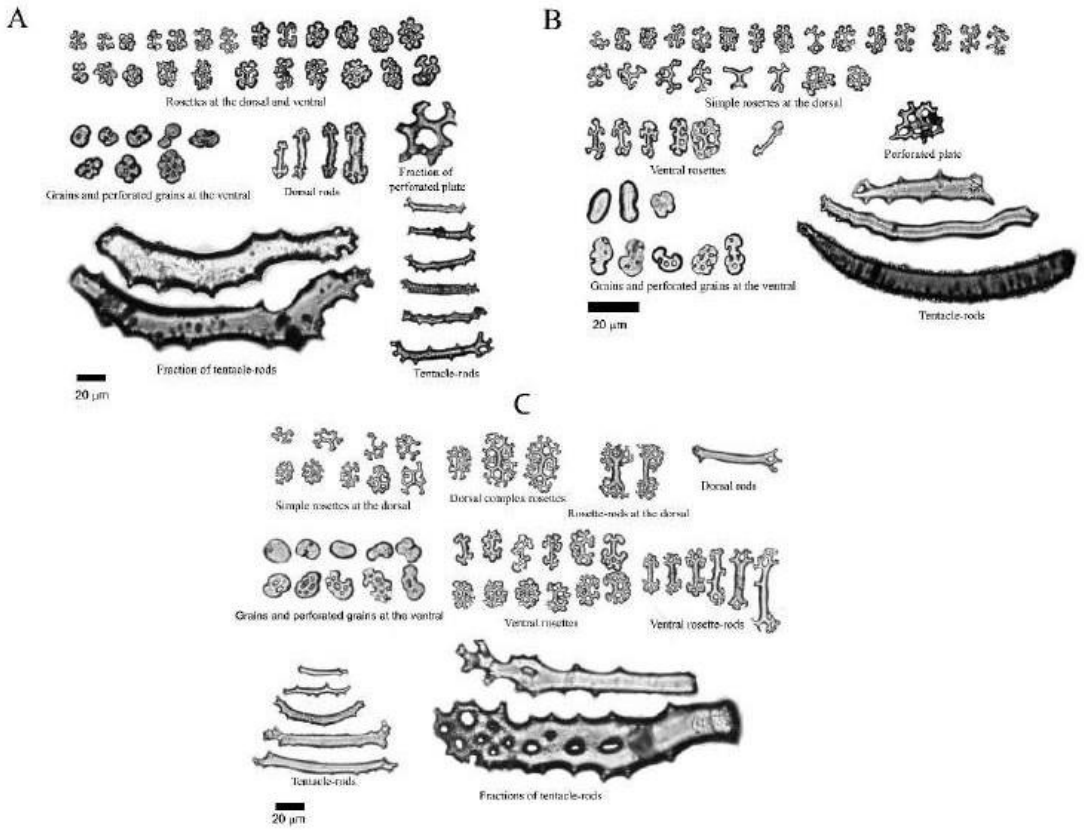

Figure 4: Ossicles of (A) *Bohadschia argus*; (B) *B. marmorata*; and (C) *B. Subrubra*.

Bohadschia marmorata Jaeger, 1833
Material - BLP 11
Dried appearance - Specimen 120 mm, 80 g, cylindrical body, rounded shape at the posterior and anterior ends, arched dorsally, flattened ventrally. Brown coloration at the background with a darker, symmetrical pattern at the dorsal, lighter at the ventral (Fig. 2D).
Ossicles - Simple rosettes (11.11 to 30.82 µm) in the dorsal and ventral regions. Grains (21.31 - 33.37 µm) and perforated grains (17.74 - 25.08 µm) in the ventral region. Spiny extremities rods at the tentacles (Fig. 4B).

Remarks - Based on external appearance

and ossicle analysis, this specimen is identified as *B. marmorata* (Clouse *et al*., 2005; Kim *et al*., 2013; Wirawati *et al*., 2019; Purcell *et al*., 2023).

Bohadschia subrubra Quoy & Gaimard, 1834

Material - BLP 4

Dried appearance - Specimen 120 mm, 95 g, cylindrical body shape, rounded body at the posterior and anterior ends. Arched dorsally, flattened ventrally. Irregular dark blotches with beige background at the dorsal, lighter color at the ventral (Fig. 2E). Ossicles - Dorsal and ventral consist of simple and complex rosettes (12.98 - 19.51 µm and 20.60 - 41.69 µm, respectively), rods (23.35 - 60.80 µm), grains (6.23 to 24.72 µm), and perforated grains (17.55 to 24.55 µm). The tentacles possessed spiny, perforated extremities (33.16 to 98.88 µm) and a fraction of larger tentacle rods (size could not be observed) (Fig. 4C).

Remarks - We presume that the fresh condition of dried BLP 4 had a rusty background with darker blotches on its dorsal surface, as well as Kim *et al*. (2013). Additionally, the ossicle profiles of this specimen are confirmed to be those of *B. subrubra* (Massin, 1999; Purcell *et al*., 2023).

Holothuria atra Jaeger, 1833

Material - BLP 8A and BLP 8B

Dried appearance - Specimens 70 mm, 10 g and 65 mm, 10 g, respectively. Both have a deep black color, a cylindrical body, transverse wrinkles on the dorsal, and a grainy surface at the ventral (Fig. 5A). Ossicles - Based on Figure 6A, rosettes and tables are present in the dorsal and ventral regions of both specimens. Small rosettes ranging from 11.62 to 17.18 µm. The table displays a maltese cross disc (30.64 - 45.41 µm), tall spires (45.98 - 62.15 µm), and four holes of perforated crowns (38.46 - 41.44 µm). A perforated plate and a fraction of a podia's pseudo plate were also found in the ventral region. Unluckily, the isolation of the specimen's tentacle was poor.

Remarks - The appearance of specimens was consistent with the dried *H. atra* described by Purcell *et al*. (2023), and their ossicle features align with those documented by Massin, (1996).

