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15D Biodiversity and coevolution of organisms associated with corals

# Association between Pedum spondyloideum (Bivalvia, Pectinidae) and live stony

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**Abstract.** Associations between the nestling and facultatively boring pectinid *Pedum spondyloideum* and stony corals (Scleractinia, Milleporidae) were reported in the Indo-Pacific from data obtained from literature and from field observations. *Pedum* used 65 hosts including the previously unrecorded species of *Coscinarea exesa* (Raja Empat), *Echinopora gemmacea* (Dahab, Sinai peninsula), *Goniopora savignyi* (Dahab, Sinai peninsula), *Porites arenatai* (Sipadan), *Porites murrayensis* (Bali) and *Millepora platyphylla* ((Dahab, Sinai peninsula). Most of the host species of *Pedum* individuals have a wide Indo-Pacific distribution and although some scleractinian coral species are common to the different studied sites, *Pedum* individuals did not infest the same species. Nevertheless, the most frequently colonized corals were of massive form. Moreover, calcareous hydrozoans of the genus *Millepora* are inhabited by *Pedum* individuals in the northern Red Sea and the eastern part of the Indian Ocean but not in the Pacific Ocean. The results indicate that the associations between the pectinid bivalve *Pedum spondyloideum* and hard corals differ regionally.

**Key words:** *Pedum spondyloideum*, Scleractinian corals, Calcareous hydrozoans, Coral associates

## Introduction

Among marine ecosystems coral reefs are particularly well known for their biodiversity. The biodiversity of coral reefs is dominated by invertebrates (Stella et al. 2011) and living scleractinian corals provide microhabitats for a large number of small, cryptic invertebrates which use the tissue and skeletons of the colonies as substrata (Frank et al. 1995; Floros et al. 2005). There are at least 860 invertebrate species that have been described as coral-associated, of which 310 and 130 are decapod crustaceans and molluscs respectively (reviewed in Stella et al. 2011) and over half of coral-associated invertebrates appear to have an obligate dependence on live corals. Nevertheless, few detailed studies have been performed in order to understand the nature of the association between invertebrates and host corals.

The nestling and facultatively boring pectinid bivalve *Pedum spondyloideum* (Gmelin 1791) is an obligate associate of living scleractinian corals in the Indo-Pacific. It attaches byssally and 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 and Endean 1988, Kleemann 1990, Savazzi 1999).

Before studies carried out by the author began in 2004, data about associations between *Pedum* individuals and hard corals were very scarce. Apart from the reports of Kleemann (1990, 2001) from the northern Red Sea, most of the observations were very punctual and not specifically dedicated to *Pedum spondyloideum*. In particular, nothing was known about these associations in the Indian Ocean and the "Coral Triangle" the global centre of marine biodiversity.

## Material and Methods

Data were obtained from the literature and from my own observations during fieldwork in the northern Red Sea (Dahab, Sinai peninsula in 2011), in the eastern part of the Indian Ocean (west coast of Thailand in 2010) an in the Coral Triangle (Indonesia: north Sulawesi in 2004, Tukang Besi Archipelago off the southeast coast of Sulawesi in 2005, East Kalimantan in 2006, Komodo in 2005, Alor in 2006, Bali in 2011, Raja Empat in 2011 and Malaysia: Sipadan island and adjacent areas in 2008) (Fig. 1).

The roving diver technique (Schmitt et al. 2002; Munro 2005) was used to record the presence of *Pedum* clams in hard corals at each dive site down to or beyond the deepest visible coral. Corals were identified in the field or in the laboratory after collection of representative samples. Coral samples were bathed in bleach for 24 to 48 h to remove living tissue. They were then rinsed in freshwater, dried and identified following Veron (2000). Calcareous hydrozoans of the genus *Millepora* were identified according to Razak and Hoeksema (2003).

