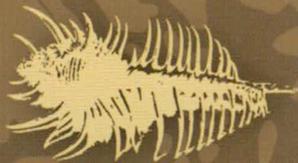


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CLUB CONCHYLIA

INFORMATIONEN

**GIGANTISCH
EINE NEUE
RIESENAUSTER**

ANTARKTISCH NEUE EULIMIDE

HAARIGE ANSICHTEN WEICHTIER DES JAHRES

STACHELIGE SCHÖNHEIT NEUE ANGARIA

VIELFÄLTIG NEUE CLAUSILIEN-TAXA

Empressostrea kostini n. gen., n. sp. (Bivalvia: Ostreoidea), a mysterious giant from the Spratly Islands, South China Sea

By MARKUS HUBER & FELIX LORENZ

FIGS. 1-11

Abstract

A new genus and species of oyster, *Empressostrea kostini* n. gen., n. sp. from Louisa Reef, Spratly Island Group, South China Sea is described. A feeding method using chords of slime so far unknown for bivalves was observed in the new taxon, which represents the largest of any recent gryphaeid. Additionally, the unusual deep water cave habitat, and the conchological dissimilarity to any other species make it necessary to erect a new genus within Gryphaeidae. *Empressostrea* is the host of a pearlfish (Carapidae: *Onuxodon* sp.).

Keywords

Large oyster, pearlfish, symbiosis, Ostreoidea, Gryphaeidae, Pycnodonteinae, Carapidae, *Hyotissa*, *Empressostrea kostini*, South China Sea, deep water caves, feeding in bivalves.

Introduction

The expeditions on board the MV Empress in search of sea-shells through Indonesia and Malaysia have produced many discoveries in the past years. Among them three species of Conidae (*Conus impressae* LORENZ 2001, *Conus wallacei* LORENZ & MORRISON, 2004, *Conus mcbridei* LORENZ, 2005), several new species of Marginellidae and other gastropod families. On our recent trip from Kota Kinabalu to Kuching (Sabah, Malaysia) via the Spratly Islands we anchored at Louisa Reef, a remote coral plateau with steep drop-offs. The Captain, VIDAR SKOGLIE, brought up a large bivalve he had hammered off the roof of a cave on a dive to 70 m. Subsequent examination of the overgrown shell revealed that it represents a new species and genus of oyster, the largest and for sure most heavy in Ostreoidea. On the following day the team of divers on board the Empress brought up several more specimens. We arrived at the conclusion that another significant new species was discovered which is described in the following.

Material and methods

All *Empressostrea* specimens were collected on October 15th and 16th, 2006 during scuba dives at depths between 44 and 71 m, conducted by VIDAR SKOGLIE, HUGH MORRISON, DIETMAR AMON, JANA KRATZSCH and the second author, at the type locality. Small to medium sized specimens were removed from the substratum with hammer and chisel. The largest and heaviest specimens were observed at 60 to 71 m, but could not be collected due to their extreme weight and the firm attachment to the substratum. The recovery of such specimens appeared too dangerous on account of the limited dive time at those depths. The dives were conducted using regular scuba-gear, Aladin™ and Suunto™ computers. The duration of the decompression stops at 9 m and 3 m suggested by the computers were usually doubled as a safety precaution. Furthermore, the MV Empress provides an oxygen-bar at 6 m, and a decompression chamber on board. Surface intervals of two hours and a maximum of three dives per day ensured that the diving was safe to the utmost possible.

Habitat-photos were taken using Sony T1™ digital cameras and the Sony Marine Pack™ type MPK-THA. These housings are claimed to withstand a maximum depth of 40 m but we found that even at 60 m they worked just fine.

The fishes taken from the mantle cavity of the oysters were preserved in 90 % ethanol and will subsequently be deposited in the WAM, Perth. The anatomy of the oysters was documented by line drawings and photographs during all stages of the dissection conducted by the second author.

The nine known worldwide gryphaeid species used for comparison herein are from the bivalve reference collection of the first author. Boring lithophagids were photographed and sent to KARL KLEEMANN, University Vienna for confirmation of the identification. *Empressostrea* photos were sent to SOMCHAI BUSSARAWIT, PMBC, Phuket, who confirmed the gryphaeid character of the shell. The fish and the photos were analyzed by members of the WAM, the identification was just tentative as *Onuxodon fowleri* (SMITH, 1955). Research on the website fishbase.org independently lead to the same result.

Empressostrea n. gen.

Description

The shells are obviously ostreoid. Adults are ovate-elongate with the attached left valve more voluminous. The valves are of equal length and close tightly at the top of their edges. A vesicular (honeycomb or spongy) shell microstructure can be seen. Older shells have an oddly irregular, flaky appearance. Two restricted areas of vermicular chomata (short, wormlike ridges) are visible left and right of the large, broad, straight hinge. The hinge is edentate. The ligament distributed on both side of the umbones (amphidetic) and low, level with the margins (alivincular). Monomyarian, the single muscle scar is ovate-rounded, impressed, and equal in both valves. The scars are placed close to the hinge. The umbonal cavity is very shallow. The pallial line is entire, clearly marked by a shallow ridge. The surface displays a fine lamellate structure with at least 50 – 75 layers. Plicate spines are missing. The area of attachment of the left valve is usually medium, about halfway of the shell in most.

The round shape and the position of the adductor muscle scars close to the hinge, the vesicular shell structure and the intestine passing through the ventricle of the heart define the new genus as Gryphaeidae VYALOV, 1936, and not Ostreidae RAFINESQUE, 1815. The extant vermicular chomata and the vesicular shell structure conform morphologically with the subfamily Pycnodonteinae STENZEL, 1959 within Gryphaeidae. The small umbonal cavity, the low ligamental area and the non coiled form exclude the subfamily Exogyrinae, the extant chomata and the non radial structure exclude the other subfamily Gryphaeinae. Hence we propose *Empressostrea* as new genus within the subfamily Pycnodonteinae, family Gryphaeidae, superfamily Ostreoida.

The unique feeding method, the rare commensalism with a pearlfish, morphology, size and habitat distinguish the new genus at once from the other gryphaeid genera.

Empressostrea kostini n. sp.

Type material

Enumerated: length x width x height in mm, (length of fish in mm), depository

Holotype: 300 × 230 × 150 (100) coll. MNHN

Paratype 1: 290 × 210 × 170 (90) coll. FL

Paratype 2: 270 × 190 × 150 (90) coll. FL

Paratype 3: 180 × 200 × 90 (90) coll. MHU

Paratype 4: 310 × 220 × 140 (100) coll. MHU

Paratype 5: 120 × 65 × 50 (60) coll. WAM

Paratype 6: 240 × 210 (bottom valve only. Height of shell and size of fish unrecorded) coll. A. KOSTIN

Description of the shell

Inequivalve, subequilateral shells, which are very large, reaching approximately 50 cm in length, very heavy, reaching approximately 8 - 10 kg in weight. The juvenile form is rounded with subequal valves, the adult form is ovate elongate with unequal valves. The attached left valve is heavier, longer and slightly more cupped. The umbonal part is very large and counts for 30-40% of the shell length. The free right valve is slightly smaller in juveniles and more lid-like in adults. Except this form change during growth, no other intraspecific features were encountered. The colour is all white outside and white with a yellowish hue inside. The smaller paratype 3 consists of about 45 lamellate layers and has an empty weight of 1.5kg. The medium sized paratype 4 disposes of about 75 lamellate layers per valve and weights 5kg.