Holothuria coluber Semper, 1868

Material - BLP 21

Dried appearance - Specimen 145 mm, 20 g, elongated body, broader posterior, narrower anterior, dark grey coloration covered in white spots on both the dorsal and ventral sides. The white spots on the dorsal side are larger than those on the ventral side. Visible cream-colored tentacles around the mouth (Fig. 5B). Ossicles - See Figure 6B, tables and buttons at the dorsal and ventral. Tables have four short spires (30.30 - 62.93 µm), a spinous disc, and a spinous crown (52.94 - 76.84 µm and 25.33 - 42.73 µm, respectively). Buttons display irregular appearance with a spinose edge (32.40 - 68.04 µm across). The ventral also displays a rod with perforated extremities (124.70 µm). The tentacles contain arched rods with spiny extremities ranging from 69.45 to 162.83 µm.

Remarks- According to the ossicle observation of this specimen, it is identified as *H. coluber*, as it exhibited cup-saucer-like-tables, a key distinguishing feature of this species (Wirawati *et al*., 2019).

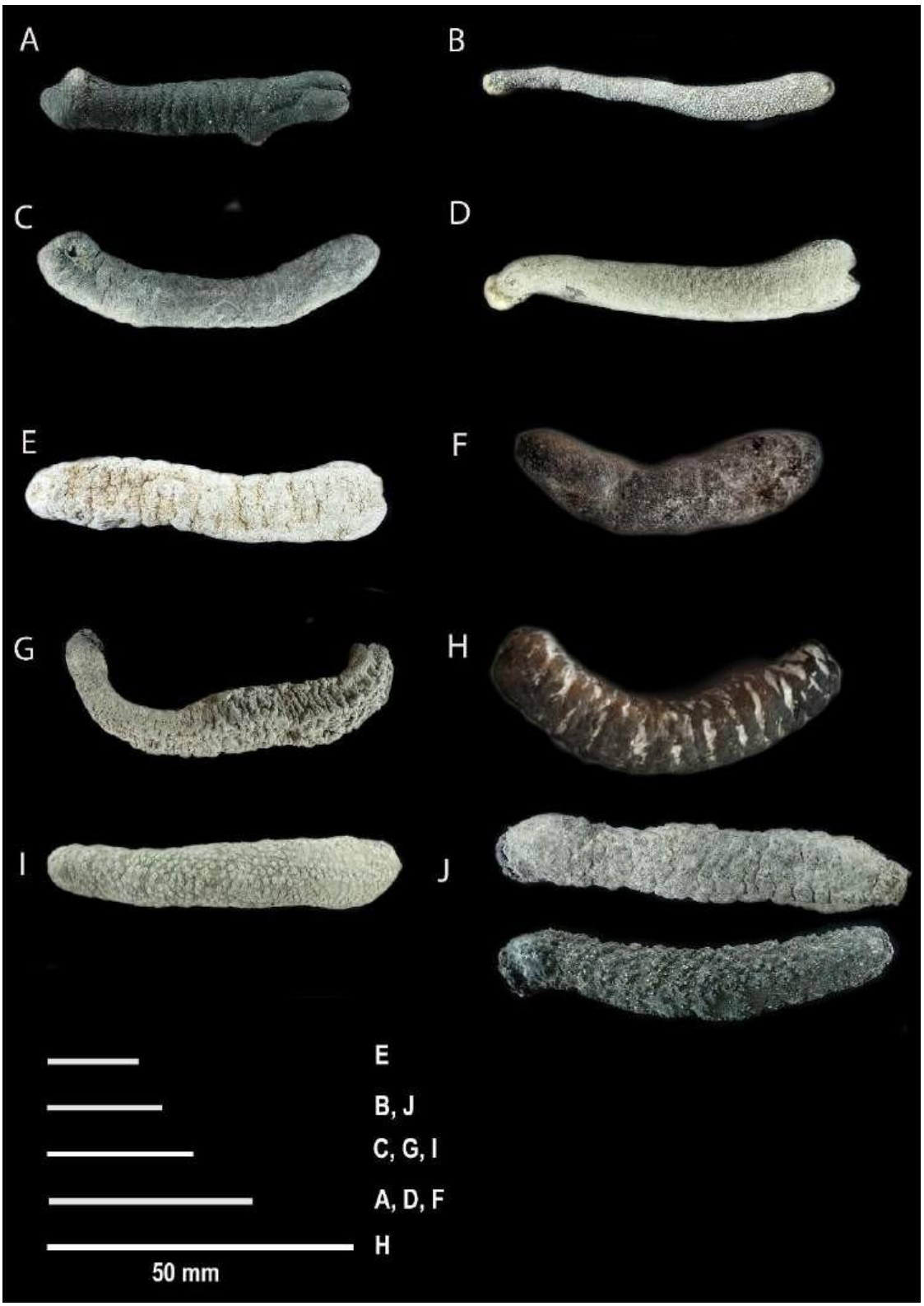

Figure 5: (A) ***Holothuria atra*****; (B)** ***H. coluber*****; (C)** ***H. edulis*****; (D)** ***H. fuscocinerea*****; (E)** ***H. fuscopunctata*****; (F)** ***H. lessoni*****; (G)** ***H. leucospilota*****; (H)** ***H. scabra*****; (I)** ***H. turriscelsa*****; and (J)** ***Pearsonothuria graeffei.***

