

**TWO NEW HOLOTHURIANS
(ECHINODERMATA: HOLOTHUROIDEA)
FROM AN ANCHIALINE LAGOON OF AN UPLIFTED ATOLL,
KAKABAN ISLAND, EAST KALIMANTAN, INDONESIA**

Claude Massin and Tomas Tomascik

ABSTRACT.- Two new species of holothurians, *Holothuria (Lessonothuria) cavans* (Holothuriidae) and *Synaptula spinifera* (Synaptidae) are described from an anchialine lagoon on the raised atoll island of Kakaban, East Kalimantan, Indonesia.

INTRODUCTION

Raised coral islands are a common feature of the Indonesian archipelago, one of the most geologically active regions on the planet (Darwin, 1842; van Bemmelen, 1949; Effendi et al., 1981; Papp, 1981; Hantoro et al., 1994), yet raised atolls that have retained their former lagoons without surface connections to the sea are rare. With the exception of Rennell Island, Solomon Islands, whose lagoon (i.e. Lake Tegano) has lost its marine character (Wolff, 1970), Kakaban Island (lat 02°08'35"N, long 118°31'13"E) is the only documented raised atoll whose former lagoon has maintained its marine character through submarine connections (Kuenen, 1933; Tomascik & Mah, 1994). Molengraaff (1929) classified Kakaban Island, and the neighboring Maratua, as raised atolls rising from a submarine platform 200 to 300 m below sea level (Fig. 1). However, the geology of Kakaban Island (roughly 2.5 km wide and six km long) was first studied during the 1929-1930 -Snellius Expedition by Kuenen (1933), who suggested that the former atoll was formed during a slow subsidence of the Borneo shelf. At some point in recent geologic history the atoll was raised 40-60 m above present day sea level (Kuenen, 1947; van Bemmelen, 1949). The former lagoon has lost all surface connections with the adjacent sea, making it anchialine (i.e. "pools with no surface connection to the sea, containing salt or brackish water, which fluctuates with the tides"; sensu Holthuis, 1973). The absence of terraces on the seaward side of the elevated coral ridge suggested that this uplift was relatively fast and steady, although complicated by sea level fluctuations during the Pleistocene (Kuenen, 1947).

Claude Massin - Department of Invertebrates, Royal Belgian Institute of Natural Sciences, 29 rue Vautier, 1000 Brussels, Belgium. **Tomas Tomascik**- School for Resource and Environmental Studies, Dalhousie University, 1312 Robie Str., Halifax, N.S., Canada.

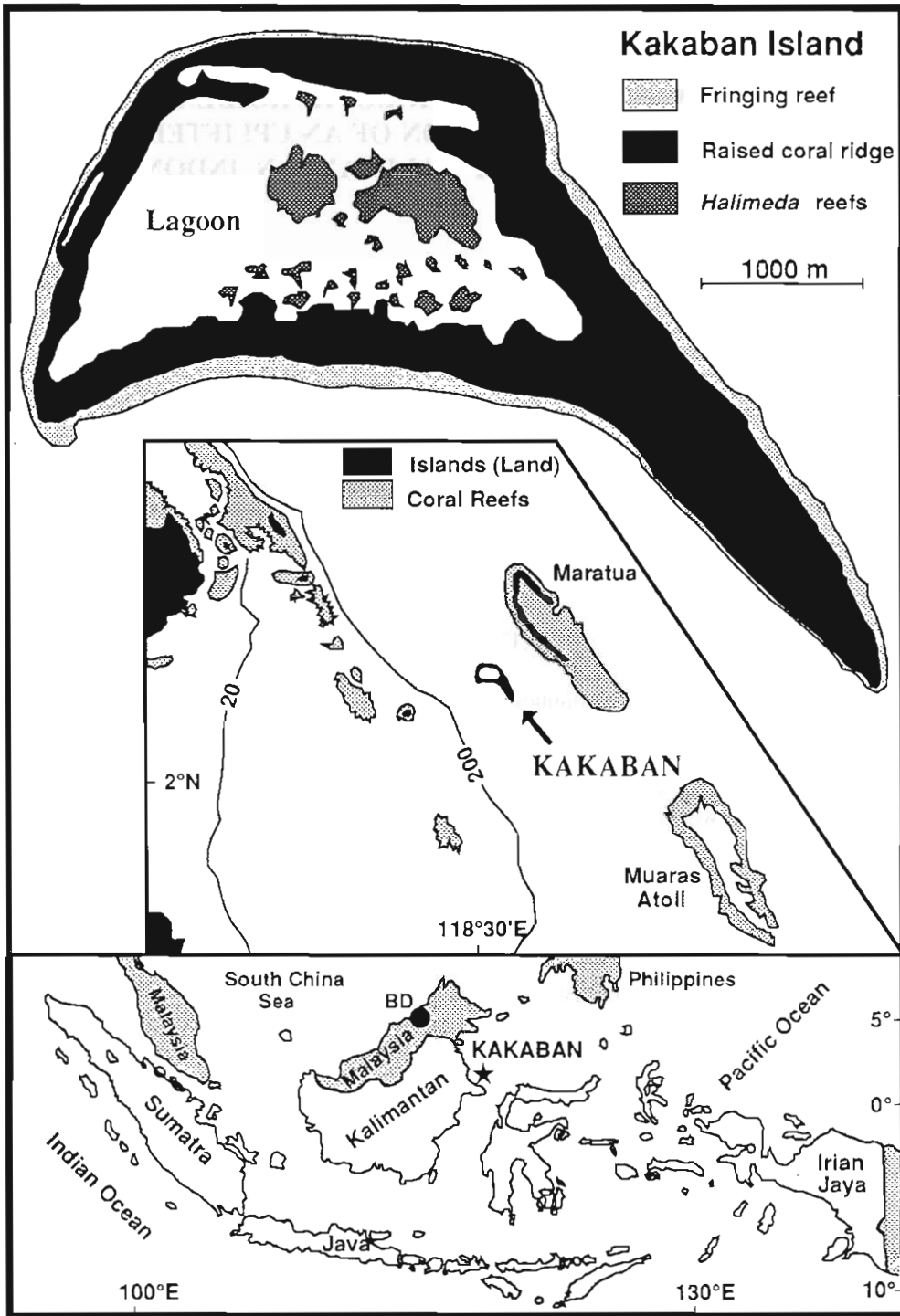


Fig. 1. Map of Indonesia (bottom), location of Kakaban Island on the east coast of East Kalimantan (centre) and map of Kakaban Island constructed from oblique photographs and video (courtesy of R. Holland). BD (in the bottom map): location of Brunei Darussalam.

With regards to its geologic history, Kakaban Island is comparable to Dana Island, a raised atoll in the Sawu Sea, Indonesia (Molengraaff, 1929). However, the bottom of the former lagoon of Dana Island was raised a few meters above present day sea level and thus, with the exception of two small saline lakes, the lagoon has dried up (Molengraaff, 1929). In comparison, Kakaban Island contains a large anchialine lagoon (1.5 km wide and 2.6 km long) that is completely encircled by a densely vegetated coral limestone ridge (Kuene 1947). The low salinity (26 to 28 psu or physical salinity units = ‰) lagoon is 11 m deep and has a tidal amplitude of 0.19 m (Tomascik & Mah, 1994). It has been estimated that the tidal flushing of the lagoon is less than 2.5% of the total lagoon volume per tidal cycle (Tomascik & Mah, 1994).