Description of the animal

The living animal of *Empressostrea kostini* shows typical features of a tetrabranchiate gryphaeid (Fig. 5). There are four prominent purplish-black pseudolamellibranch lobes of gills showing a reticulate sculpture and glandular structures on their base. There are two pairs of fleshy palps (also known as "mouth-sails") separated from the gills, surrounding the small orifice. The glandular basal structures of the gills and the mantle were observed to secrete large amounts of clear sticky mucus which formed a solid coil containing large amounts of detritus from the cave. The coil was sucked in by the orifice hidden between the palps. The mantle is relatively thick and glandular along its edge. The muscle is very large, measuring 4,5 cm in specimens of 30 cm diameter. Below the muscle, the relatively small perivisceral sack is situated. The greenish digestive gland encapsules a part of the comparatively large stomach. Just below the pericardial sack there is a distinct area with orange colored gonads. The intestine is passing through the pericardium and the ventricle, around the muscle, terminating in a very small anal opening on the opposite side of the muscle. A foot is missing. The flesh is edible, the muscle is delicious.

Locus typicus and distribution

The locus typicus is Louisa Reef (06°19,685'N 113°13,974'E, Fig. 6), an isolate offshore reef plateau that only reaches above the surface at low tide. It is surrounded by steep walls with dense coralline and poriferan growth, reaching down vertically to very deep water. These walls have numerous undercuts and caves. Louisa Reef is oval in shape, approximately 1.5 km east to west and 0.5 km north to south. It is the southernmost reef geographically belonging to the Spratly Island Group ("Dangerous Group"), west of Borneo. Louisa Reef is claimed by Brunei, whereas other islands of the Spratly Island Group are subject to international struggles involving China, Vietnam, Malaysia and Indonesia (USCINCPAC Virtual Information Center, 2007). On the