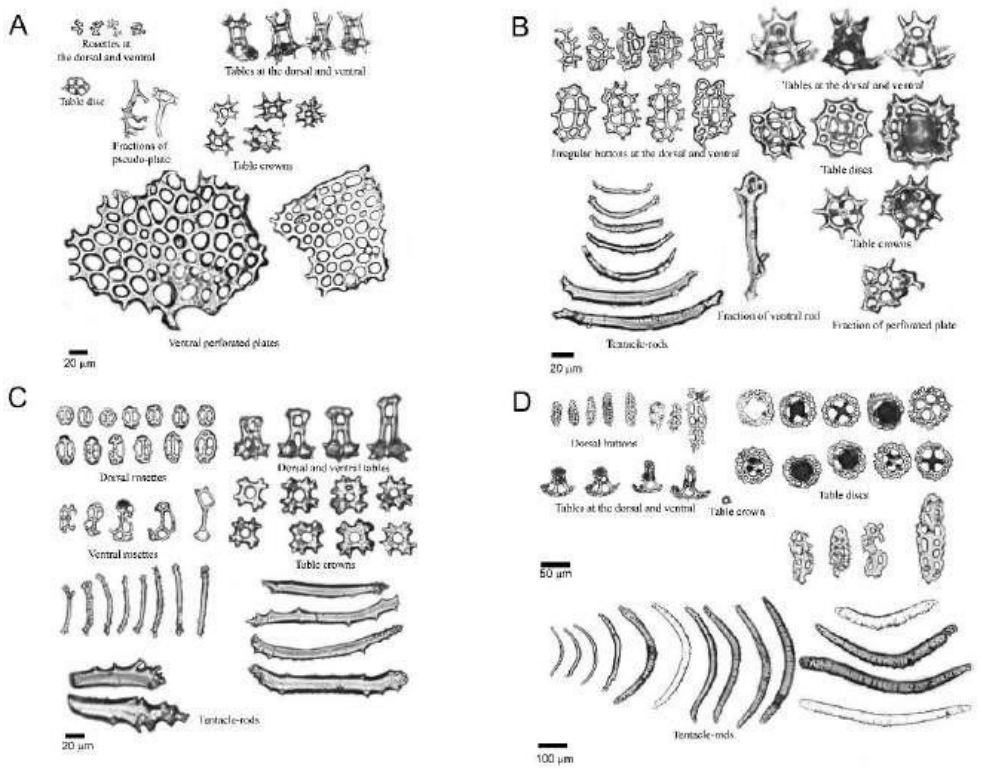

Figure 6: Ossicle profiles of (A) *Holothuria atra*; (B) *H. coluber*; (C) *H. edulis*; (D) *H. Fuscocinerea*.

Holothuria edulis Lesson, 1830

Material - BLP 17

Dried appearance - specimen 115 mm, 25 g, cylindrical body with both ends rounded, dark brown color dorsally, beige ventrally. The ventral surface was smoother than the dorsal (Fig. 5C).

Ossicles - Rosettes ranging from 21.97 to 34.8 µm, reduced tables with no disc, four tall spires (44.75 - 69.28 µm in height) and maltese crown (28.99 - 41.71 µm across) on both the dorsal and ventral. Spinous tentacle rods ranging from 63.19 to 166.72 µm in length (all documented in Fig. 6C).

Remarks - The appearance of this specimen was consistent with dried *H. edulis* described by Purcell *et al*. (2023), while its ossicle characteristics correspond with those documented by Massin, (1996).

Holothuria fuscocinerea Jaeger, 1833

Material - BLP 9

Dried appearance - Specimen 85 mm, 16 g. Elongated body and narrower at the posterior. Beige color dorsally, lighter ventrally. Tentacle visible (Fig. 5D).

Ossicles - Tables at the dorsal and ventral. Tables have four spires, small crowns (± 25.9 µm), and large discs (67.36 - 78.13 µm). Buttons display irregular appearance (39.56 - 63.57 µm). The tentacles contain arched rods ranging from 144.25 to 666.19 µm long (Fig. 6D).

Remarks - This specimen did not exhibit the small, reduced button described by Massin, (1996), but the shape of the other ossicles is identical to *H. fuscocinerea* (Khatulistiani *et al*., 2024).

Holothuria fuscopunctata Jaeger, 1833
Material - BLP 15
Dried appearance - Specimen 180 mm, 85 g, rounded body at both ends, beige color, transversely wrinkled surface on the dorsal side. Light brown, flattened ventral with a small black spot covering the entire body (Fig. 5E). Ossicles - Layered, ellipsoid buttons (64.45 - 108.09 µm), smooth, knobbed buttons with 3 to 4 pairs of holes (52.03 to 72.34 µm in length), short, small disc, spiny crown of tables at the dorsal and ventral. Most tables in BLP 15 were fragmented, and spiny plate fragments were present on the ventral. Spiny tentacle rods ranging from 49.98 to 177.51 µm at the tentacles (all can be seen in Figure 7A.

Remarks - Based on the observation, the appearance and ossicle profile of this specimen were indeed *H. fuscopunctata* (Setyastuti *et al*., 2019; Di Simone *et al*., 2023).

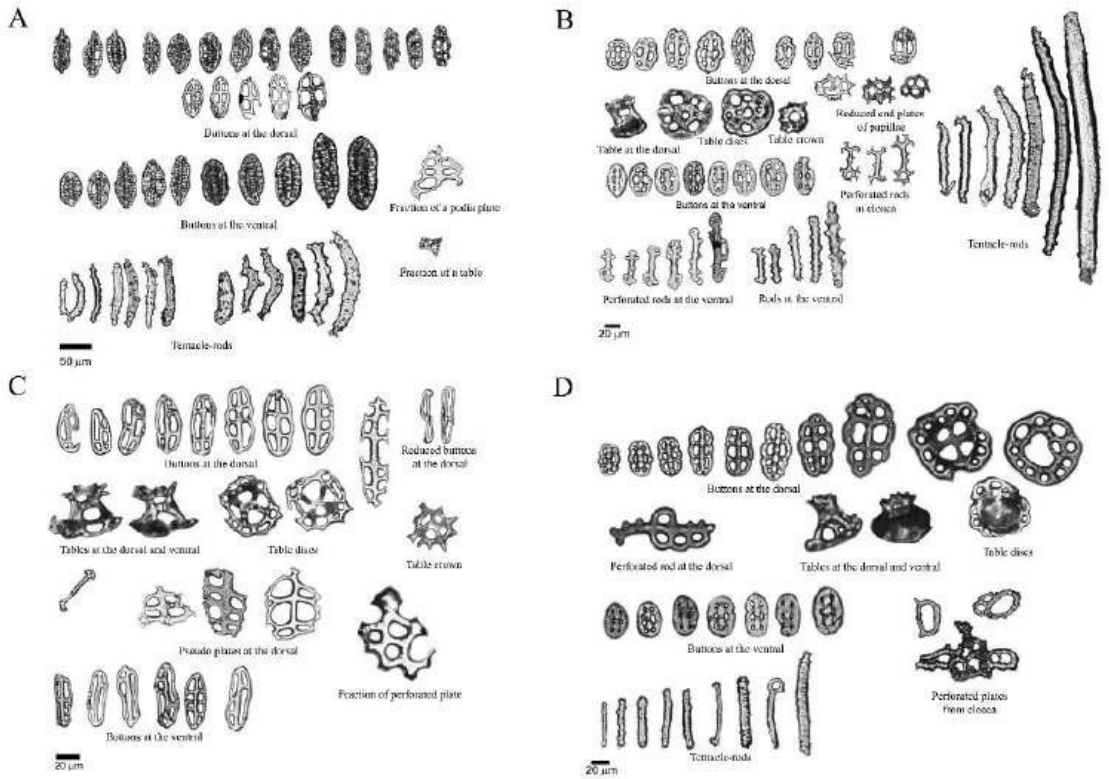

Figure 7: Ossicle profiles of (A) *Holothuria fuscopunctata*; (B) *H. lessoni*; (C) *H. leucospilota*; and (D) *H. scabra*.