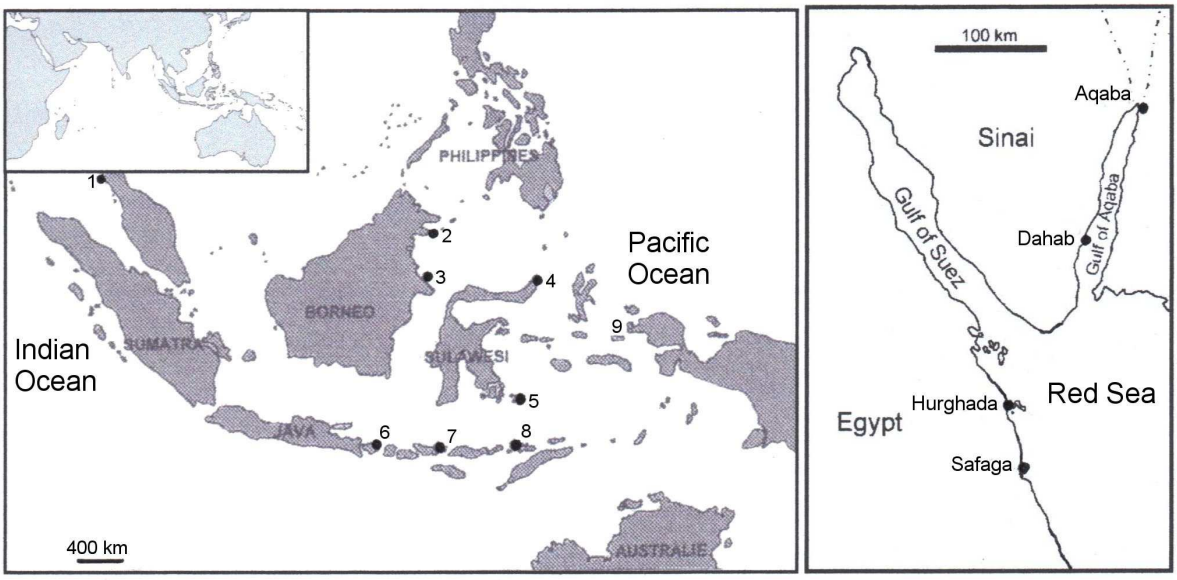


Figure 1: Map of the Indo-Pacific and the Red Sea showing the different areas where the studies concerning the association between *Pedum* individuals and their host corals were carried out. 1. West coast of Thailand; 2. Sipadan; 3. East Kalimantan; 4. North Sulawesi; 5. Southeast coast of Sulawesi; 6. Bali; 7. Komodo; 8. Alor; 9. Raja Empat.

**Results and Discussion**

During this study two new associations between *P. spondyloideum* and its scleractinian host corals were identified from Dahab, northern Red Sea (*Echinopora forskialiana* (Fig. 2) and *Goniopora savignyi* (Fig. 3)) and three from the "Coral Triangle" (*Coscinarea exaesa* (Fig. 4) from Raja Empat, *Porites arenatai* (Fig. 5) from Sipadan and *Porites murrayensis* (Fig. 6) from Bali). To date, 62 species of scleractinian corals are known to be infested by *P. spondyloideum* (Table 1). Most of the host species of *Pedum* individuals have a wide Indo-Pacific distribution and although most of the scleractinian coral species are common to the different studied sites, *Pedum* individuals do not infest the same species (Table 1). In conclusion, there appears to be a disparity between the different scleractinian coral species colonized relative to geographic location.

