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ASSOCIATION BETWEEN THE SCALLOP, *PEDUM SPONDYLOIDEUM*, (BIVALVIA: PTERIOMORPHIA: PECTINIDAE) AND SCLERACTINIAN CORALS FROM THE WAKATOBI MARINE NATIONAL PARK (SOUTHEASTERN SULAWESI, INDONESIA)

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***ABSTRACT.* –** The associations between the nestling and facultative boring pectinid bivalve *Pedum spondyloideum* and scleractinian host corals were studied at the Wakatobi Marine National Park (MNP), part of the Tukang Besi Archipelago in the Banda Sea, Indonesia. There, *Pedum* uses fifteen hosts including the previously unrecorded species *Montipora capricornis, M. danae, M. informis, M. mactanensis, Pavona clavus, Pav. duerdeni* and *Turbinaria irregularis*. Massive *Porites lobata* and *Por. lutea* are the favourites. The depth range of *Pedum* extends from 3.5–18 m. There is no correlation between the number of *Pedum* and depth, and between the number of *Pedum* per colony and depth. Local distribution indicates that associations are more diversified and *Pedum* occur in greater numbers on fringing reefs off Kaledupa Island or on sites located further off Hoga Island. Sites located near the Hoga Marine Research Station and the training platforms had only a few *Pedum* and associations. A site with a particularly heavy sedimentation rate and elevated nutrient concentration in the water contained many individuals associated only with massive *Porites*. Competitors of *Pedum* (nestling and boring bivalves, vermetid gastropods, serpulid annelids, hermit crabs, cryptochirid and cirriped crustaceans) were mainly observed in massive *Porites*.

***KEY WORDS.* –** *Pedum*, bivalvia, corals, Indonesia.

INTRODUCTION

Living scleractinian corals provide microhabitats for a large number of parasitic and commensal associates, which use the tissue and skeletons of the colonies as substrata (Frank et al.,1995; Floros et al., 2005). Coral associates are defined as sessile invertebrates that live on or within the coral skeleton (Risk et al., 2001) and apertures of the latter open through the living coral tissue (Scott, 1987). Many taxa are involved, including sponges, polychaetes, bivalves, tunicates and hydroids (reviewed in Scott, 1987). Most of these coral associates stress the coral to some degree, and some of them, particularly some sponges, polychaetes and bivalves can do considerable harm, at least to the skeleton (Sammarco & Risk, 1990; Smith & Harriott, 1988; Floros et al., 2005).

The pectinid bivalve *Pedum spondyloideum* (Gmelin, 1791) is an obligate associate of living coral that occurs in the Indo-Pacific (Kleemann, 1990, 1995, 2001; Scaps et al., 2005). It is byssally attached and it lives embedded in the coral skeleton; it is usually completely surrounded by live tissue on the coral surface, but not inside the dwelling (Yonge, 1967; Waller, 1972; DeVantier & Endean, 1988; Kleemann, 1990; Savazzi, 1999). The coral-bivalve relationship may be mutualistic, with the coral providing the bivalve with support and protection, and the bivalve enhancing water circulation for coral feeding. Furthermore, DeVantier & Endean (1988) showed that *Pedum* reduced the effects of heavy levels of predation by the starfish *Acanthaster planci* on their coral hosts on the Great Barrier Reef by repelling foraging starfish on contact by repeated expulsion of jets of water. On the other hand, *Ped. spondyloideum* may cause some structural weakness to its coral host, since its impact, both alive and dead, result in a cavity within the coral structure.

To date, little attention has been paid to the associates of living corals in Indonesia although this country lies within the triangle of biodiversity harbouring the most biologically diverse coral reefs in the world. Only recently, Scaps et al., (2005) studied coral associations and competitors for space

of *Ped. spondyloideum* from the northeast coast of Sulawesi. It was found that *Pedum* was associated with 11 host coral species (eight genera) but mainly with massive corals of the genus *Porites* (*Por. lobata* and *Por. lutea*). On the contrary, data from the Red Sea showed that *Pedum* occupied at least 25 species (14 genera) and was associated more frequently and in higher densities with encrusting to semi-massive and even branching *Montipora* species (Kleemann, 1990). Scaps et al., (2005) suggested that the associations may differ regionally.

The aim of the study was to enhance the understanding of the nature of associations between *Pedum* and its scleractinian host corals within the distribution range of the species and more specifically in the world's most diverse coral reefs, i.e where one can expect to find the most varied associations.

MATERIALS AND METHODS

The study sites were located around the islands of Hoga and Kaledupa (Figs. 1, 2). They are close (less than one hour) to a Marine Research Station run by Operation Wallacea on the small island of Hoga (approximately 6 km^2). Both islands are situated in the Wakatobi MNP, part of the Tukang Besi Archipelago, a remote island group of about 200,000 ha (2,000 km^2) off the southeastern coast of Sulawesi in the Banda Sea, in Indonesia (Elliot et al., 2001). Wakatobi MNP was established in 1996 and contains approximately 50,000 ha (500 km^2) of coral reefs. The area selected for this field study lies near the centre of global marine biodiversity or "Coral Triangle" composed of Indonesia, Philippines, Malaysia and Papua New Guinea. This region harbours the most biologically diverse coral reefs in the world.