The ecology of Kakaban lagoon has been described only recently (Tomascik & Mah 1994). Kakaban lagoon was named 'Halimeda Lagoon', because of great profusion of two species of Halimeda: i.e. *Halimeda opuntia* (Linnaeus) Lamouroux f. *trilobata* (Decaisne) J. Agardh, 1887 and *H. tuna* (Ellis & Solander) Lamouroux, 1816. *H. opuntia* forms extensive meadows throughout the lagoon, while *H. tuna* is restricted to the mangrove stilt roots where it forms 'living walls' (Tomascik & Mah, 1994). The shallow parts of the *Halimeda* meadows are heavily over-grown by a green epiphytic algae, *Enteromorpha clathrata* (Roth) Greville, 1830, which is attached to the thalli of *H. opuntia*.

The lagoonal sediments may be grouped into three types, namely: 1) dark sediments (20.8% organic content) found exclusively under the stilt roots of *Rhizophora mucronata* Lamarck, 1804, consisting primarily of mangrove detritus, some weathered beach rock mixed with *Halimeda tuna* sand and molluscan shell fragments; 2) fine organic rich muds (23.2% organic content) of the deeper parts of the lagoon; and 3) pure calcareous sediments (4.5% organic content) consisting mostly of *Halimeda* sand and molluscan shell fragments (Tomascik & Mah, 1994). The lagoon is fringed by a narrow mangrove belt consisting mainly of *Rhizophora* spp., *Bruguiera* spp., *Sonneratia* spp. and *Avicennia* spp. (Tomascik & Mah, 1994). Only one coral species, restricted to small areas where salinity reaches 30 psu, is present.

The dominant pelagic organisms in the lagoon are two species of non-stinging jellyfish: *Mastigias* cf. *papua* (Lesson, 1829) and *Aurelia aurita* (Linnaeus, 1746) that occur in great abundance, a situation that is very similar to the Jellyfish Lake in Palau, Micronesia. In addition, the lagoon contains a small non-stinging cubomedusan, *Tripedalia cystophora* Conant, 1897, and a single benthic jellyfish *Cassiopea ornata* Haeckel, 1880 (P.F.S. Cornelius, pers. comm.; Tomascik & Mah, 1994). The lagoon also contains an unusual, and as yet undescribed (den Hartog et al., in preparation) jellyfish-eating sea anemone (Actiniaria), which however differs from the jellyfish-eating sea anemone, *Entacmaea medusivora*, found in the Jellyfish Lake, Palau (Fautin & Fitt, 1991). Ng & Tomascik (1994) have recently described a new genus and species of varunine crab (*Orcovita saltatrix*) and Kott (1995) a new colonial ascidia (*Styela complexa*) from the lagoon.

In this very special environment, it is not surprising that only two species of holothurians are present. They are the subject of the present work.

SYSTEMATICS

FAMILY HOLOTHURIIDAE LUDWIG, 1894

Genus *Holothuria* Linnaeus, 1767

Subgenus *Lessonothuria* Deichmann, 1958

Holothuria (Lessonothuria) cavans, new species

(Figs. 2-4, Pl. 1A)

Material examined. - Holotype (Institut Royal des Sciences Naturelles de Belgique, Brussels: IRSNB, IG 28156/2/7), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May, 1994.

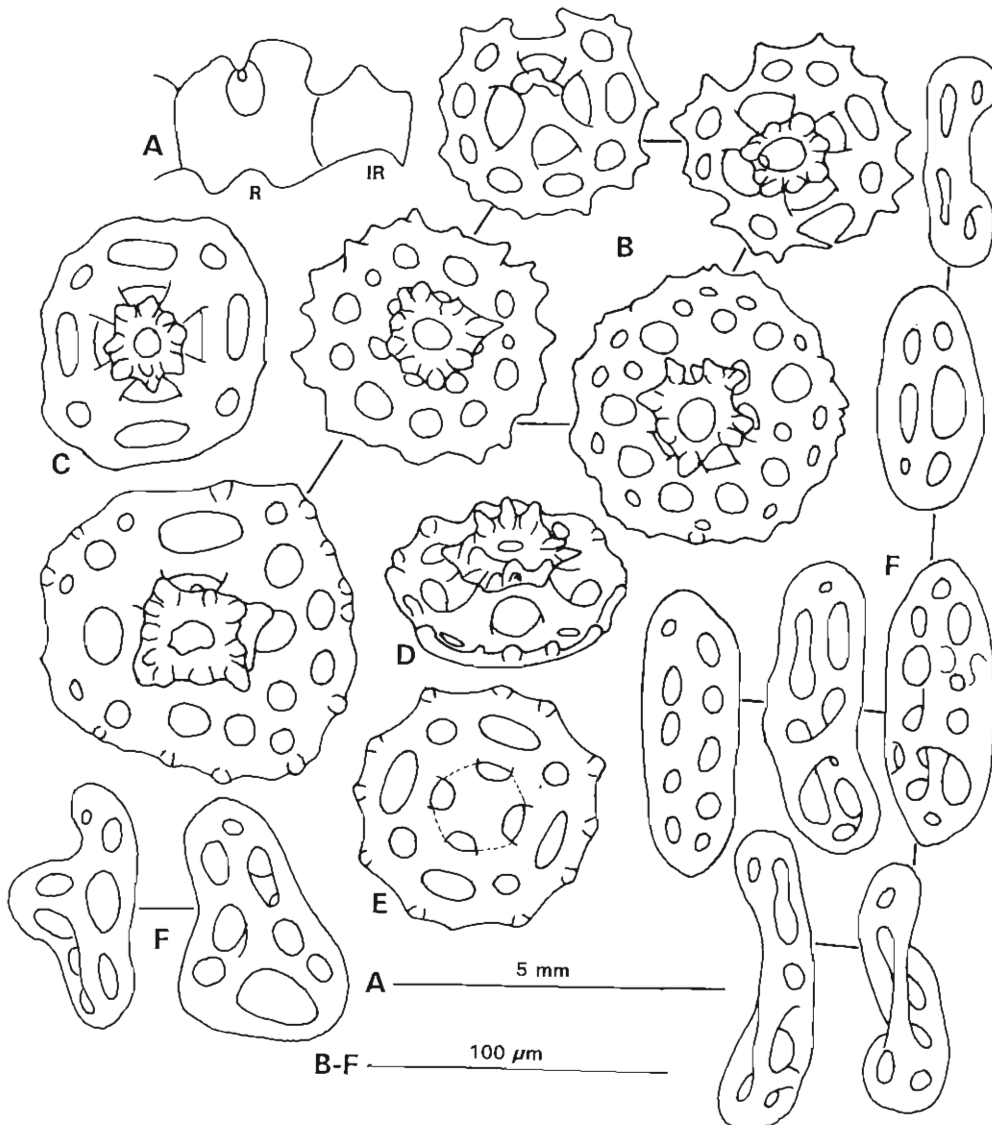


Fig. 2. *Holothuria (Lessonothuria) cavans*, new species. A: calcareous ring (R: radial piece; IR: interradial piece); B-E: tables of body wall; F: buttons of body wall.