Holothuria lessoni Massin, Uthicke, Purcell, Rowe & Samyn, 2009
Material - BLP 19
Dried appearance - Specimen 75 mm, 10 g, arched and smooth body, dark brown dorsally, lighter ventrally, smooth surface at the dorsal and ventral (Fig. 5F). Ossicles - According to Fig. 7B, buttons, tables, and rods were present on both the dorsal and ventral surfaces, while rods were observed in the tentacles. Buttons nodoulus (39.11 - 58.21 µm), tables 28.18 - 51.22 µm in height with quadrangular disc ranges 30.21 to 50.20 µm across, four spires and an extremely spiny crown. Dorsal and ventral rods with a couple or more holes on their centre, 49.27 - 86.88 µm in length. Perforated rods at the cloaca. Arched,

spiny, irregular extremity tentacle rods ranging from 55.56 to 415.54 µm.

Remarks - The specimen BLP 19 was locally named *gosok* by the collector. *Gosok* usually refers to *H. scabra*. However, our observation confirms that this specimen's absence of deep transverse wrinkles on the dorsal surface and exhibits wavy edges on its table ossicle. Those features were aligned to *H. lessoni* (Massin *et al*., 2009; Purcell *et al*., 2023).

Holothuria leucospilota Brandt, 1835
Material - BLP 22
Dried appearance - Specimen 90 mm, 25 g, body broader at posterior, narrower at anterior, grey dorsally, lighter ventrally, wrinkled at the dorsal surface and grainy at the ventral surface, visible tentacles surrounding the mouth (Fig. 5G). Ossicles - Smooth buttons with 2 - 4 pairs of asymmetrical holes, irregular reduced buttons, and tables at the dorsal, similar buttons and table types, pseudo tables and perforated plates at the ventral, absent tentacle ossicles. The length of all button types ranges from 39.48 to 62.20 µm. Tables short (29.46 to 46.95 µm), wavy or spiny table disc ranging from 29.29 to 58.55 µm across, disc has 4 - 11 peripheral holes and 4 large central holes, short spire, spinous crown (24.10 to 38.83 µm). The size of the pseudo-plates and perforated plates could not be observed in this study (Fig. 7C).

Remarks - The appearance and ossicle profile observation of this specimen are identical to *H. leucospilota* (Massin, 1999; Di Simone *et al*., 2023).

Holothuria scabra Jaeger, 1833
Material - BLP 18
Dried appearance - Specimen 55 mm, 10 g, arched and smooth body, brown, black dorsally, lighter ventrally. Transverse, deep wart-like at the dorsal surface, flattened at the ventral (Fig. 5H).
Ossicles - See Figure 7D, dorsal and ventral consist of buttons, tables and perforated rods. Dorsal buttons have smooth, nodulous, bumpy edges, with 3 - 5 pairs of holes (35.06 – 64.07 µm). Ventral buttons have smooth edges, 3 pairs of holes, smaller in size, ranging from 38.17 to 46.9 µm. Tables consist of smooth disc (66.80 - 83.19 µm), spire, and blunt-spine crown (28.06 - 56.21 µm). Perforated rods 76.05 - 71.00 µm in length. Spiny tentacle rods ranging from 65.93 to 16.17 µm. At the anal part, spiny, perforated plates from the cloaca (size was not observed).

Remarks - Based on morphology and ossicle observation, this specimen is accurately confirmed as *H. scabra* (Khatulistiani *et al*., 2022; Purcell *et al*., 2023).

Holothuria turriscelsa Cherbonnier, 1980
Material - BLP 6
Dried appearance - Specimen 110 mm, 35 g. Grey brown coloration, wart-like surface with small bumpy papillae on the dorsal. Lighter color with scattered small tubular feet on the ventral side. Visible tentacles (Fig. 5I). Ossicles - See Figure 8A, long, layered buttons forming three-dimensional structures at the dorsal and ventral (63.45 to 75.14 µm and 60.95 to 135.92 µm, respectively). Tables consist of four spires (62.18 to 74.07), large spiny discs with numerous peripheral holes (74.25 to 99.73

μm) and small crowns (17.63 - 32.13 μm). Additionally, large, irregular buttons 124.10 to 137.78 μm in length and 81.81 to 53.90 μm in width at the ventral. Curved, spiny tentacle rods in the tentacles (56.42 up to 522.15 μm).

Remarks - Based on the specimen's appearance and ossicle characteristics, this specimen is identified as *H. turriscelsa* (Massin, 1999; Setyastuti *et al*., 2019).