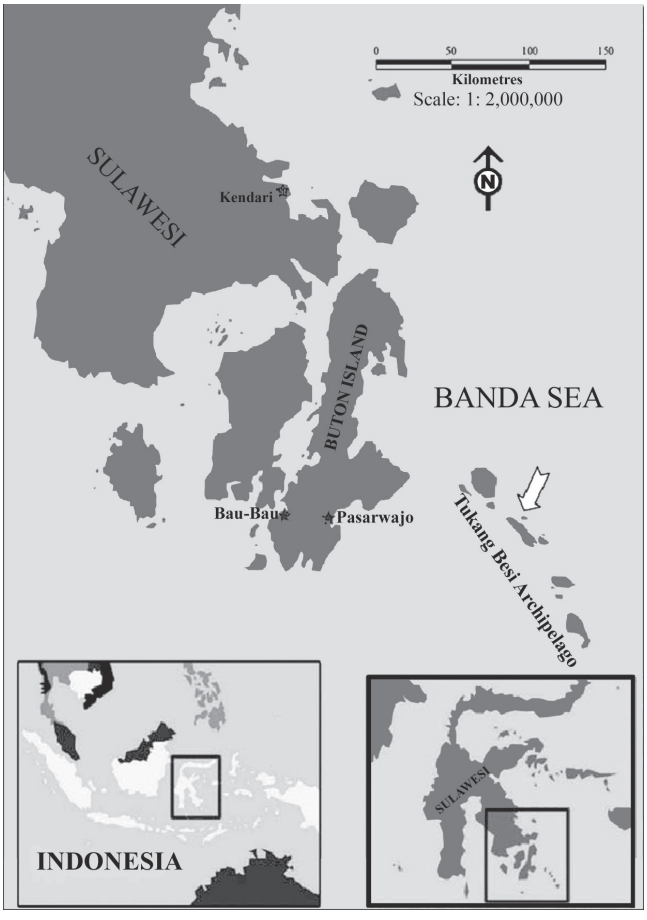

Fig. 1. Location map of the study area. The white arrow points to Hoga and Kaledupa Islands. The entire Tukang Besi Archipelago lies within the Wakatobi Marine National Park.

Observations were carried out in the field by SCUBA-diving in the summer of 2005 (between the 2 and 6 July). Ten sites were surveyed for *Pedum*-coral associations. For sampling locations and dates see Table 1. The maximal tidal range on Hoga is 2 meters but is typically 1.5 meters. During this study, the seawater temperature varied between 27 and 28°C. The salinity ranged from 32 to 33 ppm . No difference was noticed between the surface and the bottom temperature and salinity. The transparency of the water, measured with a Secchi disk, was comprised between 7 m (Site 8) and 14 m (Site 4). Most of the sites were fringing reefs, with a developped reef crest and a fairly steep reef slope after which a flat gentle slope of sandy habitat dominates. Maximum depth (18 m) and maximum dive times (45 minutes) were in compliance with the standards of Operation Wallacea. Dives consisted of a slow ascent along the reef in a zigzag path to the shallowest points. The occurence percentages of *Pedum* in the different scleractinian corals was definied as the ratio of the number of colonies of a given species infested by *Pedum* on the whole of the coral colonies colonized by *Pedum*. The distribution and population density of *Pedum* was estimated from notes in the field and from in situ underwater photography. In order to study the population structure, the width of each *Pedum* was measured with a caliper to the nearest mm. Because of our aim to document the range of host corals, genera and species, photographs were taken of new or rarely observed associations. Additional pictures were taken of known associations when the *Pedum* density was high for either the particular host or the locality. Due to difficulties in identifying massive corals of the genus *Porites* (*Por. lutea* and *Por. lobata*) and due to the fact that these two species represent the most common host corals of *Ped. spondyloideum* (Scaps et al., 2005), they were all grouped as "massive *Porites*". For the other corals, many

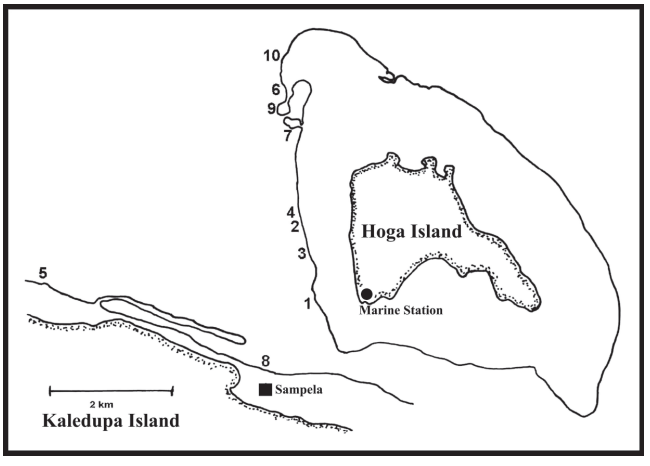

Fig. 2. Location of the study sites around Hoga and Kaledupa Islands. Thin black border represents the reef wall and the symbol (■) represents Sampela village.

Table 1. Locations and details of the study sites on Hoga and Kaledupa islands.

Date (2005)	Site	Island Name	Latitude South (S)	Longitude East (E)
02/07 AM	Hoga	Buoy 2	5°28'545"	123°45'545"
02/07 PM	Hoga	Buoy 5	5°28'02"	123°45'33"
03/07 AM	Hoga	Buoy 4	5°28'29"	123°45'40
03/07 PM	Hoga	Pat Kasim	5°27'569"	123°45'179"
04/07 AM	Kaledupa	Kaledupa	5°28'22"	123°43'47"
04/07 PM	Hoga	Ridge	5°26'565"	123°45'38"
05/07 AM	Hoga	Inner Pinnacle	5°27'22"	123°45'43"
05/07 PM	Kaledupa	Sampela	5°29'01"	123°45'08"
06/07 AM	Hoga	Outer Pinnacle	5°27'19"	123°45'25"
06/07 PM	Hoga	Coral Gardens	5°26'83"	123°45'21"

Table 2. *Pedum spondyloideum* hosts at Wakatobi Marine National Park.