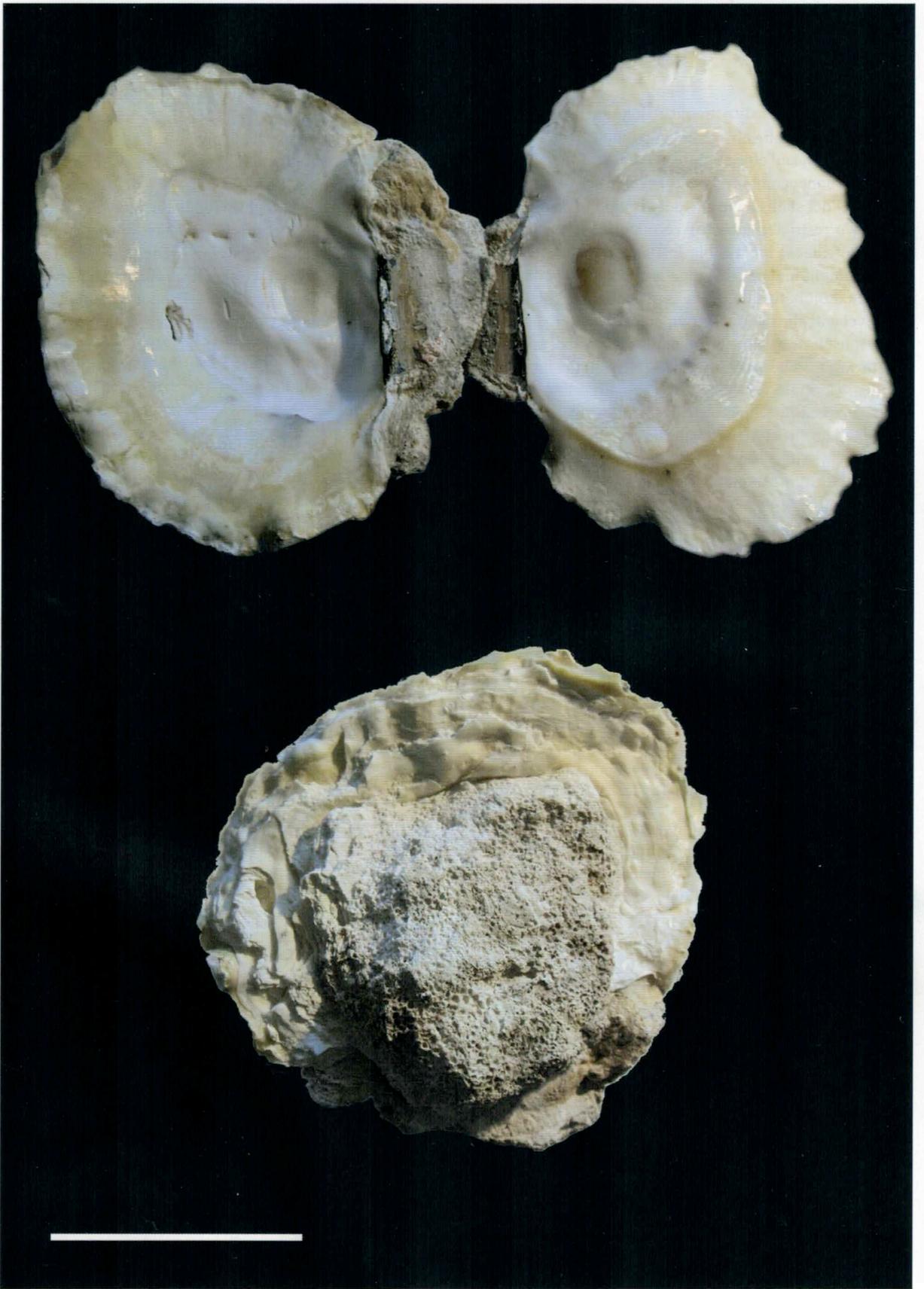


Fig. 3: *Empressostrea kostini* n. gen., n. sp., paratype 3; scale = 9 cm

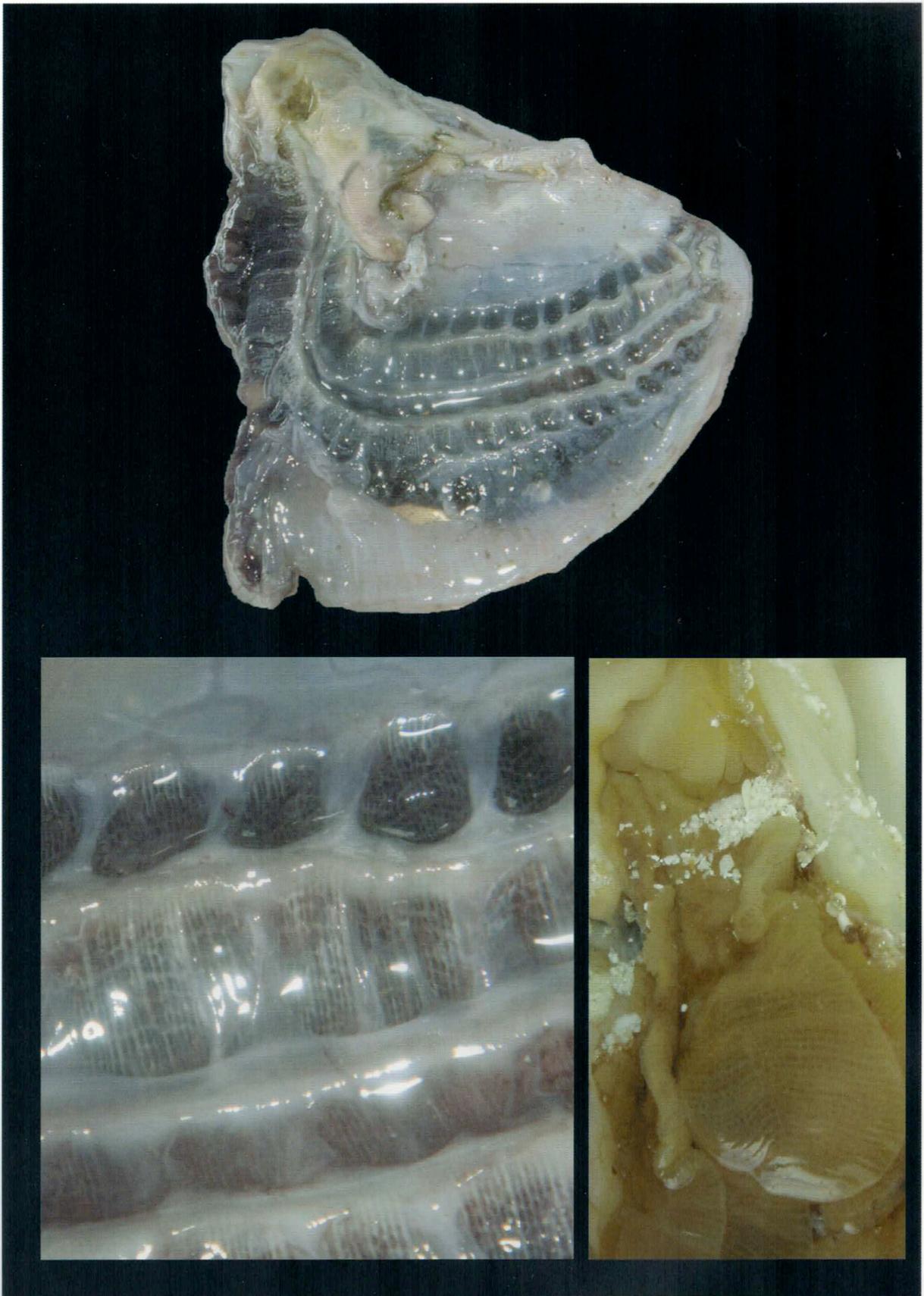


Fig. 4: *Empressostrea kostini* n. gen., n. sp.; top: animal; bottom left: detail of the gills; bottom right: the palps and a mucous string containing food-particles

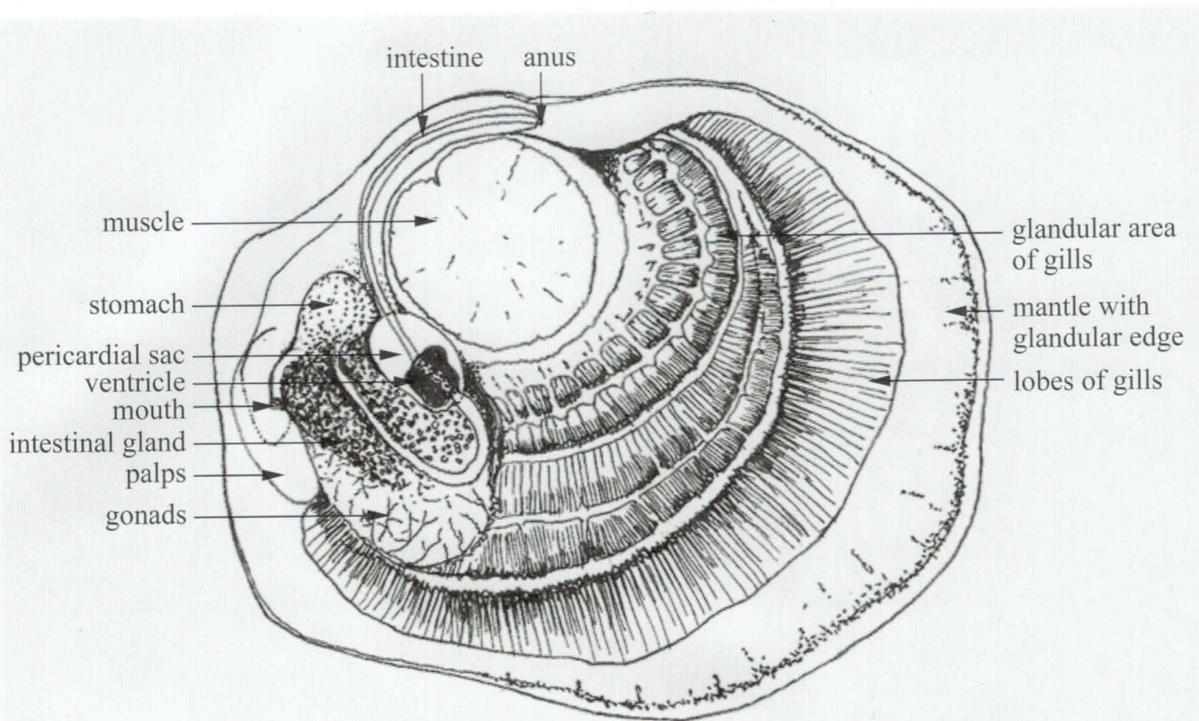


Fig. 5: Animal of *Empressostrea kostini* n. gen., n. sp.

