The Shallow-water Macro Echinoderm Fauna of Nha Trang Bay (Vietnam): Status at the Onset of Protection of Habitats

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ABSTRACT

Hon Mun Marine Protected Area, in Nha Trang Bay (South Central Vietnam) was established in 2002. In the first period after protection had been initiated, a baseline survey on the shallow-water macro echinoderm fauna was conducted. Reefs in the bay were surveyed by transects and free-swimming observations, over an area of about 6450 m^2. The main area focused on was the core zone of the marine reserve, where fishing and harvesting is prohibited. Abundances, body sizes, microhabitat preferences and spatial patterns in distribution for the different species were analysed.

A total of 32 different macro echinoderm taxa was recorded (7 crinoids, 9 asteroids, 7 echinoids and 8 holothurians). Reefs surveyed were dominated by the locally very abundant and widely distributed sea urchin *Diadema setosum* (Leske), which comprised 74% of all specimens counted. Most species were low in numbers, and showed high degree of small-scale spatial variation. Commercially valuable species of sea cucumbers and sea urchins were nearly absent from the reefs.

Species inventories of shallow-water asteroids and echinoids in the South China Sea were analysed. The results indicate that the waters of Nha Trang have echinoid and asteroid fauna quite similar to that of the Spratly archipelago. Comparable pristine areas can thus be expected to be found around the offshore islands in the open parts of the South China Sea.

The effects of echinoderms on the reefs, impacts from humans on the echinoderms and possible effects from protection of habitats are evaluated.

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1. INTRODUCTION

1.1 Background

Awareness of the need for effective protection of South East Asia's marine environments has increased in recent years. Protection usually comes in the form of the establishment of clear-cut marine reserves, or so-called Marine Protected Areas (MPAs). The protected areas are placed in important habitats such as coral reefs, mangrove forests and sea-grass beds. In 2002 the first MPA of its kind was established in Vietnam. Hon Mun Marine Protected Area, in Nha Trang Bay, was introduced after a realization of the urgent needs for management of the marine habitats in the region.

Protection of habitats is normally followed up by collection of data in conservation-oriented monitoring and research programmes (Hatcher et al., 1989). Monitoring programmes are currently being conducted in Nha Trang Bay. In order to evaluate any effects from protection, there is a need for baseline information on ecological aspects of the flora and fauna at hand. Echinoderms are an essential part of the marine biodiversity, they are ecologically important, and are affected by human activities. Some of the species have high commercial value, and are heavily exploited in Vietnam. In order to conserve and manage these resources, research on several levels is needed. This can only occur if the taxonomy, fauna composition and ecology of species present is fully understood (Samyn, 2000). This thesis is a contribution to the research done on biodiversity of the benthic fauna of Vietnam, a field of science that is receiving growing interest and appreciation in the country. The thesis deals with macro echinoderms found on the patch reefs in Nha Trang Bay, at the onset of the Hon Mun Marine Protected Area project.

It has been shown that echinoderms, especially echinoids, and in part asteroids often play a central role in reef communities. Echinoderms may form extremely dense feeding aggregations (Schiebling, 1980), and their foraging activities are known to have severe impact on reef ecology (review in Birkeland, 1988). Sea urchins are important herbivores, and are key species in controlling the algal cover on hard substrates. They can thus be powerful structuring forces determining whether algal turf or coral cover is dominating in a specific reef location (Sammarco, 1980; Carpenter, 1981; Carpenter, 1986; Hay, 1984; Lirman, 2001). Echinoids also play an important role in the turnover of organic and inorganic carbonate on coral reefs. The ingestion of dead coral substratum together with algae growing on them is referred to as echinoid bioerosion. Echinoid bioerosion is ecologically important as a limiting factor of reef growth, and sea urchins may play a key role in the conversion of corals to carbonate sediments (Glynn et al., 1979; Bak, 1990; Mokady et al., 1996; Carreiro-Silva and McClanahan, 2001). Under the right circumstances echinoderms can be a major threat to live corals as well. Sea urchins (*Diadema*) may feed on live coral when abundance of algae is reduced (Carpenter, 1981), and mortality of corals is often increased by presence of urchin grazers (Glynn et al., 1979; Sammarco, 1980). Some asteroids are well-known predators on live coral polyps, and in the last decades mass aggregations of the crown–of-thorns seastar, *Acanthaster planci* (Linnaeus, 1758) have been shown to decimate extensive areas of coral reefs (Endean, 1973; Moran, 1986; Brodie et al., 2005). Phase shifts in coral reefs, between relatively stable algal and coral-dominated phases are often governed by herbivorous and corallivorous echinoderms (Done, 1992; Roberts, 1995; Lirman, 2001; Miller et al., 2003). It is evident, that through the predation on algae and invertebrates, along with general omnivory, filter feeding and deposit feeding, the echinoderms comprise a diverse and potent group of organisms on the reefs. Echinoderms are also involved as hosts in a number of commensal and parasitic interactions (Zmarzly, 1984; Lyskin and Britaev, 2005; Parmentier and Vandewalle, 2005), and thereby contribute to the preservation of the remarkable biodiversity found in reef communities.