Species	%	N	M	SD
Montipora capricornis	1.6	1	1	-
Montipora confusa	3.2	2	2	-
Montipora danae	1.6	1	1	-
Montipora informis	1.6	1	1	-
Montipora mactanensis	4.8	3	4.66	5.50
Montipora sp.	6.4	4	1	0
Gardineroseris planulata	4.8	3	1.66	1.15
Pavona clavus	1.6	1	1	-
Pavona duerdini	1.6	1	1	-
Pavona maldiviensis	1.6	1	1	-
Cyphastrea microphthalma	1.6	1	3	-
Favia stelligera	1.6	1	2	-
Massive Porites (Porites lobata + Porites lutea)	64.8	39	1.89	1.42
Porites rus	1.6	1	1	-
Turbinaria irregularis	1.6	1	1	-

%, percentage of occurrence; N, number of infested colonies; M, mean number of *Pedum* per colony; SD, standard deviation.

species can be positively identified underwater down to species level, but several species cannot be recognized with certainty without knowing skeletal details. In the latter case, representative samples were collected to enable a positive identification in the laboratory. Corals were bleached for 24–48 h to remove living tissue. They were then rinsed in freshwater, dried and identified following Veron (2000), Veron & Pichon (1976, 1980, 1982), Veron & Wallace (1984) and Veron et al., (1977).

RESULTS

Associations with live scleractinian corals

In the Wakatobi MNP, 15 associations of *Pedum* with host corals were recorded (Table 2). *Pedum* was observed in six genera of host corals (Table 3) belonging to five families from five suborders: 1) Astrocoeniina, Acroporidae (*Montipora*); 2) Fungiina, Agaricidae (*Gardineroseris*, *Pavona*); 3) Faviina, Faviidae (*Cyphastrea*); 4) Poritiina, Poritidae (*Porites*); and 5) Dendrophylliina, Dendrophylliidae (*Turbinaria*).

Some of these associations have been reported before from other localities in the Indo-Pacific (Table 3) but four species of *Montipora* (*M. capricornis*, *M. danae*, *M. informis* and *M. mactanensis*), two species of *Pavona* (*Pav. clavus* and *Pav. duerdeni*) and a species of *Turbinaria* (*T. irregularis*) are new records. A colony of *M. capricornis* from Site 6, hosted a single *Pedum*. Also, only a single *Pedum* was found in *M. informis* (Fig. 3A) from Site 2. The association between *Pedum* and *M. mactanensis* was observed from Sites 5 and 9. We found one *Pedum* in a colony of *M. danae* (Fig. 3B) from Site 9. Other colonies of unidentified *Montipora* species hosted a single *Pedum* from Sites 5, 6, 9 and 10. Only a single *Pedum* was found in *Pav. clavus* (Fig. 3C) from Site 4 and in *Pav. duerdeni* (Fig. 3D) from Site 10. Also, a colony of *Turbinaria irregularis* hosted a single *Pedum* from Site 5.

Table 3. Host corals of *Pedum spondyloideum* (Gmelin, 1791), an update of Scaps et al., (2005).

Suborder	Family, Subfamily	Genus	Species	Reference	Locality
Astrocoeniina	Acroporidae	*Acropora*	*A. robusta*	Scaps et al., (2005)	Northeastern Sulawesi
		Montipora	*M. meandrina*	Kleemann (1990)	Northern Red Sea
			M. stilosa	Kleemann (1990)	Northern Red Sea
			M. floweri	Kleemann (1990)	Northern Red Sea
			M. tertia	Kleemann (1990)	Northern Red Sea
			M. hoffmeisteri	Kleemann (2001)	Northern Red Sea
			M. monasteriata	Kleemann (2001)	Northern Red Se
			M. tuberculosa	Kleemann (2001)	Northern Red Sea
			M. venosa	Kleemann (2001)	Northern Red Sea
			M. confusa	Scaps et al., (2005)	Northeastern Sulawesi
			M. confusa	**new record**	Wakatobi MNP
			M. capricornis	**new record**	Wakatobi MNP
			M danae	**new record**	Wakatobi MNP
			M. informis	**new record**	WakatobiMNP
			M. mactanensis	**new record**	Wakatobi MNP
		Astreopora	*A. myriophthalma*	Kleemann (2001)	Aqaba, Red Sea
Fungiina	Agaricidae	*Coeloseris*	*C. mayeri*	Scaps et al. (2005)	Northeastern Sulawesi
		Gardineroseris	*G. planulata*	Kleemann (1990)	Northern Red Sea
			G. planulata	Scaps et al. (2005)	Northeastern Sulawesi
			G. planulata	**new record**	Wakatobi MNP
		Pachyseris	*Pac. speciosa*	Kleemann (1990)	Northern Red Se
			Pac. speciosa	Scaps et al. (2005)	NorthEastern Sulawesi
		Pavona	*Pav. maldivensis*	Kleemann (1990)	Northern Red Sea
			Pav. maldivensis	**new record**	Wakatobi MNP
			Pav. cactus	Kleemann (2001)	Northern Red Sea
			Pav. varians	Kleemann (2001)	Northern Red Sea
			Pav. clavus	**new record**	Wakatobi MNP
			Pav. duerdeni	**new record**	Wakatobi MNP
		Leptoseris	*L. mycetoseroides*	Kleemann (1990)	Torres Strait, GBR
	Siderastreidae	*Coscinarea*	*C. monile*	Kleemann (1990)	Northern Red Sea

Table 3. (continued).