Paratypes - five specimens (IRSNB, IG28156/2/1,4,8,9,10), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994.- two specimens (Museum Zoologicum Bogoriense, Bogor, Indonesia: MZB), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994.- two specimens (National Museum of Natural History, Washington D.C., USA: NMNH), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994. Moreover, tens of specimens were observed for the colour and ecological data.

Diagnosis. - Medium-size holothurian (39-75mm long); 18 peltate tentacles; darkish-silver-gray with some black brownish spots dorsally and light gray to white ventrally. Ossicles as tables, buttons and rods, tube feet without perforated plates; tables with low spire and without cross-beams; end plate of the tube feet small (125-180 μm in diameter).

Type locality. - Kakaban Island, East Kalimantan, Indonesia.

Description. - Medium-size holothurian, 39-75 mm long and 16-27 mm in diameter when in alcohol. Body more or less cylindrical, narrowing anteriorly; 18 peltate tentacles in one crown. Tube feet few, scattered all over both dorsal and ventral surface; however serial arrangement visible, particularly near the mouth. Tube feet long, conical, without terminal sucker, more abundant on ventral surface than on dorsal surface. Undisturbed individuals are always partially burrowed and are covered by a layer of fine sediment. Colour in life darkish silver-gray with barely visible black-brownish spots dorsally, and light gray to white ventrally (Pl. 1A).

Calcareous ring stout (Fig. 2A); interradial pieces with a median anterior projection; radial pieces with a median anterior notch and much wider than the interradial pieces. One long Polian vesicle (nearly 1/4 of body length); one very short contorted stone canal. No Cuvierian tubules.

Ossicles represented by tables, buttons and rods. Tables and buttons dorsally and ventrally in the body wall. Tables are 80-100 μm in diameter and 25-30 μm in height (Fig. 2B). Disc of the tables with one central hole and 8-11 peripheral holes. The most common tables have eight peripheral holes: four round and four oval (Fig. 2C). In the largest tables a second outer circle of small holes is present (Fig. 2B). Rim of the disc knobbed to spinose and turned up to give a "cup and saucer" aspect to the table in lateral view (Fig. 2D); four (sometimes three or five) very short pillars without cross-beam and ending in a cluster or a crown of spines (Fig. 2B). Some tables have the pillars reduced to a cross partitioning the central hole into three-four holes (Fig. 2E). Buttons are 60-100 μm long with three-five pairs of holes (Fig. 2F), often irregular with bridges and sometimes knobs. In the body wall, the buttons are gathered in heaps which appear as small white spots on the skin. These heaps are distributed all over the body and are very abundant.

Ventral tube feet and dorsal papillae with tables, buttons and rods. Tables (60-120 μm in diameter) are similar to those of the body wall (Fig. 3A). Buttons 80-140 μm long, as irregular as in the body wall (Fig. 3B). Rods 180-400 μm long, curved, very often with enlarged perforated extremities and sometimes with a central perforated process (Fig. 3C) or a spine. Tube feet with a terminal plate 125-180 μm in diameter. In the dorsal papillae, rods with a central spine are rare; some rods have bifurcated extremities (Fig. 4A).

In the tentacles, there are few ossicles. At the base of the shaft, some tables and rods similar to those of the tube feet; in the shaft, no ossicles; at the apex, only a few rods (70-140 μm long) which are arched and thorny (Fig. 4B).

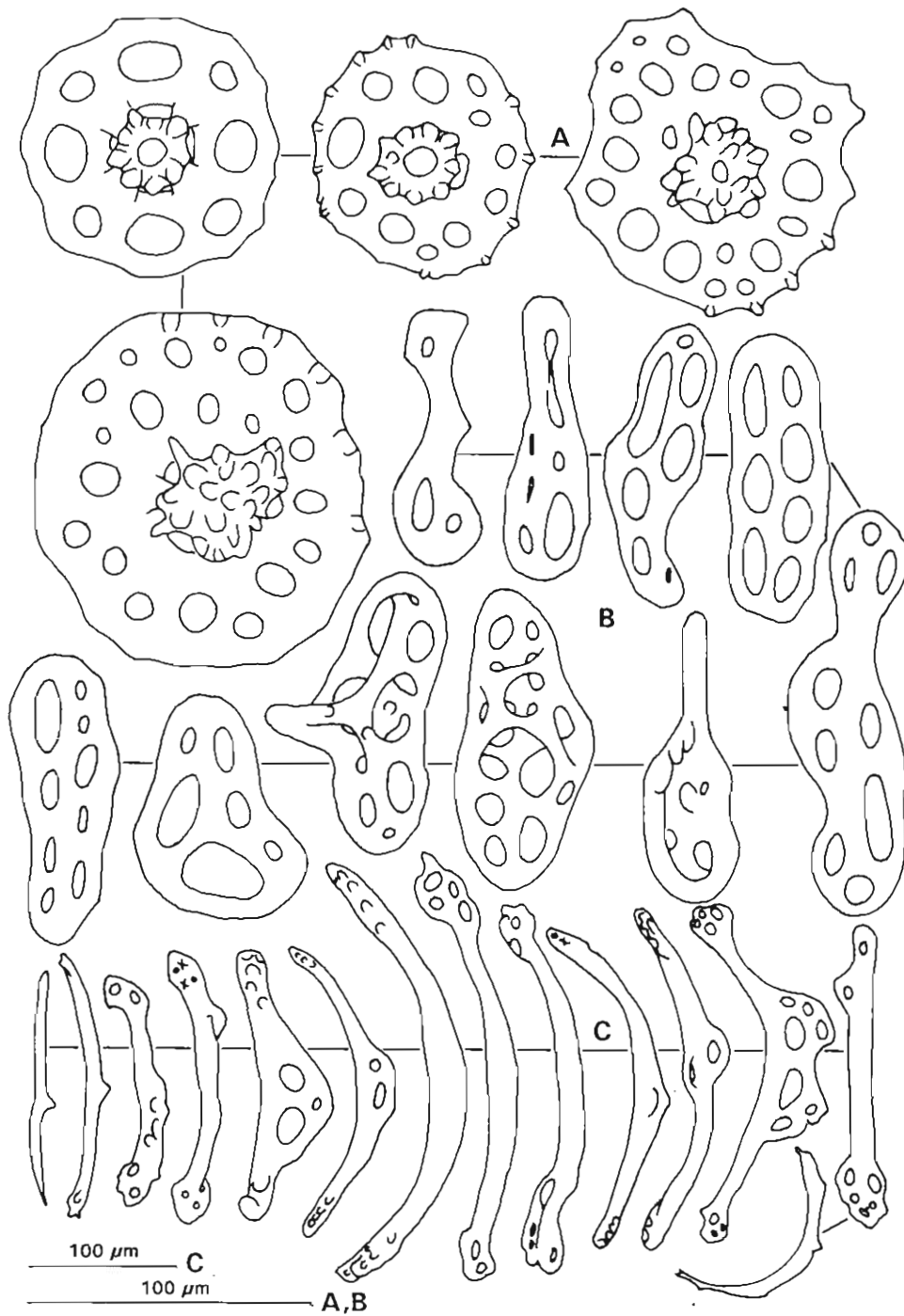


Fig. 3. *Holothuria (Lessonothuria) cavans*, new species. A: tables of tube feet; B: buttons of tube feet; C: rods of tube feet.