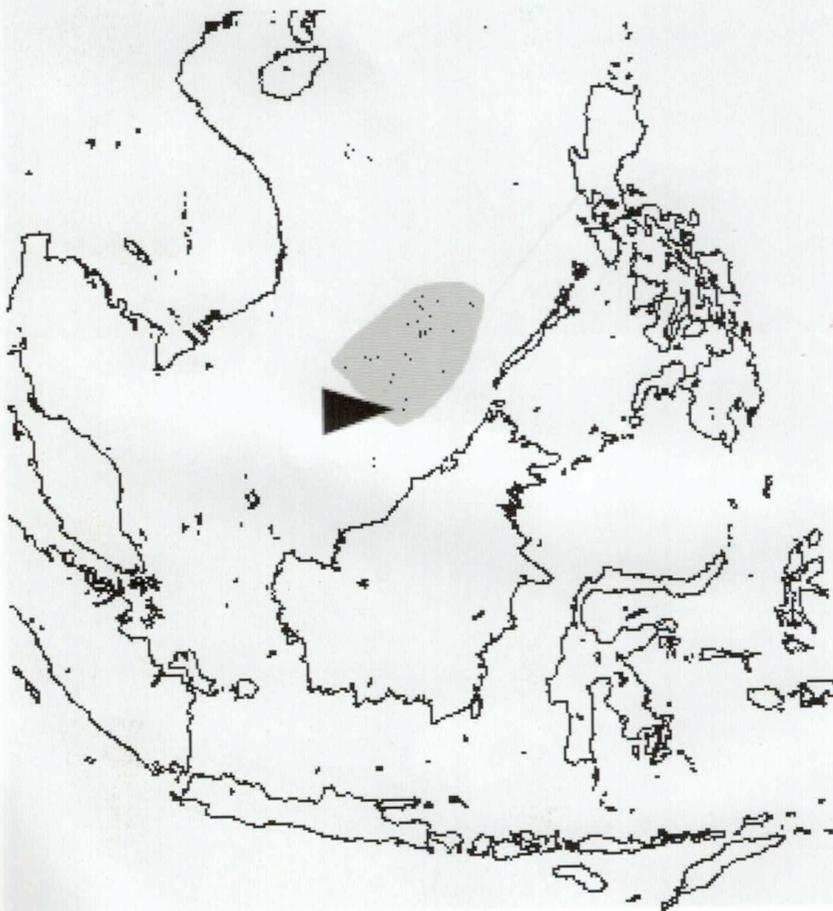


Fig. 6: South China Sea with Spratly Island Group; the arrow points to the locus typicus

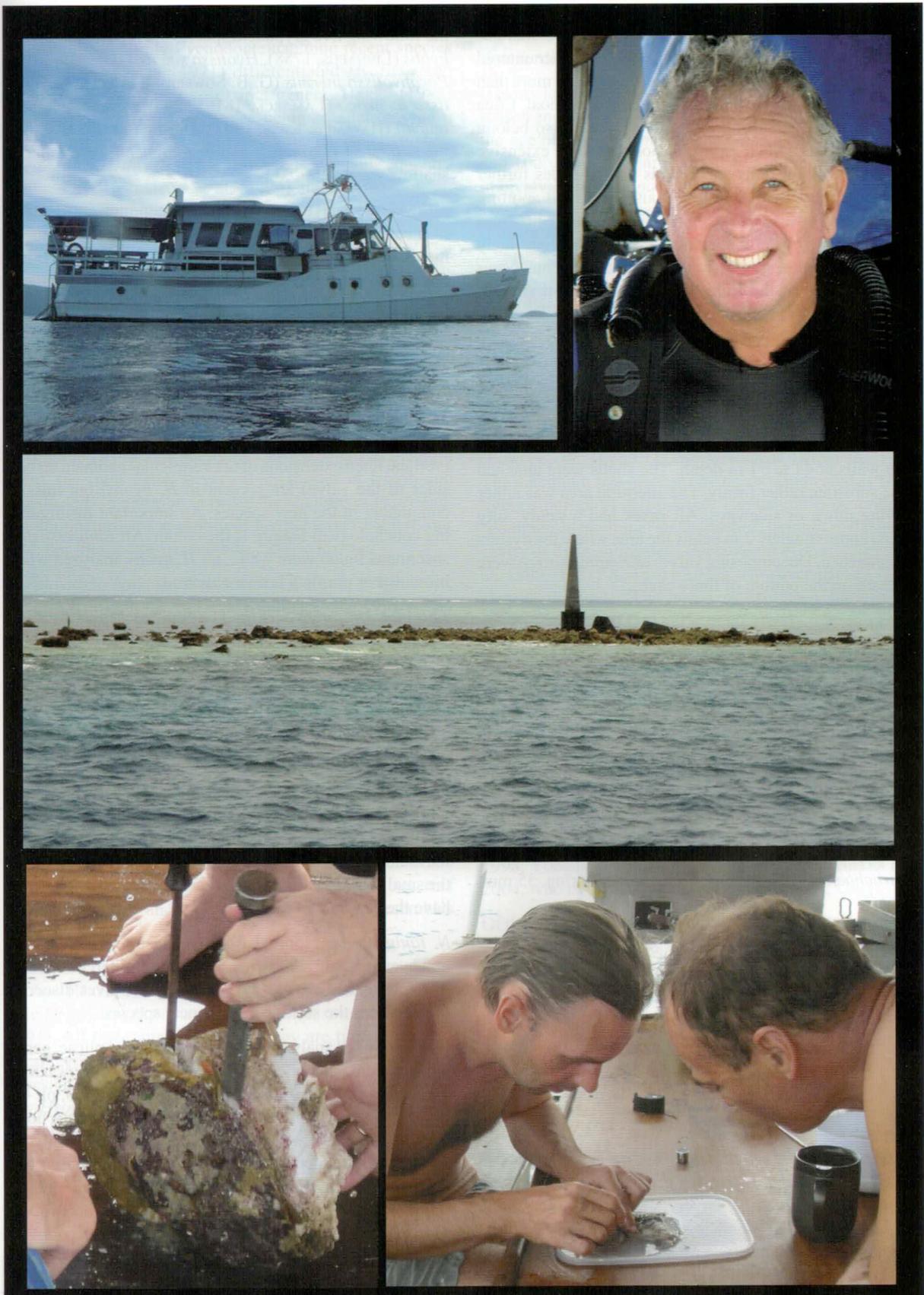


Fig. 7: Top: The MV Empress and Captain VIDAR SKOGLIE; Middle: Louisa Reef, Spratly Island Group
Bottom: left: Opening Paratype 3. Right: The authors studying an animal of *Empressostrea kostini* n. gen., n. sp.

dives made around Louisa Reef, a remarkable poverty of gastropods and bivalves in the shallower waters was observed. *Empressostrea kostini* n. sp. was not encountered anywhere else during the trip which encompassed more than 60 dive sites: Commodore Shoal, Investigator Shoal, Erica Reef and Royal Charlotte Reef, all of which also belong to the Spratly Island Group to the north, and the extensive Luconia Shoals of reefs and islands that stretches further south of Louisa Reef. HUGH MORRISON recalled spotting similar large bivalves in deep-water caves on Christmas Island, off the Western Australian coast. It is most likely that this, or related species of this fascinating genus occur in other places of the Indo-Pacific, probably in similar, difficult to access habitats.