Suborder	Family, Subfamily	Genus	Species	Reference	Locality
Faviina	Faviidae, Montastreinae	*Cyphastrea*	*C. microphthalma*	Kleemann (1990)	Northern Red Sea
			C. microphthalma	Zuschin & Piller (1997)	Northern Red Sea
			C. microphthalma	**new record**	Wakatobi MNP
		Echinopora	*E. gemmacea*	Kleemann (1990)	Northern Red Sea
		Leptastrea	*L. purpurea*	Kleemann (2001)	Northern Red Sea
			L. purpurea	Scaps et al. (2005)	Northeastern Sulawesi
	Faviidae, Faviinae	*Favia*	*F. helianthoides*	Kleemann (2001)	Northern Red Sea
			F. stelligera	Waller (1972)	Eniwetok Atoll, Pacific
			F. stelligera	Kleemann (1990)	Northern Red Sea
			F. stelligera	**new record**	Wakatobi MNP
		Goniastrea	*G. retiformis*	Kleemann (1990)	Northern Red Sea
			G. edwardsi	Kleemann (2001)	Northern Red Sea
	Merulinidae	*Hydnophora*	*H. microconos*	Kleemann (2001)	Northern Red Sea
			H. microconos	Scaps et al. (2005)	Northeastern Sulawesi
Poritiina	Poritidae	*Porites*	*Por. lutea*	Mastaller (1978)	Port Sudan, Red Sea
			Por. lutea	Nielsen (1986); Scoffin & Bradshaw (2000)	Phuket, Thailand
			Por. lutea	Kleemann (1990)	Northern Red Sea
			Por. lutea	Scaps et al. (2005)	Northeastern Sulawesi
			Por. lutea	**new record**	Wakatobi MNP
			Por. lobata	Kleemann (1990)	Mellish Reef, GBR
			Por. lobata	Scaps et al. (2005)	Northeastern Sulawesi
			Por. lobata	**new record**	Wakatobi MNP
			Por. evermanni	Scaps et al. (2005)	Northeastern Sulawesi
			Por. monticulosa	Scaps et al. (2005)	Northeastern Sulawesi
			Por. rus (as Por. convexa)	Yonge (1967)	Raboul, New Britain
			Por. rus	Kleemann (1990)	Northern Red Sea
			Por. rus	Kleemann (1995)	Lizard Island, GBR
			Por. rus	**new record**	Wakatobi MNP
Dendrophylliina	Dendrophylliidae	*Turbinaria*	*T. mesenterina*	Kleemann (1990)	Northern Red Sea
			T. irregularis	**new record**	Wakatobi MNP

Abbreviations: GBR, Great Barrier Reef; MNP, Marine National Park.

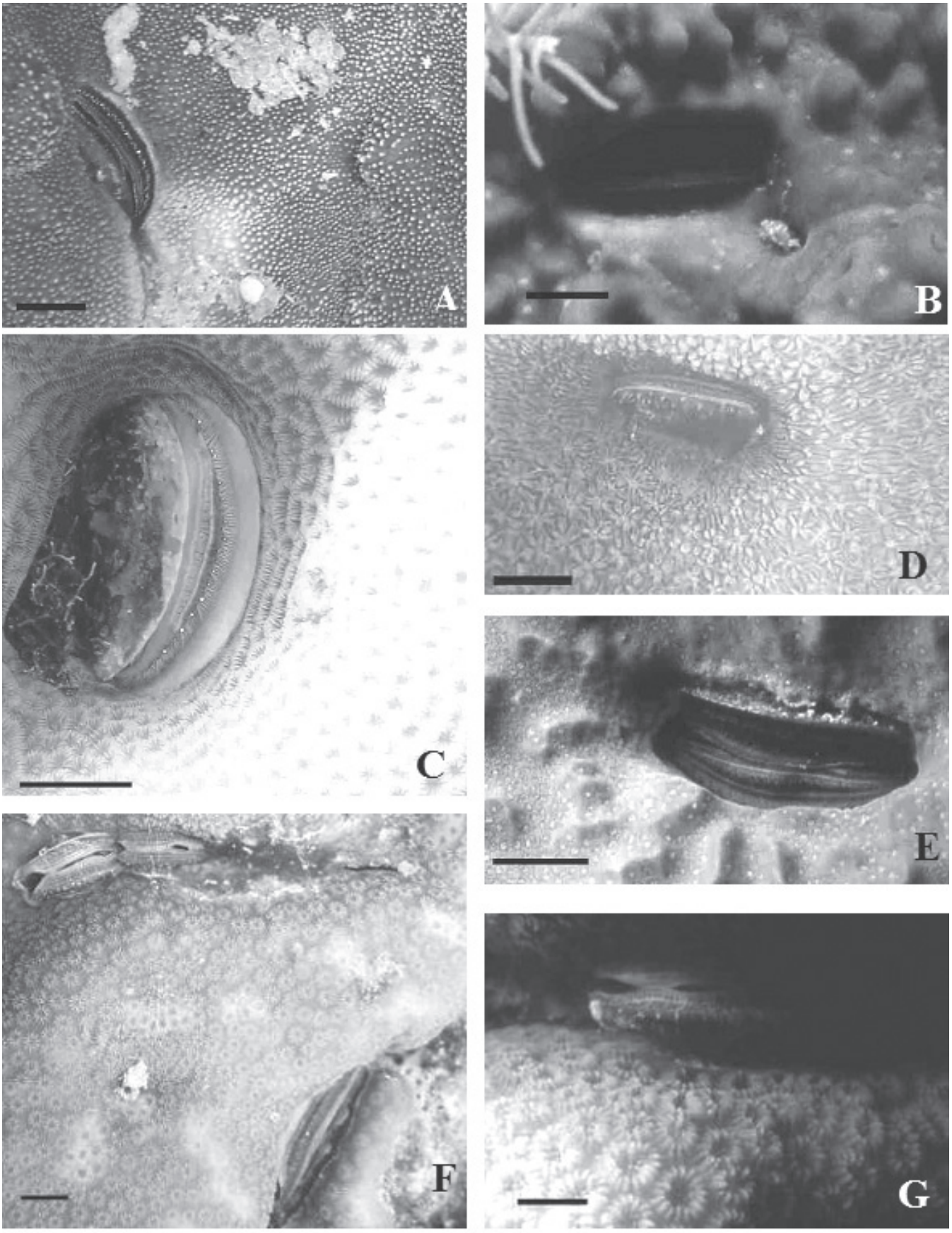

Fig. 3. Associations with *Pedum spondyloideum*: A, *Montipora informis* inhabited by *Pedum*; B, *Pedum* imbedded in *M. danae*; C, *Pavona clavus* with *Pedum*; D, *Pedum* in *Pav. duerdeni*; E, *Porites rus* inhabited by *Pedum*; F, *Pedum* aggregation in *Cyphastrea microphthalma*; G, *Favia stelligera* with *Pedum*. A–D are new associations; E, G are new records for Indonesia; Scale bars = 1 cm.