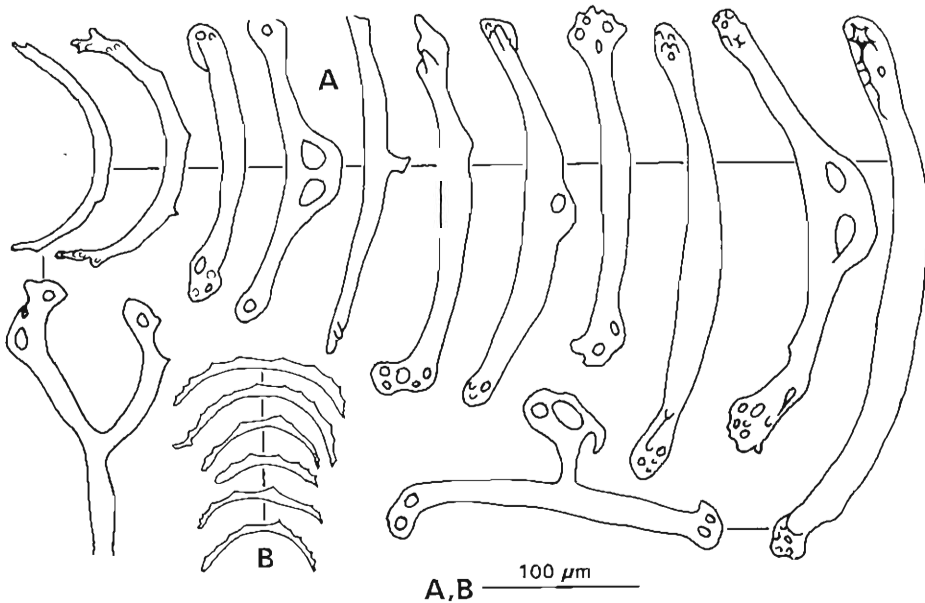


Fig. 4. *Holothuria (Lessonothuria) cavans*, new species. A: rods of dorsal papillae; B: rods of tentacles.

Etymology. - The name “*cavans*” is derived from the Latin verb “*cavare*” which means “to dig”. It refers to the burrowing habit of the species.

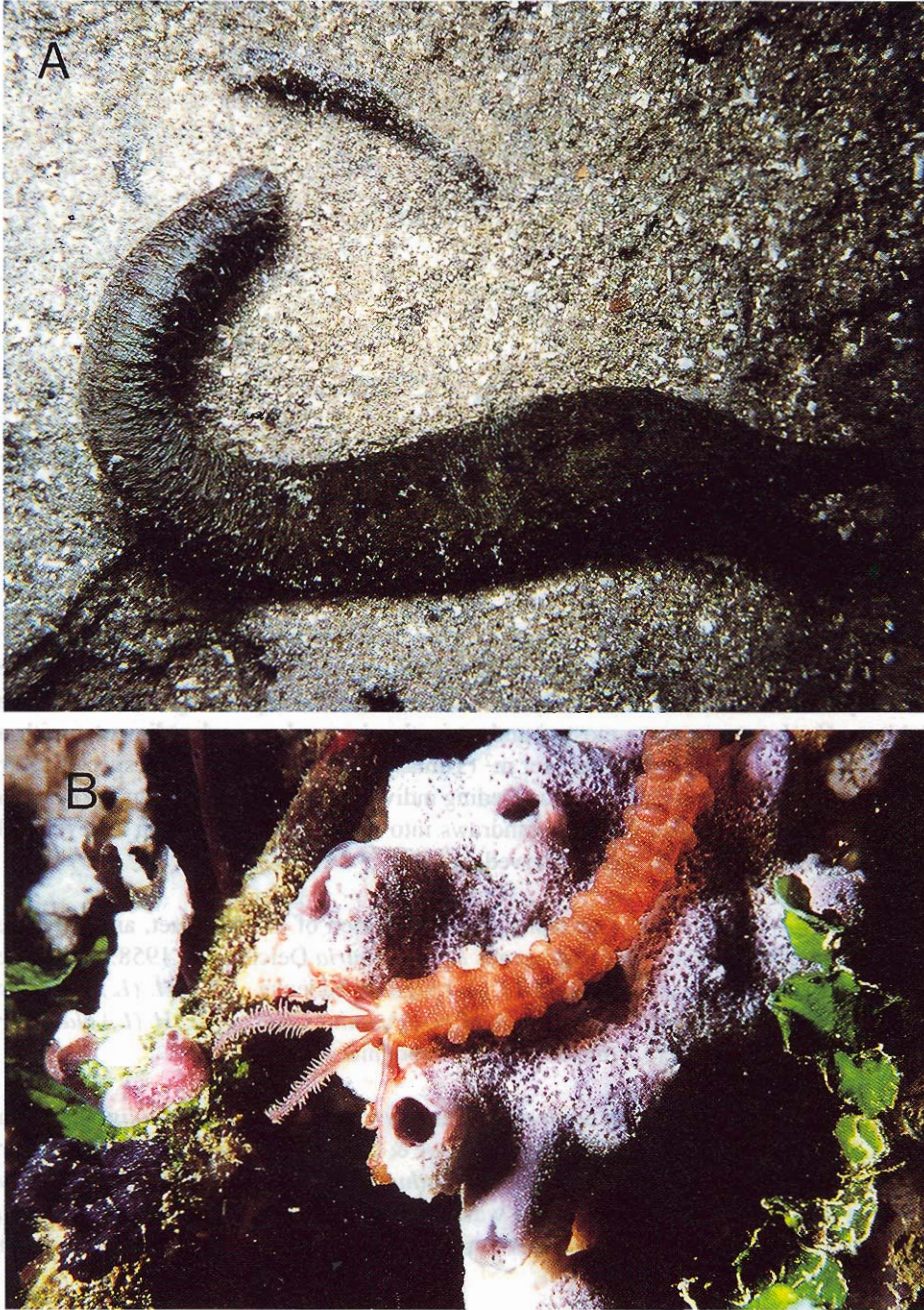
Biology. - *Holothuria (Lessonothuria) cavans*, new species, is a burrowing, deposit-feeding holothurian found throughout the lagoonal sediments. The specimens were collected from a depth of five m. However, the species has an observed depth range between 0.25 m and 11 m. *H. (L.) cavans* was most abundant in the deeper lagoonal sediments, with an average abundance of 0.8 individuals per m² (Tomascik & Mah, 1994). This species seems to feed continuously day and night, since feeding individuals were observed during both day and night. When disturbed it quickly withdraws into its burrow from which it never fully departs. No visible predators were observed.

Discussion. - The number of tentacles, the distribution of the tube feet, and the tables and buttons are characteristic of the subgenus *Lessonothuria* Deichmann, 1958. Six species are actually known in the subgenus viz: *H. (L.) pardalis* Selenka, 1867, *H. (L.) verrucosa* Selenka, 1867, *H. (L.) lineata* Ludwig, 1874, *H. (L.) cumulus* Clark, 1921, *H. (L.) glandifera* Cherbonnier, 1955, and *H. (L.) duoturricula* Cherbonnier, 1988.