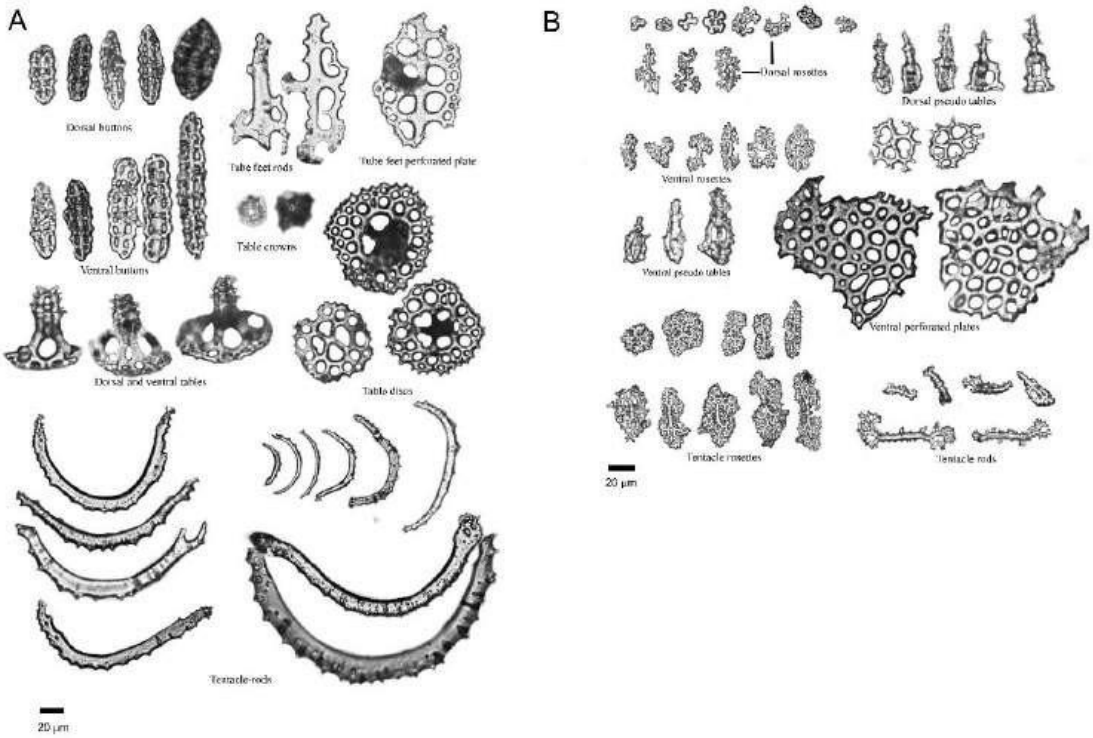

Figure 8: Ossicle profiles of (A) *Holothuria turriscelsa* and (B) *Pearsonothuria graeffei*.

Pearsonothuria graeffei Semper, 1868

Material - BLP 13, BLP 14A, BLP 14B

Dried appearance - BLP 13, BLP 14A and BLP 14B measure 130 mm (55 g), 120 mm (30 g), and 90 mm (25 g), respectively. All specimens exhibit similar appearances. Dorsally, dark brown color, wrinkled surface. Ventrally, dark brown color, three rows of ambulacral tube feet. Visible black tentacles around the mouth (Fig. 5J). Ossicles - Simple, complex rosettes (11.33 to 50.94 μm) and knobbed pseudo-tables (43.81 - 63.15 μm) present dorsally and ventrally. Pseudo-table lacks disc and crown. Large, perforated plates are present ventrally. Tentacle rods (24.30 to 72.14 μm) and complex tentacle rosettes (44.24 to 62.56 μm) in tentacles (Fig. 8B).

Remarks - All three of the dried specimens in this study closely match those documented by Purcell *et al*. (2023). Notably, *P. graeffei* is also distinguished by its pseudo-table ossicles (Massin, 1996), which are present in BLP 13, BLP 14A, and BLP 14B.

Stichopus herrmanni Semper, 1868

Material - BLP 16

Dried appearance - Specimen 130 mm, 120 g, elongated, squarish at dorso-lateral with folded body wall, flattened at ventral. Cream coloration at both dorsal and

ventral. Black spots papillae are scattered on the dorsal surface with two rows of dark brown, bumpy papillae on the lateral (Fig. 9A). Ossicles - Only a limited number of ossicles were observed in this specimen. In the dorsal and ventral, only tables, rosettes and C-shaped rods were observed. The tables include a wavy disc with peripheral holes ranging from 32.10 to 55.09 µm across, four short spires and four edges of a doubled-spiny crown. Unfortunately, mainly rosettes and C-shaped ones were damaged, probably due to the processing. Even though this study successfully measured a complete rosette and C-shaped ossicles, with a measurement of 11. 83 µm and 13.92 µm, respectively. In the tentacle found arched, spinous tentacle rods ranged from 154.5 to 253.68 µm in length (Fig. 10A).

Remarks - Based on our observation, the appearance of this specimen was similar to dried *S. herrmanni* on Di Simone *et al*. (2023). Moreover, its ossicle profile was completely aligned to *S. herrmanni* (Massin, 1996; Woo, 2018).