In the west Pacific, *Pedum* clams are associated more frequently with *Montipora* and *Porites* (Table 1). These species have small corallites and a high cœnosteum-to-corallite ratio, which may facilitate infestation by providing a sufficient surface area. These corals are competitively subordinate in terms of aggression (Sheppard 1979; Dai 1990). Similarly, Dai and Yang (1995) also documented a non-random distribution of the tube-dwelling serpulid *Spirobranchus giganteus* on coral reefs in southern Taiwan. Four scleractinian coral species, *Porites lutea*, *P. lobata*, *P. lichen* and *Montipora informis*, considered competitively subordinate were frequently colonized by the worm, whereas most coral species were not. Interestingly, the same species are the most heavily colonized by *Pedum* clams in the "Coral Triangle". It may be that the planktonic larvae of *P. spondyloideum* may be susceptible to coral nematocysts in the "Coral Triangle". On the contrary, Scaps (2011) found that, in the eastern part of the Indian Ocean, the aggressive coral *Galaxea astreata* and calcareous hydrozoans of the genus *Millepora* were inhabited by *Pedum* individuals (Table 1). Moreover, during this study, a new association between *P. spondyloideum* and the calcareous hydrozoan *Millepora platyphylla* (Fig. 7) was observed in the northern Red Sea. It could be that *P. spondyloideum* occurring in the Red Sea and the Indian Ocean is more immune to nematocyst stings

It would be important to understand the factors that determine the geographical distribution of *Pedum spondyloideum*. In this light, we can consider the hypothesis according to which populations of *Pedum* clams separated by large geographical distances would be genetically distinct. This hypothesis could explain why larvae would be more susceptible to the nematocysts of corals in the west Pacific than in the Red Sea and the Indian ocean. Genetic data are required in order to test this hypothesis.

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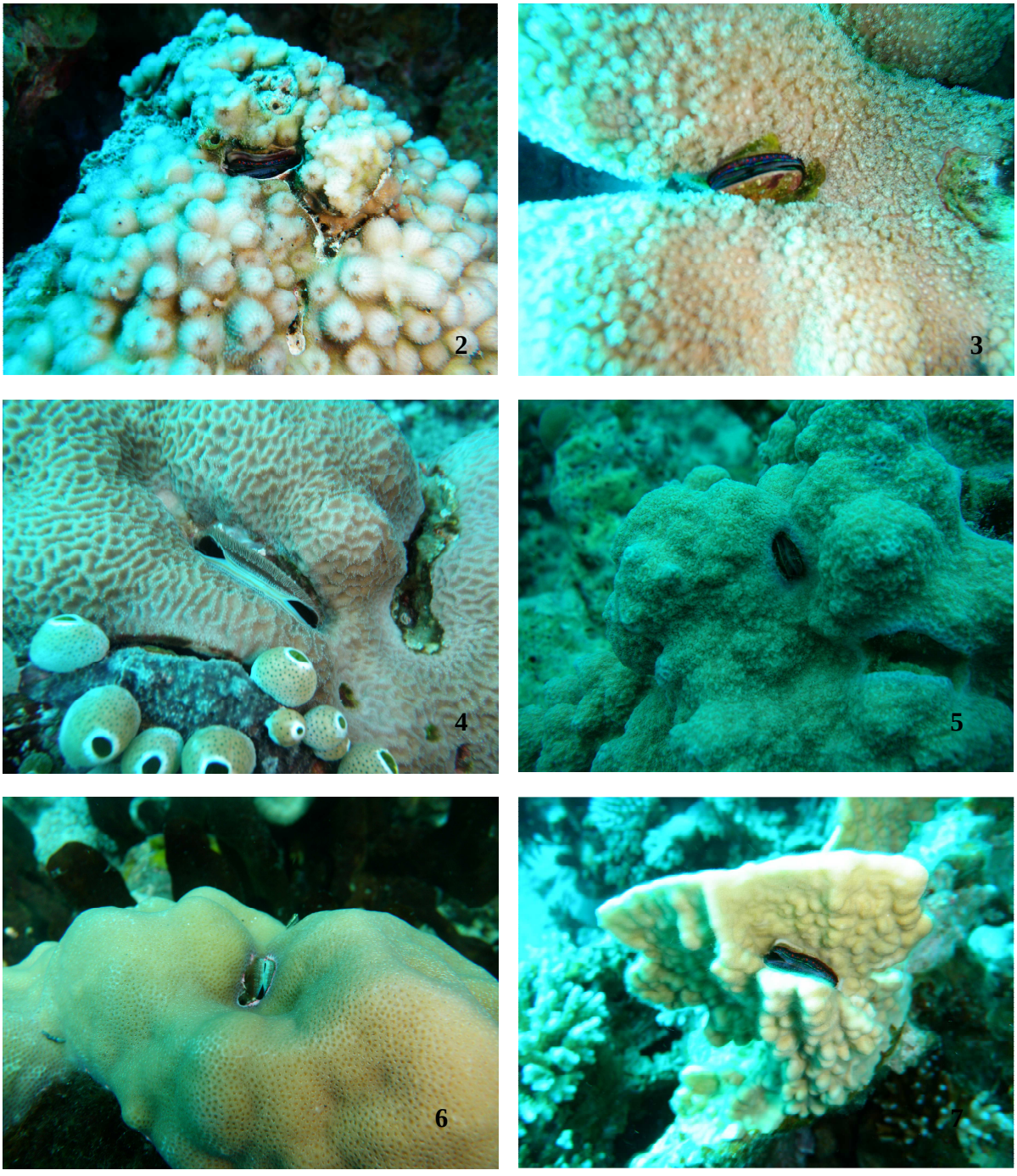