H. (L.) insignis Ludwig, 1874, is considered as a synonym of *H. (L.) pardalis* by Panning (1935), Clark (1938), Cherbonnier (1951) and Rowe & Gates (1995). *H. (L.) isuga* Mitsukuri, 1912 is considered as a synonym of *H. (Mertensiothuria) fuscorubra* Théel, 1886, by Rowe & Gates (1995) and *H. (L.) lineata*, which was considered as a synonym of *H. (L.) pardalis* by Panning (1935), Clark (1938) and Cherbonnier (1951), has been reestablished as a valid species by Rowe & Gates (1995).

H. (L.) cavans is readily distinguished from *H. (L.) pardalis*, *H. (L.) verrucosa*, *H. (L.) lineata*, *H. (L.) glandifera* and *H. (L.) duoturricula* because all these species have, in the

tube feet, large perforated plates (Ludwig, 1874; Cherbonnier, 1955a, 1988) which are missing in *H. (L.) cavans*. Moreover, the five above mentioned species have a large terminal plate (230-440 μm in diameter) in the tube feet, whereas it is small (125-180 μm in diameter) in *H. (L.) cavans*.



Pl. 1. A: *Holothuria (Lessonothuria) cavans*, new species; specimens cleaned from its sand layer (photo T. Tomascik); B: *Synaptula spinifera*, new species; specimen creeping on a sponge (photo T. Tomascik).

According to the description given by Clark (1921) and the examination of the holotype, *H. (L.) cumulus* is very close to *H. (L.) cavans*, but differs in having 20 tentacles (18 for *H. (L.) cavans*), in having few heaps of buttons (very numerous for *H. (L.) cavans*), by a low number of tables (very abundant for *H. (L.) cavans*), by table spire with two-three cross-beams (no cross-beam for *H. (L.) cavans*) and by the table disc being round and smooth (table disc quadrangular and spiny for *H. (L.) cavans*).

FAMILY SYNAPTIDAE BURMEISTER, 1837
SUBFAMILY SYNAPTINAE BURMEISTER, 1837

Genus *Synaptula* Oersted, 1849
***Synaptula spinifera*, new species**
(Figs 5-6, Pl. 1B)

Material examined. - Holotype (IRSNB, IG 28156/1/11, Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994.

Paratypes - 11 specimens (IRSNB, IG28156/1/5-10, 12-16), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994.- two specimens (MZB), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994.- two specimens (NMNH), Kakaban Island (lagoon), East Kalimantan, Indonesia, coll. T. Tomascik, May.1994. Moreover, tens of specimens were observed for the colour and ecological data.

Diagnosis. - Small holothurian with 13 tentacles, each bearing 18-22 digitations united by a web. Colour from deep brown-red to light brown-red. Very large cartilaginous ring enclosing the white calcareous ring. Ossicles present only in the body wall and represented by anchors, anchor-plates and miliary granules. Anchors with a few knobs on the vertex, smooth arms and a spiny stock which is in one piece or split in two-four lobes. Anchor-plates with six large anterior serrate holes, three smooth or serrate articular holes, and three (sometimes four-six) small smooth posterior holes. Bridge of the anchor-plate always knobbed or dentate with, very often, a long median spine. Miliary granules, present or absent; if present, few and only anteriorly located.

Type locality. - Kakaban Island, East Kalimantan, Indonesia.

Description. - The preserved specimens are 44-85 mm long and five-eight mm in diameter. The colour of undisturbed living specimens ranges from deep brown-red to light brown-red, with five very fine longitudinal white lines and numerous small white dots (Pl. 1B). Tentacles may be darker than the body wall. In alcohol, the color of the body wall is brown-gray, and the tentacles are generally darker than the body wall.

There are always 13 tentacles, each with an average of 18-22 pairs of digitations united by a web. In small specimens (<50 mm), only 16-18 pairs of digitations are present, whereas in large specimens (>75 mm) 20-23 pairs of digitations (in one case, 23-29 pairs were observed).

The calcareous ring is white (Fig. 5A) and covered by a very thick cartilaginous ring. Radial and interradial pieces are of the same size. The five radial pieces are anteriorly perforated for the nerves. 15-20 Polian vesicles of various size and one stone canal are present. The gonad is made of a main axis bearing branched tubules. Ciliated funnels are clustered in

three rows running along the base of the mesenteries. Each ciliated funnel is cup-shaped with a short stalk and hangs freely in the coelomic cavity.

There are ossicles in the body wall but not in the tentacles. The ossicles are anchors, anchor-plates, and a few miliary granules.