Human activities can indirectly or directly influence the fauna composition of echinoderms, and thus their effect on the reef communities. In areas with extensive human harvest of predators of echinoderms, the ecological impact can be high because of increased survival of echinoderms. In other areas, direct removal of echinoderms can be of importance for the condition of the reefs. Vietnam houses a population of 80 million people, who receive much of their food and income from the sea. The impact from humans on echinoderms is expected to be large in the country’s marine habitats.

A status report on the macro-echinoderm fauna at the onset of Hon Mun MPA can be indicative of the state of the reefs at present. In addition, background data on the community structure of the echinoderms in the bay, will provide valuable information for the assessment of effects of protection of habitats.

1.2 Objectives

The main objectives of this study were to:

1. Describe:
   - Fauna composition of shallow-water macro echinoderms in Nha Trang Bay;
   - abundance and body sizes of the different species;
   - spatial patterns in distribution.
2. Evaluate:
   - Factors controlling the community structure of the echinoderms in the bay;
   - ecological impacts from the echinoderms on the reefs;
   - impacts from humans on the echinoderms;
   - possible effects from protection of habitats.

Sampling was conducted by use of belt transects, and free-swimming visual surveys.

Results obtained in this study can hopefully serve as a baseline for future surveys and monitoring programmes in Nha Trang Bay.

2. LOCATION

2.1 Nha Trang Bay

Nha Trang bay (12º09' – 12º15'N, 109º13' – 109º22'E) lies in the Khahn Hoa province in the south-central part of Vietnam (Fig. 2.1). Nine islands are situated in the bay at distances of about 1 to 15 km from the coast. The islands support a wide variety of marine habitats. Coral reefs, soft bottom communities, seagrass beds, mangroves, sandy beaches and rocky shores are found in the area, and a total of about 800 species of corals, fish, molluscs, echinoderms and macro algae are reported in recent biodiversity surveys (Vo et al., 2002b).

Habitats are distributed in relation to mainland - offshore gradients. The inner parts of the bay are exposed to fluctuations in salinity and high amounts of terrigenous sediments and nutrients from the Cua Be and Cai Rivers. Seasonal runoff from Cai River in the rainy season (September - December), is known to impact areas in the northern part of the bay, where heavy siltation occurs. The southwestern and northeastern monsoons together with episodic tropical storms (typhoons) influence oceanography (e.g. water temperatures, circulation patterns and plankton concentrations), and the waves they generate contribute to the erosion of the shores and the resuspension of sediments. Depths between islands in the inner part of the bay reach 30 meters, while on the east side of Hon Mun, Hon Tre, Hon Vung and Hon Cau there is a drop down to 200 meters. Currents, usually of low to moderate velocity (< 1 knot, calculated from Pham, 2001), flow between the islands. These currents are known to transport cooler waters into nearshore areas, producing rapid temperature fluctuations and shallow (5 - 20 m) thermoclines (Vo et al. 2002b). Loi (1967) reported sea surface temperatures in Nha Trang Bay to vary between ~30C° in summer and ~23C° in winter. Salinity in the bay varies between 34 and 25 PSU (Pham and Tran, 2001).

Most reefs around the islands are patch reefs consisting of coral communities growing directly on rocks and boulders, or as coral colonies dispersed on the seafloor. There is little true reef development in the bay. Areas with sandy bottom, or rocky areas with very low coral cover often separate reef communities from each other. The structure of the reefs varies in accordance with degree of physical exposure, with coral communities being dominated by robust and wave tolerant growth forms (e.g. acroporids) on the most exposed reefs, or more sediment tolerant species (e.g. poritids and fungiids) in sheltered parts. In areas with good coral cover, relatively large reef flats can be found. These can in some cases be divided into a shallow part and a slope. In general hard corals are aggregated in patches or belts lying at depths down to 25 meters, and at distances up to about 50 meters from shore. Coral patches are generally surrounded by rubble and sand with the relative proportion of silt or mud increasing with depth. For most of the reefs the coral growth tapers off to almost negligible coral cover at a depth of approximately 20 meters. The substrate on the off-reef floor in Nha Trang Bay is of poorly sorted sediments as well as living and dead coral colonies together with their epibiota.