Some of the associations are new records from Indonesia. A colony of *Por. rus* from Site 6, hosted a single *Pedum* (Fig. 3E). Also a single *Pedum* was found in *Pav. maldivensis* from Site 7. We found three *Pedum* in a colony of *Cyphastrea microphthalma* (Fig. 3F) from Site 7 and two *Pedum* in a colony of *Favia stelligera* (Fig. 3G) from Site 9. *Pedum* also occured commonly in *Por. lutea* and *Por. lobata* and occasionally in *M. confusa* (Sites 6 and 7) and *Gardineroseris planulata* (Sites 2 and 7).

Abundance and depth distribution of *Pedum*

The number of *Pedum* per infested colony varied from one to eleven. A colony of *M. mactanensis* from Site 5 hosted a very high number of *Pedum* (11 individuals) at 15 m. Several specimens of *Pedum* were also found in *M. confusa* (maximum three individuals), *Gardineroseris planulata* (maximum three individuals), *Cyphastrea microphthalma* (maximum three individuals) and *Favia stelligera* (maximum two individuals). Up to six *Pedum* were found on massive *Porites* (Fig. 4) but in most cases *Pedum* occured only once (60%). The highest *Pedum* density (six individuals) was found between six to thirteen metres. For all other associations only one *Pedum* was found. The mean number of *Pedum* per infested colony is maximum for *M. mactanensis* (Table 2). No relationship was found between the number of *Pedum* associated with host corals and the depth (correlation coefficient r = 0.2123, P = 0.3688; considered not significant) and between the number of *Pedum* per association and the depth (correlation coefficient r = 0.0371, P = 0.8371; considered not significant). The population of *Pedum* was composed mainly of one–two cm wide individuals (Fig. 5), a width which corresponds to young adults.

The depth range of *Pedum* in the Wakatobi MNP extended from 3.5 to 18 m. The depth records of *Pedum* in the various host corals were 12.5 m in *M. capricornis*, 15 m in *M. confusa*, 9 m in *M. danae*, 8 m in *M. informis*, 13–15 m (14.33 ± 1.15 m) in *M. mactanensis*, 3.5–15.5 m (10.66 ± 6.33 m) in *Gardineroseris planulata*, 7 m in *Pav. clavus*, 14.5 m in *Pav. duerdeni*, 7 m in *Pav. maldivensis*, 5 m in *Cyphastrea microphthalma*, 3.5–18 m (8.86 ± 6.64 m) in massive corals of the genus *Porites,* 17 m in *Por. rus* and 8 m in *T. irregularis*.

Local distribution of *Pedum*

All the sites surveyed contained several individuals of *Pedum* (Table 4). The sites located on the fringing reefs near the Marine Research Station and near the training platforms on Hoga Island (Sites 1–4; Fig. 2) contained only a few individuals and *Pedum* was associated with a few coral species. On the contrary, the sites located further off Hoga Island (Sites 6, 7, 9 and 10) contained more individuals and the associations were more diversified, particularly at Site 7. *Pedum* from Sites 6 and 9 were recorded from five different coral species. The sites located on the fringing reefs on Kaledupa Island (Sites 5 and 8) contained many individuals; nevertheless, *Pedum* was recorded from four different coral species from Site 5 whereas it was only associated with massive corals of the genus *Porites* from Site 8.

Competitors

Apart from intraspecific competition for food and space, *Pedum* often has to cope with several competitors associated with the same host colony, dwelling in crevices or settling on dead parts of the coral (Kleemann, 2001; Scaps et al., 2005). Competitors were mainly observed in massive corals of the genus *Porites* (*Por. lutea* and *Por. lobata*). *Pedum* occured with other bivalves byssally attached to corals or within corals (*Tridacna* spp.), byssally attached in crevices of

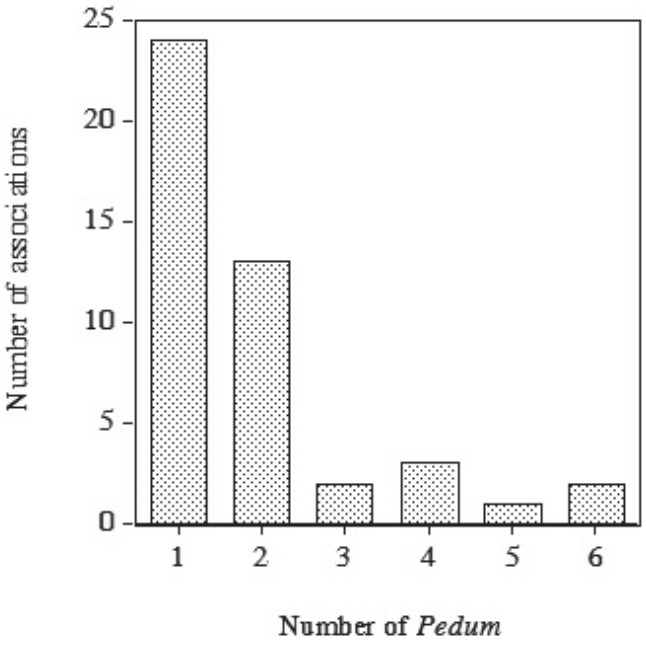

Fig. 4. The number of *Pedum spondyloideum* occuring in *Porites lobata* and *Por. lutea*.