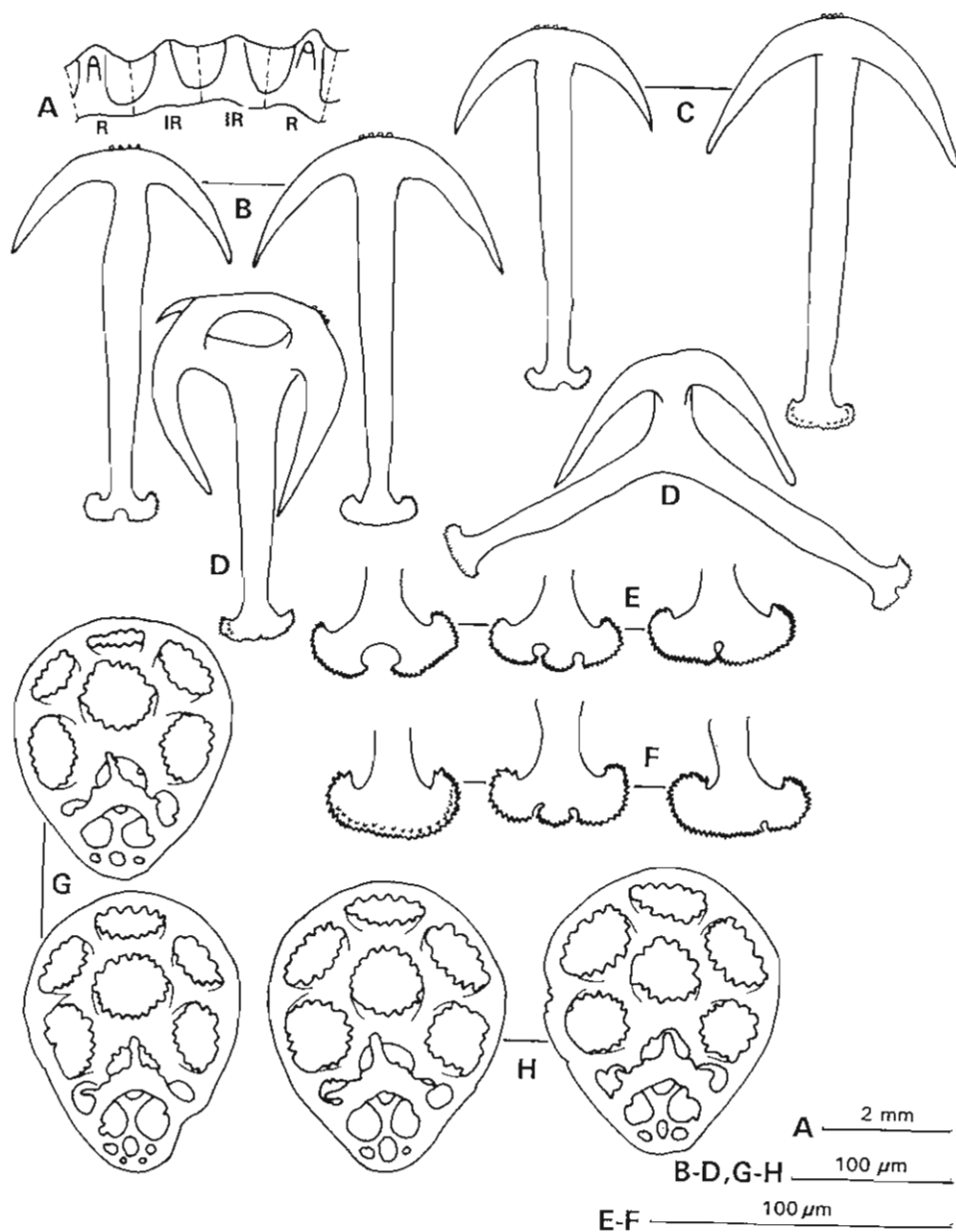


Fig. 5. *Synaptula spinifera*, new species. A: calcareous ring (R: radial piece; IR: interradial piece); B: anchors of anterior body wall; C: anchors of posterior body wall; D: abnormal anchors; E: stock of posteriorly located anchors; F: stock of anteriorly located anchors; G: anchor-plates of anterior body wall; H: anchor-plates of posterior body wall.

The anchors (Figs. 5B, C) have four knob-like projections on the vertex, smooth arms and a spiny stock. Sometimes they are irregular (Fig. 5D). The stock is highly variable; in a single holothurian, at both ends of the body, it can be in one piece or split in two-four pieces (Figs. 5E, F). The anchors, located anteriorly or posteriorly, have always the same proportions (length/width) and the same size (230-275 μm long; 140-175 μm width) whatever the length of the specimen.

The anchor-plates (Figs. 5G, H) have six large anterior dentate holes and three-four articular holes which are smooth or slightly serrate along their anterior margin. There are three-six small posterior holes (three being the most common). The bridge is always knobbed or spinose, very often with a very long median spine (Figs. 6A, B). This spine is normally free at the apex, but can be fastened to the anterior margin of the articular hole. The spine is seldom present (on zero-five % of the plates) in small specimens (<50 mm). In larger specimens (> 50 mm), the proportion of anchor-plates with a spine on the bridge is 60-90%. The anchor-plates posteriorly located have a constant length (160-180 μm) and width (140-155 μm) whatever the size of the specimens, whereas the anteriorly located anchor-plates increase in length with increasing body length (145-170 μm long in a 43 mm long specimen, to 180-200 μm long in a 85 mm long specimen).

The miliary granules are rosettes, U-shaped (Fig. 6C) or star-shaped (Fig. 6D), 13-20 μm in diameter. They are few, anteriorly located, and have been found in only one paratype (67 mm long).

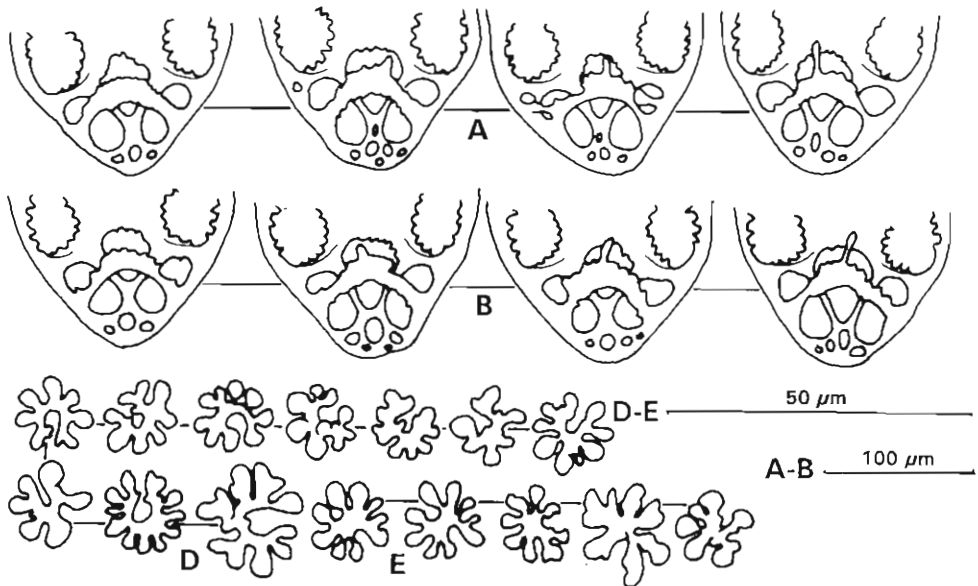


Fig. 6. *Synaptula spinifera*, new species. A: bridge of anchor-plates anteriorly located; B: bridge of anchor-plates posteriorly located; C: U-shaped miliary granules; D: star-shaped miliary granules.

Etymology. - The name "*spinifera*" means one which bears spines. It refers to the long spine on the bridge of the anchor-plates.

Biology: *Synaptula spinifera*, new species, is found throughout the lagoon, but is most abundant in the shallow *Halimeda* meadows, where it is either lodged between the *Halimeda*

thalli or attached to *Enteromorpha clathrata*. The specimens were collected from a depth of one meter. The observed depth range of the species is 0.25 to eight meters. The average abundance of *S. spinifera* in the *Halimeda* meadows range between 20 to 34 individuals per m² (Tomascik & Mah, 1994). A few individuals were also found creeping on the sediments adjacent to the algal meadows. *S. spinifera* is also abundant in the *Rhizophora* stilt root habitats, where it is found creeping over and among sponges (Pl. 1B) and other sessile invertebrates and epiphytic algae.

Synaptula spinifera is a deposit- or suspension-feeding holothurian. However, it feeds primarily as a suspension-feeder by actively picking up suspended particulate matter from the water column with its feeding tentacles. It was frequently observed extended into the water column where it actively captured suspended particulate matter. During the course of the field work it was not observed to pick up food particles directly from the sediments. No visible predators were observed.

Discussion.- The size, the number of tentacles and the type of ossicles are characteristic of the genus *Synaptula* Oersted, 1849. Of the 30 species belonging to the genus, five have anchor-plates with a bridge bearing a long median spine: *Synaptula denticulata* Heding, 1928, *S. mortensenii* Heding, 1929, *S. reciprocans* (Forskål, 1775), *S. recta* (Semper, 1868) and *S. virgata* (Sluiter, 1901). *Synaptula spinifera*, new species, with its 13 tentacles each bearing 18-22 digitations united by a web is easy to distinguish from *S. mortensenii* which has only 11-13 tentacles each with 10-12 digitations not united by a web (Heding, 1929). Moreover, *S. mortensenii* has rods in the tentacles whereas there are no rods in those of *S. spinifera*. Even the smallest *S. mortensenii* (<40 mm) has the long median spine on the bridge of the anchor-plates (Cherbonnier, 1988). *S. spinifera* is also readily distinguished from *S. reciprocans* which has 15 tentacles. Moreover; a long spine on the anchor-plate bridge of *S. reciprocans* is illustrated only by Clark & Rowe (1971). Heding (1928) and Cherbonnier (1955b: observation of 59 specimens; 1988) never mentioned a long spine on the anchor-plate bridge whatever the size of the *S. reciprocans*.