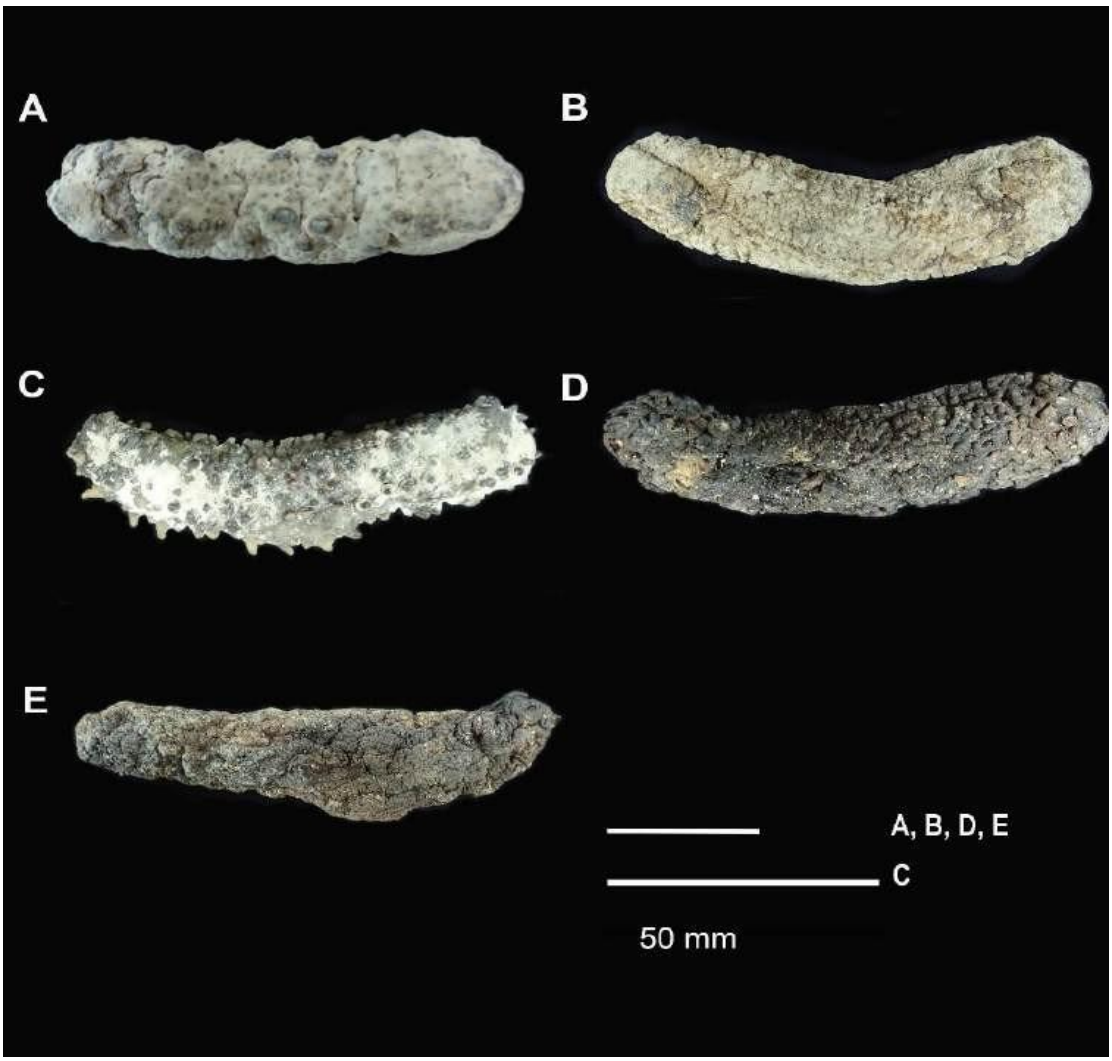

Figure 9: (A) *Stichopus herrmanni*; (B) *S. monotuberculatus*; (C) *S. quadrifasciatus*; (D) *Thelenota ananas*; and (E) *T. anax*.

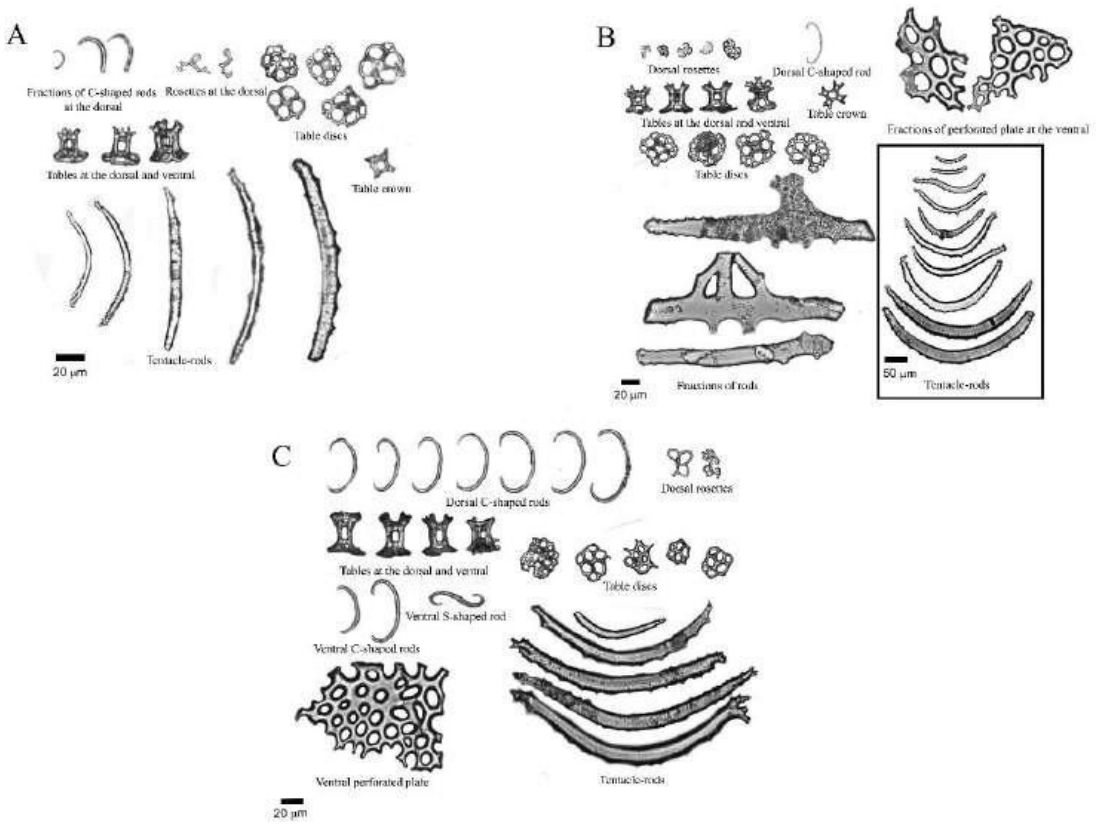

Figure 10: Ossicle profiles of dried (A) *Stichopus hermanni*.; (B) *S. monotuberculatus*; and (C) *S. quadrifasciatus*.

Stichopus monotuberculatus Quoy & Gaimard, 1834

Material - BLP 3

Dried appearance - Specimen 85 mm, 25g. Squarish body shape, dilated on the lateral. Color light brown with a darker spot from the tip of the dorsal papillae. Ventral smooth and flattened surface, visible tentacle (Fig. 9B). Ossicles - See Fig. 10B, the dorsal and ventral with rosettes, C shapes, tables and perforated plates. Mainly, rosettes and C-shaped were damaged. Rosettes 2.59 to 24.34 µm across; C-shaped ossicle ±99.59 µm. Tables contain disc ±40.54 µm; spire, 33.73 µm height; and maltese cross crown, 29.56 µm across. Moreover, rods are also found in the ventral. Ventral rods represent a unique feature, which is large and has two holes at its centre. Unfortunately, this study couldn't record the size of the ventral rod, considering its incomplete ventral rod morphology. Tentacles have arched rods which are spiny on one side and smooth on the other side (69.85 – 424.53 µm).

Remarks - Based on external appearance and ossicle analysis, this specimen is identified as *S. monotuberculatus* (Di Simone *et al*., 2023; Gray *et al*., 2023).

Stichopus quadrifasciatus Massin, 1999

Material - BLP 5

Dried appearance - Specimen 155 mm, 115 g, trapezoidal body shape, light brown at the dorsal, slightly darker at the ventral. Lateral papillae are larger than dorsal papillae and form a "wing-like" shape. Papillae on its lateral surface were bumpier than at the dorsal surface. Ventral was flattened; tentacles were visible (Fig. 9C). Ossicles -

See Figure 10C, tables, C-shaped and rosettes in both the dorsal and ventral. Tables contained a wavy disc (24.39 to 38.59 µm) with four large central holes, a spiny crown, and about 41.07 µm spires. C-shaped ossicles have various sizes from 19.84 to 61.74 µm. One-shaped ossicles and perforated plates are found in the ventral region. The tentacles are arched, spiny rods and branch rods.