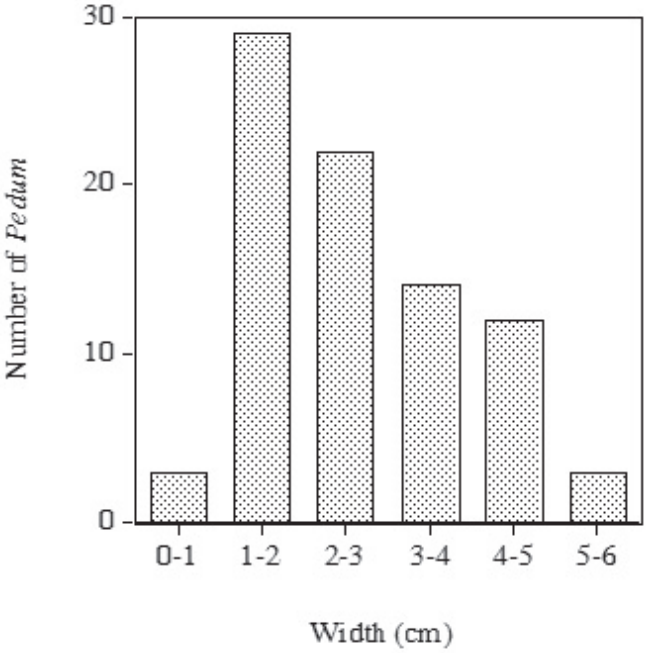

Fig. 5. Size distribution of *Pedum spondyloideum* in the Wakatobi MNP.

Table 4. Associations of *Pedum spondyloideum* according to sites.

Site	N_{ass}	Nd_{ass}	N_{ped}	Depth (m)	Size (cm)
1	1	1	3	7	1.2-2.8
2	4	3	8	3.5-15.5	1.4-3.7
3	1	1	2	8.5	1.6-2.4
4	2	2	2	7-7.5	2.4-3.2
5	7	4	21	5-14	1.4-4.8
6	7	5	11	5.5-17	1.8-4.6
7	12	6	23	5-15	0.6-5.8
8	11	1	22	4-7.5	0.7-5.6
9	11	5	14	5-18	1.2-4.4
10	4	3	9	6-14.5	1.4-3.8
Total	49	15	115	3.5-18	0.6-5.8

N_{ass}, number of associations; Nd_{ass}, number of different associations; N_{ped}, number of *Pedum*.

living corals (*Arca ventricosa*, *Barbatia foliata* and *Modiolus philippinarum*) or boring in living corals (*Lithophaga* spp.). It also occured with vermetid gastropods (*Dendropoma maxima* and *Serpulorbis grandis*) encrusted to living corals, serpulid annelids (*Spirobranchus giganteus*), hermit crabs of the genus *Paguritta* living in self-created boreholes in living corals (Lewinsohn, 1978; Patton & Roberston, 1980) and cryptochirid and cirriped crustaceans. Massive corals carried also sometimes some individuals of the corallivorous gastropod *Coralliophila neritoidea*.

DISCUSSION

Fifteen coral species are occupied to some degree by the scallop *Pedum spondyloideum* in the Wakatobi region; nevertheless, *Pedum* shows a strong preference for massive species of *Porites* (65%) with few records of other hosts. Previous reports from other localities in the western Indo-Pacific also showed that *Pedum* is mostly restricted to massive species of *Porites* (Table 3). *Pedum* was found associated with *Por. lutea* and *Por. lobata* at Phuket in Thailand and at Mellish Reef (Great Barrier Reef) in Australia (Nielsen, 1986; Kleemann, 1990; Scoffin & Bradshaw, 2000). At Lizard Island (Great Barrier Reef) *Pedum* was only found in *Por. rus* (Kleemann, 1995). More recently, Scaps et al., (2005) found that in the Pulisan region, located on the northeast coast of Sulawesi, *Pedum* was also mainly associated (87.5%) with massive *Porites* species (*Por. lobata* and *Por. lutea*). However, the associations are more diversified in the Wakatobi region compared to the Pulisan region. Thus, 15 different associations were found in the Wakatobi region for 10 surveyed sites compared to 11 associations for 21 surveyed sites in the Pulisan region. Moreover, although the same coral host species for *Pedum* are present in the two areas, some associations observed on the northeast coast of Sulawesi were not recorded in the Wakatobi region and vice-versa (Table 3). Thus, apart from massive species of *Porites*, *Pedum* was found associated with massive (*Coeloseris mayeri*, *Gardineroseris planulata*, *Hydnophora microconos*, *Por. evermanni* and *Por. monticulosa*) or encrusting (*Acropora robusta*, *Montipora confusa*, *Pachyseris speciosa* and *Leptastrea purpurea*) species of corals in the Pulisan area while it was observed associated with massive (*Gardineroseris planulata*, *Pav. maldivensis, Pav. clavus, Pav. duerdeni, Cyphastrea microphthalma, Favia stelligera*) or encrusting to semi-massive to even laminar species mainly of the genus *Montipora* (*M. capricornis*, *M. confusa*, *M. danae*, *M. informis*, *M. mactanensis, Por. rus, T. irregularis*) in the Wakatobi region. Data from the Red Sea showed that *Pedum* has so far been recorded from 14 host genera (Table 5) and is associated more frequently and in higher densities with *Montipora* species; however, *Pedum* do not infest the same *Montipora* species (such as *M. meandrina*, *M. stilosa*, *M. floweri*, *M. tertia*, *M. hoffmeisteri*, *M. monasteriata*, *M. tuberculosa* and *M. venosa*) as in the Wakatobi MNP. Although some species of *Montipora* are endemic to the Red Sea (*M. meandrina* and *M. stilosa*) the others have a large Indo-Pacific distribution and can be found on the coasts of Sulawesi. In consequence, the differences observed between the different regions of the biogeographic distribution of the species suggest that the associations may differ regionally. As yet, it is unclear what type of association exists between *Ped. spondyloideum* and its host coral. It is certain, however, that the distribution of *Ped. spondyloideum* on different coral species is not random, and there is a distinct habitat preference for certain corals over others.