S. denticulata, *S. recta* and *S. virgata* differ from *S. spinifera* in having the median long spine only on abnormal anchor-plates (see Heding 1928, fig. 20-5), and in having the apex of the spine always fastened to the anterior margin of the articular hole (Semper, 1868; Sluiter, 1901; Heding, 1928). *S. recta* differs also from *S. spinifera* by the presence of miliary granules in the tentacles and by the absence of a web between the digitations of the tentacles. *S. denticulata* differs also from *S. spinifera* by a green calcareous ring and by a greater number of posterior holes in the anchor-plates. *S. virgata* is very similar to *S. spinifera* but differs in having smooth articular holes in the anchor-plates, by the presence of different anchors at the two ends of the body and by the numerous miliary granules present all over the body wall.

The long spine on the anchor-plate bridge becomes more frequent with increasing body size. The question then arises: does any of the established species fit a growth stage of *S. spinifera*? Several characters of *Synaptula* spp. are known to vary with increasing body size: size of anchors and anchor-plates, presence of a long spine on the anchor-plate bridge, number of tentacles and number of tentacular digits. If *S. spinifera* were a growth stage of a known species, then individuals smaller than the material here observed (≤ 40 mm) should have 1) anchor-plates bridges without a long spine, 2) anteriorly located anchor-plates ≤ 145 μ m, 3) tentacles number ≤ 13 and 4) number of tentacular digits ≤ 16 pairs. Individuals larger than the material here observed (≥ 85 mm) should have 1) all the anchor-plate bridges with

a long spine, 2) anteriorly located anchor-plates $\geq 200 \mu\text{m}$, 3) number of tentacles ≥ 13 and 4) number of tentacular digits ≥ 23 pairs.

According to the descriptions given by Semper (1868), Sluiter (1887, 1901), Clark (1907, 1924, 1938), Heding (1928, 1929, 1931), Nair (1946), Cherbonnier (1988) and Cherbonnier & Féral (1984), not a single *Synaptula* spp. ≥ 85 mm fits with the above requirements. For the *Synaptula* spp. ≤ 40 mm, the following species could fit a growth series: *Synaptula bandae* Heding, 1928, *S. minima* Heding, 1928, *S. neirensis* Heding, 1928, and *S. oestergreni* Heding, 1928. *S. violacea* Heding, 1928, known from a 30 mm long fragment, can not be considered as a small species because its diameter is 20 mm. Among the species belonging to the genus *Synaptula*, the proportion between diameter and length of the body is 1/10 to 1/30. The known specimen of *S. violacea* would then be at least 300 mm long.

If we take other discriminant characters which are not dependant on the body size into account, viz. the importance of the cartilaginous ring, the colour of the calcareous ring, the presence of miliary granules and tentacular ossicles, *S. spinifera* can not be considered as belonging to a growth series of *S. bandae*, *S. minima*, *S. neirensis* or *S. oestergreni* because they all have a faint cartilaginous ring and numerous miliary granules, whereas *S. spinifera* has a prominent cartilaginous ring and few or no miliary granules.

DISCUSSION

The narrow outer reef of Kakaban Atoll supports a diverse flora and fauna including many species of holothurians (Tomascik, personal observations). The lagoon, however, harbours only two holothurian species, here described. Kakaban lagoon is considered to be isolated from the outside reef since seawater enters the lagoon only through the porous carbonate reef matrix and small fissures. As a result of this filtering effect, larval flow into the lagoon from outside populations must be very limited, if it occurs at all. Extensive surveys of surrounding reefs failed to locate outside populations of the species described here. Moreover, if few echinoderm larvae manage to penetrate into the lagoon their survival and recruitment into the lagoonal adult population is highly unlikely, since most echinoderm larvae are particularly sensitive to low salinities (Stickle & Diehl, 1987).

Echinoderms in general are stenohaline (Binyon 1966, 1972; Stickle & Diehl, 1987) and holothurians in particular appear to be very sensitive to low salinities (Pawson, 1966). However, a few species are able to tolerate temporarily at least significant salinity fluctuations without permanent injury (Binyon, 1972). Permanent low salinity is much more difficult to tolerate and only a few echinoderms living in the Black and Baltic Seas were able to adapt to low salinity environments. In tropical waters, only *Protankira similis* (Semper, 1868) is able to live in brackish waters where salinity drops to 20-21 psu (Semper, 1868; Singh & Choudhury, 1992). A value as low as 26-28 psu is already difficult to tolerate for most echinoderms (Stickle & Diehl, 1987).

The unique fauna of Kakaban lagoon (Tomascik & Mah, 1994) is probably derived from a much richer fauna that was present in the original atoll lagoon, before the relatively rapid uplift of the entire atoll. It is suggested that progressive modifications of environmental conditions in the lagoon during and subsequent to the uplift, and particularly the year-round low salinities, have eliminated most of the marine stenohaline fauna and induced the appearance of new species adapted to low salinity environments. It would be very interesting

to know the age of the uplifting of the lagoon in order to have an idea of how long it takes for speciation to occur. Unfortunately, the isolation of the lagoon has not yet been dated.

ACKNOWLEDGMENTS

The field work of the second author (TT) was funded by *The Ecology of Indonesian Seas* component of the Environmental Management Development in Indonesia (EMDI), a joint project of the Ministry of Environment, Government of Indonesia and Dalhousie University. EMDI project is funded by the Canadian International Development Agency. TT is grateful to Anmarie J. Mah, co-discoverer of the new species, for her support and assistance in the field, and to Garuda Indonesia airlines for travel assistance. The fieldwork was supported by Borneo Divers and Sea Sports (Sabah) and PT. Sangalaki Dive Resort. Thanks are due to Ron Holland, Peter and Paul Sugiono, Graham and Dona Taylor and the staff of Sangalaki Dive Resort for their assistance and hospitality. We thank P.F.S. Cornelius (The Natural History Museum, London) for identification of Scyphozoa. We thank R.M. Woollacott (The Museum of Comparative Zoology, Cambridge) for the loan of type material. We thank J. van der Land (National Museum of Natural History, Leiden) for his kind assistance with specimen transportation. The first author (C.M.) thanks N. Cominardi for welcoming him at the Musée National d'Histoire Naturelle (Paris). Both authors thank two anonymous reviewers for their constructive comments.

LITERATURE CITED

- Binyon, J., 1966. Salinity Tolerance and Ionic Regulation. In R.A. Boolotian (ed.) *Physiology of Echinodermata*. Interscience, New-York. Pp. 359-377.
- Binyon, J., 1972. *Physiology of Echinoderms*. Pergamon Press, Oxford. i-x + 264 pp.
- Cherbonnier, G., 1951. Holothuries de l'Institut Royal des Sciences Naturelles de Belgique. *Mém. Inst. R. Sci. nat. Belg. 2ème ser.*, **41**: 1-68.
- Cherbonnier, G., 1955a. Holothuries récoltées en Océanie française par G. Ranson en 1952 (4ème note). *Bull. Mus. natn. Hist. nat.*, (2)**27**(4): 319-323.
- Cherbonnier, G., 1955b. Les holothuries de la Mer Rouge. *Ann. Inst. Océanog. Monaco*, N.S. **30**: 129-183 + 28 pls.
- Cherbonnier, G., 1988. Echinodermes: Holothurides. *Faune de Madagascar*, **70**: 1-292.
- Cherbonnier, G. & J.P. Féral, 1984. Les holothuries de Nouvelle-Calédonie. Deuxième contribution (Deuxième partie: Stichopodidae, Cucumariidae, Phyllophoridae et Synaptidae). *Bull. Mus. natn. Hist. nat. Paris*, 4^e sér., **6**, section A (4): 827-851.
- Clark, A.M. & F.W.E. Rowe, 1971. *Monograph of shallow-water Indo-West Pacific echinoderms*. Trustees British Museum, London. i-ix + 238 pp + 31 pls.
- Clark, H.L., 1907. The apodous Holothurians. *Smithson. Contr. Knowl.*, **35**: 1-231 + 13 pls.
- Clark, H.L., 1921. The echinoderm fauna of Torres Strait: its composition and its origin. *Carnegie Institution Washington*, **10**: i-viii + 223 pp + 38 pls.
- Clark, H.L., 1924. The Holothurians of the Museum of Comparative Zoölogy. The Synaptinae. *Bull. Mus. Comp. Zoöl.*, **65**(13): 457-501 + 12 pls.