Remarks - According to the appearance and ossicles characterization, this specimen belonged to *Stichopus quadrifasciatus*. This species has large lateral papillae and table ossicles that have four large central holes (Massin, 1999; Wirawati *et al*., 2019).

Thelenota ananas Jaeger, 1833
Material – BLP 2
Dried appearance - Specimen 160 mm, 100 g, trapezium body shape, dark brown dorsally with distinctive 'star-shaped' papillae. Slightly lighter ventrally, covered with small granular podia (Fig. 9D). Ossicles - Isolating the ossicles of BLP 2 proved challenging due to the broken ossicle resulting from processing. Ossicles of dorsal miliary petite grain 2 - 6 µm across, fractions of the dichotomous spiny branched±46.08 µm. In the ventral miliary petite grains and perforated plate. Spiny branched rods in the tentacle ranged from 63.32 to 111.95 µm high. Tentacle rods 28.83 to 60.42 µm (Fig. 11A).

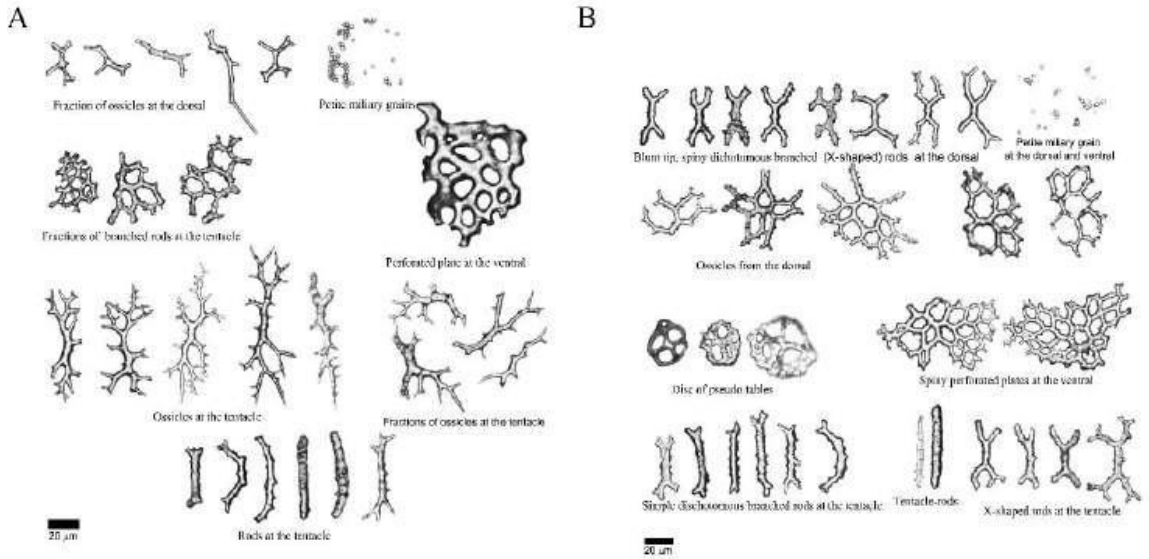

Figure 11: Ossicle profiles of (A) *Thelenota ananas* and (B) *T. anax*.

Remarks - The star-shaped papillae are a distinctive characteristic of *T. ananas* and remain visible in the dried product. The ossicle characteristic identification in this study was also identical to *T. ananas* (Wirawati *et al*., 2019; Purcell *et al*., 2023).

Thelenota anax Clark, 1921
Material - BLP 1
Dried appearance - Specimen 170 mm, 150 g, trapezium body shape, dark brown with a bumpy surface on the dorsal. Ventral was slightly lighter and covered with granular podia. Based on its appearance, there are no specific features of a certain species (Fig. 9E). Ossicles - Miliary petite grain 2 - 6 µm across, spiny dichotomous branched rods with a blunt tip or X-shaped 33.54 to 60. 33

µm, branched rods 53.97 to 86.53 across, and pseudo tables at the dorsal and ventral. This study did not observe the three dimensions of pseudo tables, even though the disc on pseudo tables was well documented. Some fraction of the large spiny perforated plates are on the ventral side. In the tentacles, dichotomous branched rods 47.01 to 53.83 µm and rods were observed (Fig. 11B).

Remarks - According to the appearance and ossicles characterization, this specimen belonged to *T. anax* (Massin, 1999; Di Simone *et al*., 2023).

Table 1 displays the local names of *trepangs* that were purchased during this study. Several specimens shared the same local namebut were identified as different species. For example, specimens BLP 3, BLP 5 and BLP 16 were all named as *kawasa*.

Table 1: Exploited species of trepang products from East Kalimantan, Indonesia.

Sample Code	Local name from the Collector	Identified species	International name (Purcell *et al*., 2023)	Catch Location*
BLP 1	Donga	*Thelenota anax*	Amber fish	2,4,5
BLP 2	Nanas	*T. ananas*	Prickly redfish	2,4,5
BLP 3	Kawasa	*Stichopus monotuberculatus*	-	1,2,3,4,5
BLP 4	Bintik	*Bohadschia subrubra*		1,2,3,4,5
BLP 5	Kawasa	*S. quadrifasciatus*	-	1,2,3,4,5
BLP 6	Kunyit	*Holothuria turriscelsa*	-	2,3,4,5
BLP 7	Mata tujuh or lado-lado	*Actinopya echinites*	-	3
BLP 8A; 8B	Hitam	*H. atra*	Lollyfish	1,2,3,4,5
BLP 9	Pisang	*H. fuscocinerea*	-	2,3,4,5
BLP 10	Kasur or kapok	*A. lecanora*	-	1,2,3,4,5
BLP 11	Bintik	*B. marmorata*	Brown spotted sandfish	1,2,3,4,5
BLP 12	Ginti	*Bohadschia argus*	Leopard fish	1,2,3,4,5
BLP 13	Pisang	*Pearsonothuria graeffei*	Blackspotted sea cucumber	2,3,4,5
BLP 14A; 14	Pisang	*P. graeffei*	Blackspotted sea cucumber	2,3,4,5
BLP 15	Kunyit	*H. fuscopunctata*	Elephant trunkfish	1,2,3,4,5
BLP 16	Kawasa or jagung	*S. herrmanni*	-	2,3,4
BLP 17	Cera merah	*H. edulis*	Pinkfish	1,2,3,4,5
BLP 18	Gosok	*H. scabra*	Sandfish	1,2,3,4,5
BLP 19	Gosok	*H. lessoni*	Golden sandfish	1,2,3,4,5
BLP 20	Mata	*A. echinites*	Deep water redfish	3
BLP 21	Talengko lado-lado	*H. coluber*	Snakefish	sea 2,3,4
BLP 22	Keling	*H. leucospilota*	White threads fish	2,3,4,5