The depth distribution of *Pedum* in the Wakatobi MNP ranges from 3.5 to 18 m, which is within the range for other localities: 0.5–25 m in the northern Red Sea (Kleemann, 1990); below seven metres in Eniwetok Atoll (Waller, 1972); four metres on the northeast coast of Redika Island, south of Noumea, New Caledonia (Waller, 1972); two–ten metres below the reef crest on Holbourne Island Reef and Keeper Reef, central Great Barrier Reef (DeVantier & Endean, 1988) and two–sixteen metres in the north-east coast of Sulawesi (Scaps et al., 2005).

High population densities within single coral heads from Raboul, New Britain (Yonge, 1967) and from the Red Sea (Kleemann, 1990, 2001; Zuschin & Piller, 1997) are less frequent in Wakatobi MNP. Densities are more important in the Wakatobi region (49 associations observed and 115 *Pedum* counted during 7.5 hours of diving) than in the Pulisan area (112 associations observed and 212 *Pedum* counted during

24 hours of diving). At the Great Barrier Reef, low densities in *Porites* were also noted, the highest values being 10 per 0.46 m coral diameter and 24 per 1.06 m across (DeVantier & Endean, 1988). From the Philippines, Savazzi (1999) reported even lower densities, rarely more than two–three *Pedum* per *Porites* one metre across.

In the Wakatobi region, *Pedum* was present at all the sites surveyed. Nevertheless, *Pedum* was rarer on the sites located on the fringing reefs near the Marine Research Station and near the training platforms on Hoga Island (Sites 1–4). On the contrary, *Pedum* was more common on the sites located around Hoga Island but further away from the Marine Research Station (Sites 6, 7, 9 and 10) and around Kaledupa Island (Sites 5 and 8). Therefore, it seems that *Pedum* is sensitive to the disturbance induced by SCUBA-divers or to chemical factors or marine currents which are likely to differ between the sites close or further away from the Marine Research Station.

Pedum is particularly common in Site 8 (Sampela) but is only associated with massive corals of the genus *Porites*. This Site is on the reef surrounding the Baujo village of Sampela on Kaledupa Island and sedimentation rates are particularly important (four times higher at Sampela than at Kaledupa; Crabbe & Smith, 2002). Sediment being deposited on the Sampela reef consists of fine sublittoral sands (Crabbe & Smith, 2002). The coral reef cover at Sampela is particularly low due to the fact that the scleractinian coral community is severely impacted by sedimentation. The coral community at this site is less diversified and dominated by species that can survive in a turbid environment such as massive *Porites* species. Nevertheless, although the coral cover is much less important at Sampela compared to the other sites, the number of *Pedum* specimen associated with scleractinian host corals is comparable or even higher than that of other sites indicating that the massive colonies of *Porites* are heavily infested by *Pedum*. These data are in concordance with previous studies indicating that *Pedum* is mainly found in sheltered areas with high sedimentation rates and high nutrient content (Kleemann, 1990; Scaps et al., 2005) and is rare at exposed sites (Kleemann, 1995; Waller, 1972).

As has been observed by Kleemann (1990, 2001) from the northern Red Sea and by Scaps et al., (2005) from the Pulisan region, we also found in the Wakatobi MNP that *Pedum* occurring on massive coral colonies occurred alone or together with other nestling (*Tridacna* spp., *Arca ventricosa*, *Barbatia foliata*, *Modiolus philippinarum,* vermetid gastropods) and/or boring endolithic associates (crustaceans, serpulids, and bivalves of the genus *Lithophaga* or *Gastrochaena*). Sometimes, in addition to these competitors, massive corals are infested by the corallivorous snail *Coralliophila neritoidea*. Almost all coral associates are filter-feeding heterotrophs and hence, would be expected to increase in numbers in water with elevated nutrient concentrations (Risk et al., 2001 ; Floros et al., 2005). When describing rapid techniques for assessing coral reef health, Risk et al., (2001) suggested that the health of a reef may be evaluated by scoring the density of coral associates on massive corals. This is based on the theory that coral associate numbers will increase with organic loading: stressed corals will be less able to protect themselves from settlement and overgrowth (Risk et al. 1993). In that sense our results are particularly interesting since we have found that *Pedum* is more common on a reef severely impacted by sedimentation and with a low coral cover.

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LITERATURE CITED

Crabbe, M. J. C. & D. J. Smith, 2002. Comparison of two reef sites in the Wakatobi marine national park (SE Sulawesi, Indonesia) using digital image analysis. *Coral Reefs*, **21**: 242–244.

DeVantier, L. M. & R. Endean, 1988. The scallop *Pedum spondyloideum* mitigates the effects of *Acanthaster planci* predation on the host coral *Porites*: host defence facilitated by exaptation? *Marine Ecology Progress Series*, **47**: 293–301.

Elliott, G., B. Mitchell., B. Wiltshire., I. R. Abdum Manan & S. Wisman, 2001. Community participation in marine protected area management: Wakatobi national park, Sulawesi, Indonesia. *Coastal Management*, **29**: 295–316.

Floros, C. D., M. J. Samways & B. Armstrong, 2005. Polychaete (*Spirobranchus giganteus*) loading on South African corals. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **15**: 289–298.

Frank, U., I. Brickner., B. Rinkevich., Y. Loya., R. P. M. Bak., Y. Achituv & M. Ilan, 1995. Allogeneic and xenogeneic interactions in reef-building corals may indice tissue growth without calcification. *Marine Ecology Progress Series*, **124**: 181–188.