Figure 2: New associations between *Pedum* clams and hard corals. 2. *Echinopora forskaliana* inhabited by *Pedum* clam (Dahab, 2011); 3. *Pedum spondyloideum* imbedded in *Goniopora savignyi* (Dahab, 2011). 4. A *Pedum* clam imbedded in *Coscinarea exaesa* (Raja Empat, 2011). 5. *Porites arenatai* with *Pedum* clam (Sipadan, 2008). 6. *Porites murrayensis* inhabited by *Pedum* clam (Bali, 2011). 7. A *Pedum* clam in *Millepora platyphylla* (Dahab, 2011).

| Species | locality and reference |
|---|---|
| **CLASS ANTHOZOA** | |
| **ORDER SCLERACTINIA** | |
| **FAMILLY ACROPORIDAE (23)** | |
| *Acropora robusta* | North Sulawesi (Scaps et al. 2005) |
| *Astreopora myriophthalma* | Aqaba, Sinai peninsula (Kleemann 2001) |
| *Montipora aequituberculata* | Komodo, Alor (Scaps et al. 2008), Raja Empat (this study) |
| *Montipora caliculata* | West coast of Thailand (Scaps 2011), Flores (Veron 2000: t1, 128, fig. 1), Sipadan, Bali (this study) |
| *Montipora capricornis* | Southeast coast of Sulawesi (Scaps and Dennis 2007) |
| *Montipora confusa* | North Sulawesi (Scaps et al. 2005), Southeast coast of Sulawesi (Scaps and Dennis 2007), East Kalimantan, Komodo, Alor (Scaps et al. 2008) |
| *Montipora crassituberculata* | Southeast coast of Sulawesi (Scaps and Dennis 2007), Alor (Scaps et al. 2008) |
| *Montipora danae* | Southeast coast of Sulawesi (Scaps and Dennis 2007) |
| *Montipora digitata* | Sipadan (Scaps 2009) |
| *Montipora efflorescens* | Alor (Scaps et al. 2008) |
| *Montipora floweri* | Northern Red Sea (Kleemann 1990) |
| *Montipora hispida* | Komodo (Scaps et al. 2008), Sipadan (this study) |
| *Montipora hoffmeisteri* | Northern Red Sea (Kleemann 2001) |
| *Montipora informis* | Sinai peninsula (Veron 2000 : t1, 113, fig. 3), Southeast coast of Sulawesi (Scaps and Dennis 2007), Komodo, Alor (Scaps et al. 2008) |
| *Montipora mactanensis* | Southeast coast of Sulawesi (Scaps and Dennis 2007), Alor (Scaps et al. 2008) |
| *Montipora meandrina* | Northern Red Sea (Kleemann 1990), Dahab Sinai peninsula (this study) |
| *Montipora monasteriata* | Northern Red Sea (Kleemann 2001), Komodo (Scaps et al. 2008) |
| *Montipora spongodes* | Alor (Scaps et al. 2008) |
| *Montipora stilosa* | Northern Red Sea (Kleemann 1990), Dahab Sinai peninsula (Veron 2000, t1, 103, fig. 5, this study) |
| *Montipora tertia** | Northern Red Sea (Kleemann 1990) |
| *Montipora tuberculosa* | Northern Red Sea (Kleemann 2001), Dahab Sinai peninsula (this study) |
| *Montipora turgescens* | East Kalimantan, Alor (Scaps et al. 2008) |
| *Montipora undata* | East Kalimantan, Komodo, Alor (Scaps et al. 2008), Bali (this study) |
| *Montipora venosa* | Northern Red Sea (Kleemann 2001), Alor (Scaps et al. 2008) |
| **FAMILLY AGARICIDAE (10)** | |
| *Coeloseris mayeri* | West coast of Thailand (Scaps 2011), North Sulawesi (Scaps et al. 2005) Alor (Scaps et al. 2008), Sipadan, Raja Empat (this study) |
| *Gardineroseris planulata* | Northern Red Sea (Kleemann 1990), West coast of Thailand (Scaps 2011), North Sulawesi (Scaps et al. 2005), Southeast coast of Sulawesi (Scaps and Dennis 2007), East Kalimantan, Komodo (Scaps et al. 2008), Sipadan, Raja Empat (this study) |