- Clark, H.L., 1938. Echinoderms from Australia. *Mem. Mus. Comp. Zool. Harvard*, **55**: i-vii + 596 pp + 28 pls.
- Darwin, C. R., 1842. *The Structure and Distribution of Coral Reefs*. Smith, Elder and Company, London (Reprinted 1962, University of California Press, Berkeley, CA).
- Effendi, I., T. Priantono, S. Tjokrosapoetro & K. Budiono, 1981. Overview of disastrous tectonic earthquakes in the period between April 1979 - April 1980. *Bull. Geol. Res. and Dev. Centre*, **4**: 18-20.
- Fautin, D. G. & W.K. Fitt, 1991. A jellyfish-eating sea anemone (Cnidaria, Actiniaria) from Palau: *Entacmaea medusivora* sp. nov. *Hydrobiologia*, **216/217**: 453-461.
- Hantoro, W.S., P.A. Pirazzoli, C. Jouannic, H. Faure, C.T. Hoang, U. Radtke, C. Causse, M. Borel Best, R. Lafont, S. Bieda & K. Lambeck, 1994. Quaternary uplifted coal reef terraces on Alor Island, East Indonesia. *Coral Reefs*, **13**: 215-223.
- Heding, S.G., 1928. Papers from Dr. Th. Mortensen's Pacific Expedition. 46. Synaptidae. *Vidensk. Meddr. Dansk natur. Foren.*, **85**: 105-323 + 2 pls.
- Heding, S.G., 1929. Contribution to the knowledge of the Synaptidae. I. *Vidensk. Meddr. Dansk natur. Foren.*, **88**: 139-154.
- Heding, S.G., 1931. Über die Synaptiden des Zoologischen Museums zu Hamburg. *Zool. Jb. Abt. f. Systematik*, **61**(5/6): 637-696 + 1 pl.
- Holthuis, L.B., 1973. Caridean shrimps found in land-locked saltwater pools at four Indo-West Pacific localities (Sinai Peninsula, Funafuti Atoll, Maui and Hawaii Islands), with the description of one new genus and four new species. *Zool. Verh., Leiden*, **128**: 1-48, pls. 1-7.
- Kott, P., 1995. A new colonial *Styela* (Ascidiacea: Styelidae) from an isolated marine habitat, Kakaban Island, East Kalimantan, Indonesia. *Raffles Bull. Zool.*, **43**(2): 469-474.
- Kuenen, P. H., 1933. *Geology of coral reefs*. The Snellius-Expedition in the Eastern Part of the Netherlands East-Indies 1929-1930. Geological Results. Kemink & Zoon, NV., Utrecht. Vol. 5, Part 2, 125 pp.
- Kuenen, P. H., 1947. Two problems of marine geology: atolls and canyons. *Kon. Ned. Akad. v. Wet., Afd. Natuurkunde*, 2nd section, **43**(3): 1-69.
- Ludwig, H., 1874. Beiträge zur Kenntniss der Holothurien. *Arb. Zoolzootom Inst. Würzburg*, **2**(2): 77-118 + 2 pls.
- Molengraaff, G.A.F., 1929. The coral-reefs in the East Indian Archipelago their distribution and mode of development. *Proc. Fourth Pacific Science Congress*, Java 1929, Vol. 2: 55-99.
- Nair, R.V., 1946. On *Chondrocloea varians*, a new apodous holothurian from the Madras Harbour. *Proc. natn. Inst. Sci. India*, **12**: 361-384.
- Ng, P.K.L. & T. Tomascik, 1994. *Orcovita saltatrix*, a new genus and species of anchialine varunine crab (Crustacea: Decapoda: Brachyura: Grapsidae) from Kakaban Island, Indonesia. *Raffles Bull. Zool.*, **42**(4): 937-948.
- Panning, A., 1935. Die Gattung *Holothuria*. 5. Teil, Schluss. *Mitt. Zool. Staatinst. Zool. Mus. Hamburg*, **46**: 1-18.
- Papp, Z., 1981. Temporal variation of elastic strain release in the Banda Seas region. *Bull. Geol. Res. and Dev. Centre*, **4**: 13-17.

Massin & Tomascik: Two new holothurians from Kakaban Island

- Pawson, D., 1966. Ecology of holothurians. In R.A. Boolotian (ed.) *Physiology of Echinodermata*. Interscience, New-York. Pp. 63-71.
- Rowe, F.W.E. & J. Gates, 1995. Echinodermata. In Wells, A. (ed.) *Zoological Catalogue of Australia*. Melbourne, CSIRO, Australia. Vol. 33, xiii + 510 pp.
- Semper, C., 1868. *Reisen im Archipel der Philippinen*. 2. *Wissenschaftliche Resultate*. 1. *Holothurien*. Leipzig. i-x + 288 pp + 40 pls.
- Singh, B.N. & A. Choudhury, 1992. A new record of *Protankyra similis* (Semper) (Holothurioidea, Apodida) from Indian brackish water environment. *Oebalia*, 18, N.S.:109-119.
- Sluiter, C. Ph., 1887. Die Evertebraten aus der Sammlung des königlichen naturwissenschaftlichen Vereins in Niederländisch Indien in Batavia. *Natuur. Tijdschr. Ned. Indie*, 47 8th ser. (8): 181-220 + 2 pls.
- Sluiter, C. Ph., 1901. Die Holothurien der Siboga-Expedition. *Siboga-Exped.*, 44: 1-142 + 10 pls.
- Stickle W.B. & W.J. Diehl, 1987. Effect of salinity on echinoderms. *Echinoderm Studies*, 2: 235-285.
- Tomascik, T. & A.J. Mah, 1994. The ecology of 'Halimeda Lagoon': An anchialine lagoon of a raised atoll, Kakaban Island, East Kalimantan, Indonesia. *Tropical Biodiversity*, 2(3): 385-399.
- van Bemmelen, R. W., 1949. *The Geology of Indonesia: General Geology of Indonesia and Adjacent Archipelagoes*. Martinus Nijhoff, The Hague. 732 pp.
- Wolff, T., 1970. Lake Tegano on Rennell Island, the former lagoon of a raised atoll. *Natural History of Rennell Island British Solomon Islands*, 6: 7-29.

Received 10 Oct 1995

Accepted 11 Mar 1996