Notes: *Catch location: 1= Balikpapan, 2= Balikukup, 3= Bontang, 4= Derawan, 5= Maratua

However, our observation of those specimens suggested that their appearance and ossicle profiles were identical to *Stichopus monotuberculatus* (BLP 3), *S. quadrifasciatus* (BLP 5) and *S. herrmanni* (BLP 16). Similarly, BLP 4 and BLP 11 were both named as *bintik*; yet our identification revealed BLP 4 as *Bohadschia subrubra* and BLP 11 as *B. marmorata.* Moreover, BLP 6 and BLP 15 were named as *kunyit*, but both specimens were identified as *Holothuria turriscelsa* (BLP 6) and *H. fuscopunctata* (BLP 15). Furthermore, BLP 9, 13, 14A, and 14B

were locally named as *pisang*, yet our analysis showed that BLP 9 was *H. fuscocinerea, while* BLP 13, 14A and 14B were *Pearsonothuria graeffei.* Lastly, BLP 18 and BLP 19 were named *gosok,* yet it was indicated that BLP 18 was *H. scabra* and BLP 19 was *H. lessoni.*

Discussion

From the 24 specimens that we collected during this study, we have successfully identified 20 species of *trepang*, including the description of *Bohadschia marmorata*, *B. subrubra* and *Stichopus quadrifasciatus* which are reported from this location for the first time. Overall, the species described here belong to six genera, *i.e., Actinopyga*, *Bohadschia*, *Holothuria*, *Pearsonothuria*, *Stichopus* and *Thelenota* (see Table 1). These findings complement our previous study, which reported 15 species of *trepangs* from Derawan in 2019 (Setyastuti *et al*., 2019). The number of species collected from East Kalimantan in this study is represents about 36% of the total 55 species of *trepang* harvested in Indonesia (Setyastuti *et al*., 2024b), illustrating the species diversity in this respected area.

Our results illustrate the complexity of local names among fishers and collectors driven by changes in color, shape and texture of *trepangs* after processing. The duplicity of *trepang's* local names around Indonesia has also been documented in our previous study (Setyastuti *et al*., 2024b; Sjafrie *et al*., 2024). This local name confusion may lead to two major problems related to product fraud and conservation of wild stocks. Product fraud might occur when high-value *trepangs* are replaced by the lower-value ones for profit. Similarly, conservation efforts by the authorities can be challenging when the correct identification of *trepangs* is lacking.

According to the value categorization by Setyastuti *et al*. (2019), 30% of the total species in our study were categorized as high-value commodities (*i.e.*, *S. monotuberculatus, S. quadrifasciatus, S. hermanni, H. scabra and H. lessoni, and T. ananas*), 15% belong to medium value *trepangs* (*i.e., A. lecanora, A.echinites* and *B.subrubra*), and the rest were classified as low-value species. Popular commodities including *H. lessoni*, *H. scabra* and *T. ananas* are currently listed as endangered by the IUCN (Conand *et al*., 2013a; Hamel *et al*., 2013). However, *H. scabra* is not included in the CITES appendices due to its high aquaculture potential in artisanal ponds (Firdaus and Indriana, 2019). On the other hand, *S. herrmanni* is currently classified as vulnerable (Conand *et al*., 2013b), while the status of *S. monotubercalus* and *S. quadrifasciatus* is still undefined due to insufficient data. Following the uplisted of several *trepang* species (*i.e., H. fuscogilva*, *H. nobilis*, and *H. whitmaei*, *T. ananas*, *T. anax*, and *T. rubralineata*) in Appendix II of CITES, Indonesia is currently developing management measures via a quota system for wild catches at the national level. Recommendation of wild catch quota for sea cucumber has been introduced by the Indonesian scientific authority for *H. fuscogilva*, *H. nobilis*, *H. whitmaei*, *T. ananas*, *T. anax*, and *T. rubralineata* in 2021 (Wirawati *et al*., 2021). Additionally, the National Research and Innovation Agency (BRIN), as a

scientific authority, has proposed a standardized national naming system for common *trepangs* in 2024 (B-1157/IV/KS.00/2/2024), as managed by the Ministry of Marine Affairs and Fisheries of Indonesia. These joint efforts reflect Indonesia's commitment to ensuring sustainable sea cucumber management and enforcing conservation
of valuable sea cucumber species.

Conclusion

Our current study has successfully identified 20 species from 24 specimens of *trepangs* traded in East Kalimantan. We discovered species that had not been reported as commercial species in this region, including *Bohadschia marmorata*, *B. subrubra*, and *Stichopus quadrifasciatus*. Recognizing these newly recorded commercial species will help the local management authority in managing species-specific trading data. Thus, the conservation effort for the sustainable use of sea cucumber can be carried out more accurately.

Although some ossicles may be damaged during processing, the remaining ossicles often retain distinct features that allow identification at the species level. In this study, more than 90% of the collected specimens were successfully identified. Our findings are consistent with the previous study by Setyastuti and Purwati (2015), which successfully identified seven of eight dried specimens using ossicle observation from the dorsal and ventral body wall. This confirms that ossicle examination remains a robust and reliable method for trepang species identification, particularly in coastal areas where access to advanced laboratory equipment is limited. Therefore, as part of the government efforts to combat *trepang* fraud and enforce conservation and sustainable use of trepangs, we suggest including ossicle examination as a standard procedure in species identification for regulatory controls and clearance processes.

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Conflicts of Interest

No potential conflict of interest was reported by the authors.

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