Kleemann, K., 1990. Coral associations, biocorrosion, and space competition in *Pedum spondyloideum* (Gmelin) (Pectinacea, Bivalvia). *P.S.Z.N.: Marine Ecology*, **11**: 77–94.

Kleemann, K., 1995. Associations of coral and boring bivalves: Lizard Island (Great Barrier Reef, Australia) versus Safaga (N Red Sea). *Beiträge zur Paläontologie*, **20**: 31–39.

Kleemann, K., 2001. The pectinid bivalve *Pedum spondyloideum* (Gmelin, 1791): amount of surface and volume occupied in host corals from the Red Sea. *P.S.Z.N.: Marine Ecology*, **22**: 111–133.

Lewinsohn, C., 1978. Bemerkungen zur Taxonomie von *Paguritta harmsi* (Gordon) (Crustacea Decapoda, Anomura) und Beschreibung einer neuen Art der gleichen Gattung aus Australien. *Zoologische Mededelingen*, **53**: 243–252.

Mastaler, M., 1978. The marine molluscan assemblages of Port Sudan, Red Sea. *Zoologische Mededelingen*, **53**: 117–144.

Nielsen, C., 1986. Fauna associated with the coral *Porites* from Phuket, Thailand. Part 1: Bivalves with description of a new species of *Gastrochaena*. *Research Bulletin of the Phuket Marine Biological Center*, **42**: 1–24.

Patton, W. K. & D. R. Roberston, 1980. Pair formation in a coral inhabiting hermit crab. *Oecologia*, **47**: 267–269.

Risk, M. J., J. Dunn., W. R. Allison & C. Horrill, 1993. Reef monitoring in Maldives and Zanzibar: low-tech and high-tech science. In: R.N. Ginsburg (Ed.), *Global Aspects of Coral Reefs: Health, Hazards and History*. University of Miami, Pp. 66–72. Miami.

Risk, M. J., J. M. Heikoop., E. N. Edinger & M. V. Erdmann, 2001. The assessment 'toolbox': community-based reef evaluation methods coupled with geochemical techniques to identify sources of stress. *Bulletin of Marine Science*, **69**: 443–458.

Sammarco, P. W. & M. J. Risk, 1990. Large-scale patterns in the internal bioerosion of *Porites*: cross continental shelf trends in the Great Barrier Reef. *Marine Ecology Progress Series*, **59**: 145–156.

Savazzi, E., 1999. Constructional morphology of the bivalve *Pedum*. In: Johnston P.A. & J.W. Haggart (Eds.), *Bivalves: an Eon of evolution. Paleontological studies honoring Norman D. Newell*. Calgary University Press, Pp. 413–421.

Scaps, P., V. Denis., S. Berhimpon & F. Kaligis, 2005. Coral associations and space competitors of *Pedum spondyloideum* (Gmelin, 1791) (Bivalvia, Pteriomorphia, Pectinidae) from the northeast coast of Sulawesi, Indonesia. *Basteria*, **69**: 157–166.

Scott, P. J. B., 1987. Associations between coral and macro-faunal invertebrates in Jamaica, with a list of Caribbean and Atlantic coral associates. *Bulletin of Marine Science*, **4**: 271–286

Scoffin, T. P. & C. Bradshaw, 2000. The taphonomic significance of endoliths in dead–versus live–coral skeletons. *Palaios*, **15**: 248–254.

Smith, S. D. A. & V. J. Harriott, 1998. Tube-building polychaete worms smother corals in the Solitary Island Marine Park, northern NSW, Australia. *Coral Reefs*, **17**: 342.

Veron, J. E. N., 2000. *Corals of the World. Volume 1*. Australian Institute of Marine Sciences, Townsville. 463 pp.

Veron, J. E. N., 2000. *Corals of the World. Volume 2*. Australian Institute of Marine Sciences, Townsville. 429 pp.

Veron, J. E. N., 2000. *Corals of the World. Volume 3*. Australian Institute of Marine Sciences, Townsville. 490 pp.

Veron, J. E. N. & M. Pichon, 1976. Scleractinia of eastern Australia. Part I. Families Thamnasteridae, Astrocoeniidae, Pocilloporidae. *Australian Institute of Marine Sciences Monograph Series*, **1**: 1–86.

Veron, J. E. N. & M. Pichon, 1980. Scleractinia of eastern Australia. Part III. Families Agaricidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae, Dendrophylliidae. *Australian Institute of Marine Sciences Monograph Series*, **4**: 1–422.

Veron, J. E. N. & M. Pichon, 1982. Scleractinia of eastern Australia. Part IV. Family Poritidae. *Australian Institute of Marine Sciences Monograph Series*, **5**: 1–195.

Veron, J. E. N., M. Pichon. & M. Wijsman-Best, 1977. Scleractinia of eastern Australia. Part II. Families Faviidae, Trachyphylliidae. *Australian Institute of Marine Sciences Monograph Series*, **3**: 1–233.

Veron, J. E. N. & C.C. Wallace, 1984. Scleractinia of eastern Australia. Part V. Familly Acroporidae. *Australian Institute of Marine Sciences Monograph Series,* **6**: 1–485.

Waller, T. R., 1972. The Pectinidae (Mollusca: Bivalvia) of Eniwetok Atoll, Marshall Islands. *Veliger*, **14**: 221–264.

Yonge, C. M., 1967. Observations on *Pedum spondyloideum* (Chemnitz) Gmelin, a scallop associated with reef-building corals. *Proceedings of the Malacological Society of London*, **37**: 311–323.

Zuschin, M. & W. E. Piller, 1997. Bivalve distribution on coral carpets in the northern Bay of Safaga (Red Sea, Egypt) and its relation to environmental parameters. *Facies*, **37**: 183–194.