Habitat

Specimens of *Empressostrea kostini* were observed attached to the walls and the roofs of sheltered caves and caverns in steep walls at 44 to 71 m depth. The shells were attached to the substrate rather firmly. The apertural area was either pointing down or sideways. All caves had a sandy, silty bottom approximately 2 m below the area where the oysters were attached. Decomposing valves of *Empressostrea* were scattered on the bottom of these caves.

Cohabitants

Attached to, nestling in or boring into valves of *Empressostrea*, the following 8 bivalve species could be observed:

Chama pacifica BRODERIP, 1835 (attached, 42 mm, 71 m)

Chama sp. (attached, 17 mm, 53 m)

Gastrochaena pexiphora STURANY, 1901 (boring, 13.5 mm, 58 m, first record for the South China Sea)

Gastrochaena gigantea (DESHAYES, 1830) (boring, 35 mm, 58 m)

Spengleria sp. (boring, 16 mm, 58 m)

Lithophaga (Diberus) pulchra LAMY, 1919 (boring, 28 mm, 58 m, first record for the South China Sea)

Lithophaga (Diberus) malaccana (REEVE, 1857) (boring, 16 mm, 58 m)

Musculus sp. (byssally attached in holes, 9 mm, 58 m)

All specimens of *Empressostrea kostini* contained a fish of the genus *Onuxodon*, family Carapidae (Actinopterygii: Ophidiiformes). That fish is very slender, eel-like, with a translucent body. The mouth is beak-shaped. The specimens we found measured between 60 and 100 mm in length, in correlation with the size of the oyster (Fig. 8, bottom).

Discussion

Conchological comparison: From the South China Sea, the following five gryphaeid species are reported. *Hyotissa hyotis* (LINNAEUS, 1758), *Hyotissa sinensis* (GMELIN, 1791), *Parahyotissa inermis* (G. B. SOWERBY II, 1871), *Parahyotissa numisma* (LAMARCK, 1819) and *Neopycnodonte taniguchii* (HAYAMI & KASE, 1992). During our trip all except the two rarest *H. sinensis* and *N. taniguchii* were found in shallow water.

H. hyotis (Fig. 11, top) is well known, common and depicted in most Indo-Pacific books. It is a large species, but the maximal length of 271 mm (reported from Tonga) does not reach the new species. Adult specimens of *H. hyotis* are roundish, whereas the adults of the new species are elongate. *H. hyotis* has a characteristic strongly plicate-spinose surface throughout growth, whereas the new species has a lamellate surface structure without spines. The yellowish-brown muscle scar in *H. hyotis* is much larger and uniquely elevated in adult specimens, whereas in the new species it is flat, subimpressed and whitish. Remarkable lath chomata (vertical lined extensions of the vermicular chomata on both sides of the valve) are present in *H. hyotis*, but missing completely in the new species. An important distinguishing conchological feature is the colour. All *Empressostrea* specimens found were white, all *H. hyotis* analyzed were brownish or purplish brown coloured.

The rare *H. sinensis* (Fig. 11, bottom) grows to about 200 mm as well. It is much flatter and much less plicate than *H. hyotis*. The typical flat, brownish-black muscle scar, which is larger than in the new species, and the lath comata are clear differentiating features. In addition *H. sinensis* is a shallow water dweller occurring in offshore coral reefs at 7 – 25 m.

P. numisma is a small rotund gryphaeid, usually around 50 mm in diameter. It is also white, but often with traces of purple, especially around the muscle scar. In *P. numisma* the attached, lower valve is larger and clearly encompasses the small lid-like right valve. In the new species both valves have the same extension.

N. taniguchii is reported from Malaysian caves as well, however it is only known occurring subtidal 10 – 30 m. The fragile, curved, glossy, very unequal valves discern it at once from the solid, lamellate new species.

P. inermis in all analyzed specimens has radial plicae, generally extending as hollow spines; see also G. B. SOWERBY II (1871) as *Ostrea inermis* and OKUTANI & al. (2000, pl. 460 f. 5) as *Hyotissa imbricata*. The new species has a finely lamellate structure without spines. *P. inermis* generally has a lighter shell, which is usually bright reddish coloured, also purplish, brownish, even golden specimens occur. The new species was only found to be white, the shell is more robust. The muscle scars in *P. inermis* are more rounded, comparatively larger and less close to the hinge than in the new species. In addition *P. inermis* is a common, shallow water gryphaeid, and has a much smaller size, hardly exceeding 100 mm. No commensalism is reported for *P. inermis* and

nothing else than suspension feeding is known.

Within the subfamily Pycnodontinae nine recent species are known. STENZEL (1971) differentiated *Hytotissa* and *Neopycnodonte*, plus two extinct genera. HARRY (1985) added *Parahytotissa* for species being smaller, having a closed promyal passage and lacking the characteristic lath chomata of *H. hyotis*. This last genus was subsequently doubted by KIRKENDALE & al. (2004) and by BIELER & al. (2004). However, the four known recent *Parahytotissa* species, especially *P. numisma* and *quercinus* (G. B. SOWERBY II 1871), are quite different from the large *Hytotissa* species in many respects. The proposed resynonymization of *Parahytotissa* appears to be based on few material, too little simultaneously analyzed species and inappropriate criteria. It is not followed herein.

Neopycnodonte is known by two extant species: *N. cochlear* (POLI, 1795) (syn. *O. musashiana* YOKOYAMA, 1920) and *N. taniguchii* (HAYAMI & KASE, 1992), living either bathyal or in subtidal caves. The shells are curved, small to medium sized, the right valve is very thin, shorter in length and translucent. In addition, a prismatic shell layer is present. No commensalism is reported; neither exact habitat, nor size, nor morphology resembles *Empressostrea*.

Parahytotissa contains four species. Two are small, solid, flat, whitish with the right valve remarkably shorter than the left, with none to very weak plication and no spines: the Panamian *P. quercinus* (G. B. SOWERBY II, 1871) and the Indo-Pacific *P. numisma* (LAMARCK, 1819). One species is slightly larger, very solid, saw-toothed and reddish to cream colored: the amphiatlantic, uncommon (Western Africa) to common (Caribbean) *P. roseus* (GMELIN, 1791) (syn. *Parahytotissa mcgintyi* HARRY, 1985). Finally, the highly variable Indo-Pacific *P. inermis* (G. B. SOWERBY II, 1871) (syn. *Ostrea imbricata* LAMARCK, 1819 non GMELIN, 1791) grows largest to about 125 mm. It is lighter, strongly radially plicate and in general hollowly spinose. No commensalism is reported for either of them, neither their shallow reef habitats, nor size and weight, nor morphology resembles *Empressostrea*.