| *Leptoseris mycetoseroides* | Torres Strait, GBR (Veron 1986 : 305, fig. 1) |
| *Pachyseris rugosa* | West coast of Thailand (Scaps 2011), Raja Empat (this study) |
| *Pachyseris speciosa* | Northern Red Sea (Kleemann 1990), North Sulawesi (Scaps et al. 2005), Komodo, Alor (Scaps et al. 2008) |
| *Pavona cactus* | Northern Red Sea (Kleemann 2001) |
| *Pavona clavus* | West coast of Thailand (Scaps 2011), Southeast coast of Sulawesi (Scaps and Dennis 2007), East Kalimantan, Komodo, Alor (Scaps et al. 2008), Sipadan, Raja Empat (this study) |
| *Pavona duerdeni* | West coast of Thailand (Scaps 2011), Southeast coast of Sulawesi (Scaps and Dennis 2007), Alor (Scaps et al. 2008), Sipadan, Raja Empat (this study) |
| *Pavona maldivensis* | Northern Red Sea (Kleemann 1990), Southeast coast of Sulawesi (Scaps and Dennis 2007), Komodo (Scaps et al. 2008), Bali (this study) |
| *Pavona varians* | Northern Red Sea (Kleemann 2001) |
| **FAMILLY SIDERASTREIDAE (3)** | |
| ***Coscinarea exesa*** | **new record Raja Empat** |
| *Coscinarea monile* | Northern Red Sea (Kleemann 1990) |
| *Psammocora digitata* | West coast of Thailand (Scaps 2011), Sipadan (Scaps 2009) |
| **FAMILLY FAVIIDAE (10)** | |
| *Cyphastrea microphthama* | Northern Red Sea (Kleemann 1990, Zuschin and Piller 1997), Dahab Sinai peninsula (this study), Southeast coast of Sulawesi (Scaps and Dennis 2007), Bali, Raja Empat (this study) |
| *Cyphastrea serailia* | West coast of Thailand (Scaps, 2011) |
| ***Echinopora forskaliana*** | **new record Dahab Sinai peninsula** |
| *Echinopora gemmacea* | Northern Red Sea (Kleemann 1990), Dahab Sinai peninsula (this study) |
| *Favia helianthoides* | Northern Red Sea (Kleemann 2001), Dahab Sinai peninsula (this study) |
| *Favia stelligera* | Northern Red Sea (Kleemann 1990), Dahab Sinai peninsula (this study), West coast of Thailand (Scaps 2011), Southeast coast of Sulawesi (Scaps and Dennis 2007), Sipadan, Bali, Raja Empat (this study), Eniwetok Atoll, Pacific (Waller 1972) |
| *Favites abdita* | West coast of Thailand (Scaps 2011) |
| *Goniastrea edwardsi* | Northern Red Sea (Kleemann 2001), Dahab Sinai peninsula (this study) |
| *Goniastrea retiformis* | Northern Red Sea (Kleemann 1990), Bali (this study) |
| *Leptastrea purpurea* | Northern Red Sea (Kleemann 2001), North Sulawesi (Scaps et al. 2005) |
| **FAMILLY MERULINIDAE (1)** | |
| *Hydnophora microconos* | Northern Red Sea (Kleemann 2001), North Sulawesi (Scaps et al. 2005), Sipadan (this study) |
| **FAMILLY OCULINIDAE (1)** | |
| *Galaxea astreata* | West coast of Thailand (Scaps 2011) |
| **FAMILLY PORITIDAE (11)** | |
| ***Goniopora savignyi*** | **new record Dahab Sinai peninsula** |
| *Porites annae* | Alor (Scaps et al. 2008), Solomon islands (Veron 2000 : t3, 310, fig. 4) |
| ***Porites arenatai*** | **new record Sipadan** |
| *Porites evermanni* | North Sulawesi (Scaps et al. 2005) |
| *Porites lichen* | Sipadan (Scaps 2009) |