Hytotissa contains three large species: the Panamian *H. fischeri* (DALL, 1914), and the two predominantly Indo-Pacific *H. hyotissa* (LINNAEUS, 1758) and *H. sinensis* (GMELIN, 1791). All three attain 200 mm. They are typical shallow coral reef inhabitants, but not recorded from deeper water caves. In bivalve literature, no commensalism is reported for any *Hytotissa*. Besides the habitat, *Hytotissa* typically show strong radial plications that usually form strong upright spines, whereas *Empressostrea* has a lamellate structure with many flaky layers. Long vermiculate and extended lath chomata as defined by HARRY (1985) are a characteristic feature of *Hytotissa*. *Empressostrea* has a short area of vermiculate chomata only.

In addition, none of these three genera is known to reach

the size and weight of *Empressostrea* and none is known to have developed any other feeding mechanism than suspension feeding.

If every lamellate layer is assumed to represent one growth season and if a growth season is equaled with one year, then the age of larger *Empressostrea* specimens is between 50 and 100 years. Thus approaching the highest ages known in bivalves (as for *Tindaria callistiformis* VERRILL & BUSH, 1897, *Arctica islandica* (LINNAEUS, 1767) or *Tridacna gigas* (LINNAEUS, 1758).

The Biology of *Empressostrea kostini*

It is well known that certain pearlfish of the genus *Onuxodon* live in some sort of relationship with large "oysters", according to fish-literature. At least three species of *Onuxodon* have been described from the entire Indo-Pacific, from Natal to Panama: *O. fowleri* (SMITH, 1955), *O. parvibrachium* (FOWLER, 1927) and *O. margaritiferae* (RENDAHL, 1921). The maximum size of these rare fishes is indicated as 10 cm, living subtropical and marine. The habitat is described as "commensal inquiline" or "parasitic", living at in the mantle cavity of the giant oyster „*Pycnodonta hyotis*” (NIELSEN & al. 1999, TROTT & TROTT 1972). However, BRUCE (1981) clearly objected: "The host was originally identified as *Pycnodonta hyotis* (L.) but is not correctly referable to that species". For *O. margaritiferae* and *O. fowleri* also *Pinctada* spp. are mentioned as "hosts".

For bivalves, many forms of symbiosis, parasitism and commensalism are reported: *Pinna nobilis* (LINNAEUS 1758) with a small crab, the mytilid *Fungiacava* living within life corals, *Paramya* with echinurid worms, and many galeommatids living in or on various hosts. However, nothing is mentioned in the case of the common and well known *Hytotissa hyotis* (see for example STENZEL 1971; HARRY 1985; BEESLEY & al. 1998; YOOSUKH & al. 1999; or, most recently, BIELER & al. 2004, who collected live *H. hyotis* in Florida, USA).

Of the six small to medium-sized *Empressostrea* specimens collected alive, each housed exactly one *Onuxodon* sp. The valves brought aboard were tightly closed and the fish was always caught inside. The size of this translucent, eel-like fish ranged from 60 – 100 mm, in correlation to the size of the valves. However, as only small to medium sized *Empressostrea* specimens were taken, the fish might reach greater lengths. Remarkable is the special shape and the fragility of the fish, missing explicit dorsal fins. The mouth is peculiarly beak-shaped. From these observations we assume that the fish leads a permanent life inside the bivalve, in a highly specialized, host-specific symbiosis characterizing *Empressostrea*.

A second feature of the new genus is the special habitat as described above. Within this special habitat the new species occurred quite commonly. *Onuxodon* were formerly known only from rare, accidental finds. Obviously, bivalves required for their occurrence all have similar, difficult to

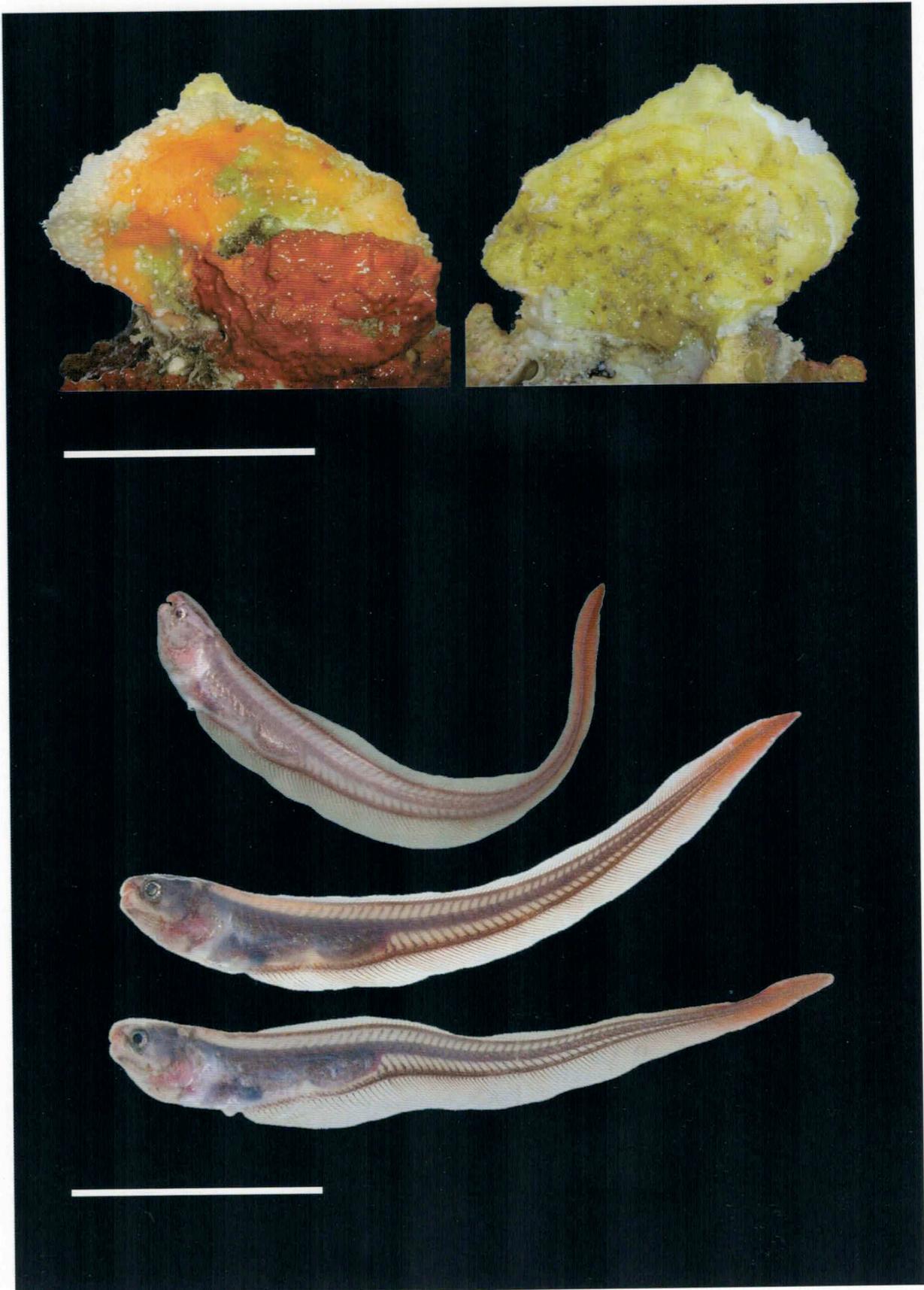


Fig. 8: Top: *Empressostrea kostini* n. gen., n. sp.; subadult paratype 5; scale = 7.5 cm

Bottom: Specimens of the pearlfish *Omuxodon* sp. from the mantle cavity of *Empressostrea kostini* n. gen., n. sp.; scale = 3.5 cm

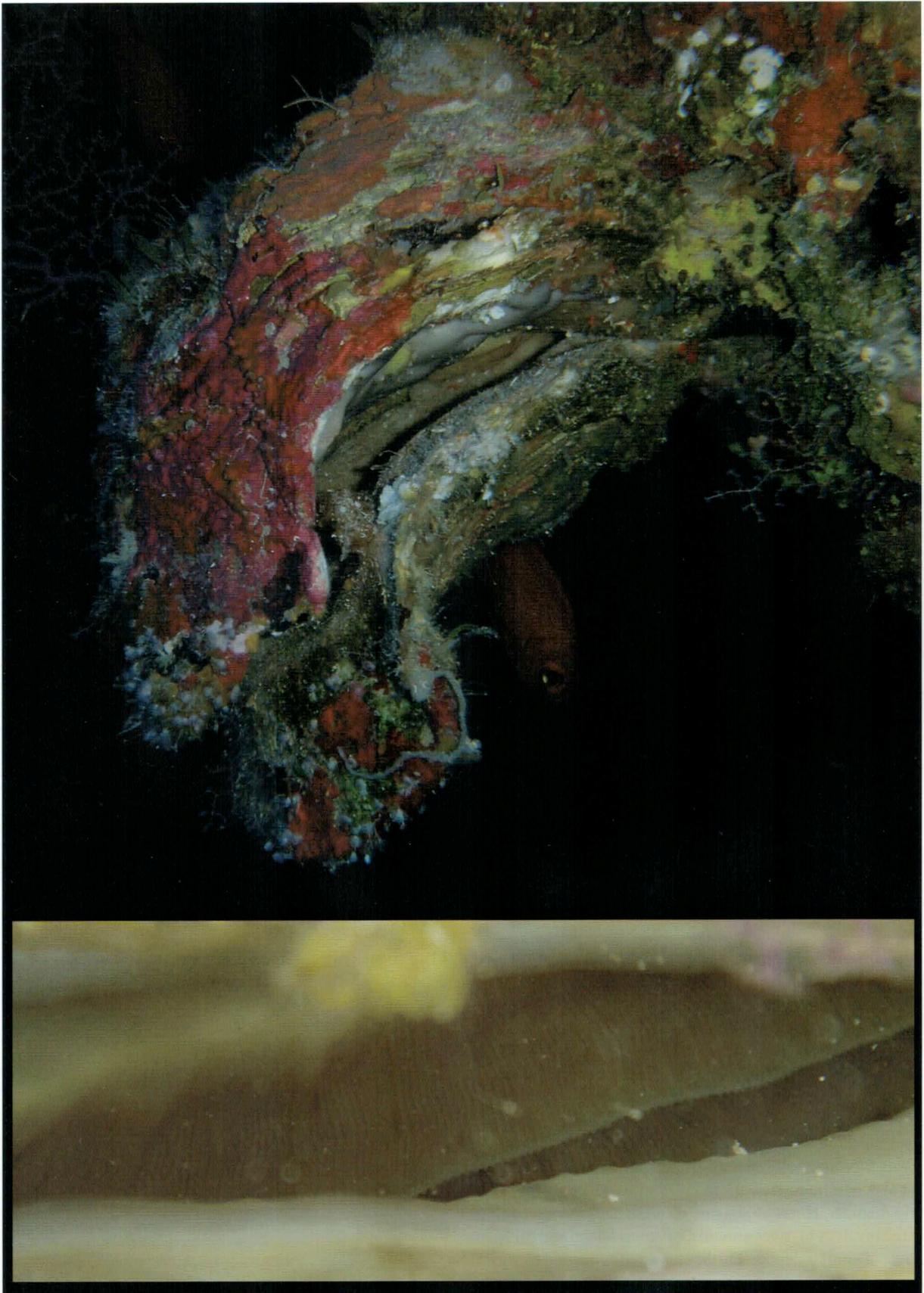


Fig. 9: Top: *Empressostrea kostini* n. gen., n. sp., living specimen attached to wall of cave at 55-60 m, Louisa Reef, Spratly Island group. Photo: D. AMON; Bottom: detail of gills in situ

access habitats. Dredging, trawling and other collecting methods are unlikely to ever produce living specimens of *Empressostrea*.

An astonishing feature is the huge size and the heavy weight of *Empressostrea* as a bivalve species living at these depths. Bivalves with a comparable weight of several kilograms – e.g. the tridacnids – are living in shallow coral reefs. Their size and weight is supported by a special feeding combination, mainly suspension feeding, but additionally photosymbiosis by farming vast numbers of zooxanthellae, microscopic unicellular symbiotic *Symbiodinium* algae, in their mantle.

This feeding-method is obviously impossible in deep water caves. Anatomical examination of *Empressostrea* revealed that the huge gills allow vast quantities of water to be filtered. As mentioned above, a second method was observed that apparently supports feeding. The animal disposes of long soft strings, which must be reaching far outside the shell to gather additional larger food particles that are permanently rinsing through cavities of the porous reef walls. Inside the shell, the mucus is rolled up to a solid string densely packed with particles. This “food-roll” is sucked in by the orifice. This feeding method was never reported before, neither in oysters nor in other bivalves (see for example STENZEL 1971; HARRY 1985; BEESLEY & al. 1998; COAN & al. 2000). However, similar methods of gathering food-particles are known from some polychaets and in few sessile gastropods (i. e. vermetids). It explains how the shells can reach these enormous sizes and great weight. It may also explain the function and morphology of the pearlfish: participating from the particles the oyster gathers and having a cleaning effect to the mantle-cavity of the oyster - a possible strategy of gathering food and shelter in such difficult environments as the caves of Louisa Reef.

Adding up the unique features of *Empressostrea* could justify a new bivalve family within Ostreoida. However, as the shell itself has affinities to Gryphaeidae and morphology is still prevalent in taxonomy, we place the new genus within this ostreoid family.