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|---|---|
| *Porites lobata* | West coast of Thailand (Scaps 2011), North Sulawesi (Scaps et al. 2005), Southeast coast of Sulawesi (Scaps and Dennis 2007), East Kalimantan, Komodo, Alor (Scaps et al. 2008), Sipadan, Bali, Raja Empat (this study), Mellish Reef, GBR (Veron 1986, 220-221, fig. 2) |
| *Porites lutea* | Red Sea (Mastaller 1978, Kleemann 1990), Dahab Sinai peninsula (this study), West coast of Thailand (Nielsen 1986, Scaps 2011), North Sulawesi (Scaps et al. 2005), Southeast coast of Sulawesi (Scaps and Dennis 2007), East Kalimantan, Komodo, Alor (Scaps et al. 2008), Sipadan, Bali, Raja Empat (this study) |
| *Porites monticulosa* | North Sulawesi (Scaps et al. 2005), Southeast coast of Sulawesi (Scaps and Dennis 2007) |
| ***Porites murrayensis*** | **new record Bali** |
| *Porites nodifera* | Sinai peninsula (Veron 2000 : t3, 297, fig. 6) |
| *Porites rus* | Northern Red Sea (Kleemann 1990), Dahab Sinai peninsula (this study), West coast of Thailand (Scaps 2011), Alor (Scaps et al. 2008), Sipadan, Bali, Raja Empat (this study), Lizard Island, GBR (Kleemann 1995) |
| **FAMILLY DENDROPHYLLIIDAE (3)** | |
| *Turbinaria irregularis* | Southeast coast of Sulawesi (Scaps and Dennis 2007) |
| *Turbinaria mesenterina* | Northern Red Sea (Kleemann 1990) |
| *Turbinaria stellulata* | Komodo (Scaps et al. 2008) |
| **CLASS HYDROZOA** | |
| **ORDER ATHECATAE** | |
| **FAMILLY MILLEPORIDAE (3)** | |
| *Millepora dichotoma* | West coast of Thailand (Scaps 2011) |
| *Millepora exaesa* | West coast of Thailand (Scaps 2011) |
| ***Millepora platyphylla*** | **new record Dahab Sinai peninsula** |

*Non valid species

Table 1 : Host stony corals (Scleractinia, Milleporidae) of *Pedum spondyloideum*

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