The discovery of one of the heaviest and largest bivalve species as late as year 2006 is at first sight astonishing. However, as *Onuxodon* reports demonstrate, *Empressostrea* has obviously been observed by fish-experts in the past, but was continuously wrongly identified. The deep water habitat at the end range of scuba-diving delayed the discovery. As several species of *Onuxodon* have been described, it is possible that *Empressostrea* consists of several species, each of them with its specific symbiont. In fish literature *Onuxodon* spp. are reported from Natal, South Africa, tropical Australia to Hawaii and further east to Panama. One trip member, HUGH MORRISON, recalled having seen similar large bivalves in caves around Christmas Island and off Irian Jaya, at similar depths. Further research is needed to verify the exact relation between the various *Onuxodon* species and the bivalves they live in, and also, how many species of *Empressostrea* are still waiting for their discovery.

Etymology

The name for the new genus *Empressostrea* is chosen for two reasons. First of all, to honour the boat MV Empress and its crew, Captain VIDAR SKOGLIE and his wife ALICE, and the deck-hands NOEK, GATOT and ELI. Secondly, because it is the largest and most heavy “empress” of the oysters. The species is named in honour of ANDREY KOSTIN of Moscow, an avid diver, collector and amateur malacologist.

Acknowledgements

Our thanks go to Captain VIDAR SKOGLIE, who dived the first specimen and to his wife ALICE, as well as the crew of the MV Empress, all of whom supported us in any way they could. We are also indebted to HUGH MORRISON and SIMONE PFÜTZNER, who organized the trip and contributed further specimens. Many thanks also to DIETMAR AMON for excellent underwater photography of shells in situ, and last not least to JANA KRATZSCH, who also helped the second author on the dive that produced paratype 5.

For determination support in the rare, boring lithophagids thanks go to K. KLEEMANN, University Vienna. For confirmation of the gryphaeid character thanks go to S. BUSSARAWIT, Head of PMBC, Phuket, Thailand.

The entirely privately funded expeditions on board the MV Empress target the study of molluscan diversity in remote, poorly investigated areas of the western Pacific. We are most thankful to people like ANDREY KOSTIN for supporting this kind of modern explorations, whose reward is the discovery of new species and new insights to a hidden world full of mysteries and fascination.

Abbreviations

MNHN: Muséum National d'Histoire Naturelle, Paris, France

WAM: Western Australian Museum, Perth, Australia

FL: Private collection Dr. F. LORENZ, Germany.

MHU: Private bivalve reference collection Dr. M. HUBER, Switzerland

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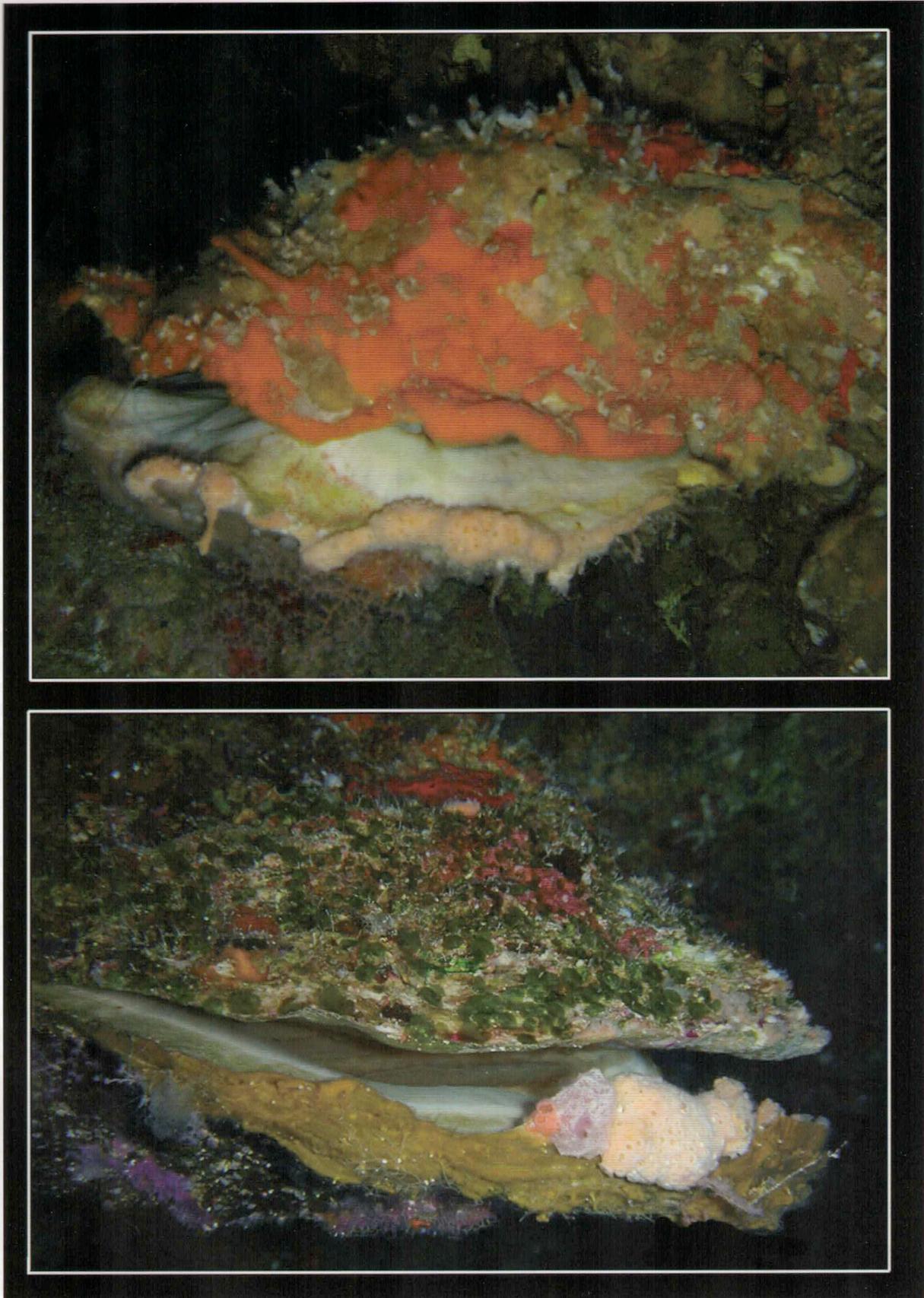


Fig. 10: *Empressostrea kostini* n. gen., n. sp., living specimens attached to wall of cave at 55-60 m, Louisa Reef, Spratly Island group. Photo: D. AMON



Fig. 11: Top: *Hyotissa hyotis* (length 155 mm), Saudi Arabia, Red Sea, in coral reef at 5 m
Bottom: *Hyotissa sinensis* (length 160 mm), Rawai, Phuket, Thailand, off 10 m