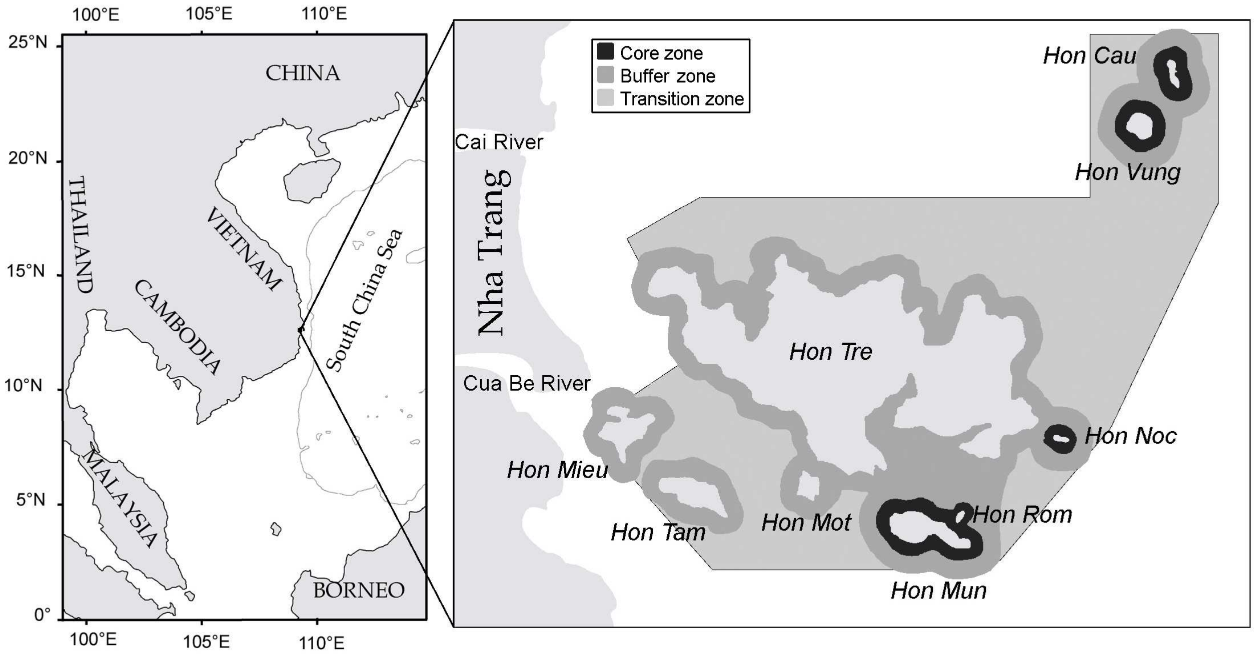

Fig. 2.1: Nha Trang Bay and Hon Mun MPA (map redrawn from Hon Mun MPA regulations booklet, 2002).

2.2 Hon Mun Marine Protected Area

Reefs in Nha Trang Bay are influenced by seasonal natural disturbances and predation from the crown-of-thorns seastar (*Acanthaster planci)*; in addition, they are severely affected by human activities. Nha Trang City is populated by some 300 000 people while the islands in the bay support 5 000 villagers. About 397 000 tourists visited the city in the year 2000, of which 70% went to the islands in the bay for recreation (Pham and Tran, 2001). The city port is base to intense shipping activities, and supports numerous small fishing vessels. Fishing anchovy, tuna and cuttlefish as well as catching ornamental fishes are the main activities around the islands in the bay. The local fishermen also collect sea cucumbers and other invertebrates for food and souvenirs by diving. The combined effects from severe over-harvesting, aquaculture activities, shipping, pollution, dynamite and poison fishing, careless anchoring and extensive tourism has led to complete, or partial degradation of many of the habitats in the bay.

A Marine Protected Area (MPA) was established in the bay in March 2002. The World Conservation Union (IUCN) defines a MPA as: "Any area of intertidal or subtidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, which has been reserved by legislation or other effective means to protect part or all of the enclosed environment" (Kelleher, 1999). The MPA is part of a larger project in Vietnam where integrated networks of MPAs are being developed. A total area of about 160 km^2 has been divided into three preliminary zones with different levels of use and protection: Transition-, buffer- and core-zones (Fig 2.1). In the transition zone there is minimal limitation on access and activities, in the buffer zone intermediate levels of access and extraction is allowed, and in the core zone tourism is to be regulated, and extractive activities (i.e. fishing and collection of invertebrates) forbidden. Ecological conservation value, socio-economic considerations and considerations for sustainable management, was key concerns when planning the zoning scheme. Areas designated to be core zones in the MPA were chosen because they generally have high amounts of hard coral cover and are known to support higher biodiversity than many of the areas in the buffer zone (Vo et al., 2002a). In addition, islands in the core zones support the local birds nest industry, and are patrolled regularly because of this.

3. MATERIAL AND METHODS

3.1 Study sites and time of field work

Surveys were carried out in Nha Trang Bay 15 March to 20 May 2003. A map showing the location of sites visited is presented in Fig. 3.1. The shallow waters around the islands in the bay were main areas of interest during the project.

Most of the 10 sites investigated were reef areas but they differed from each other with regards to underwater topography, degree of exposure and amount of coral cover (Table 3.1). Site 1 has got one of the best-developed reefs in Nha Trang Bay with hard coral cover approaching 100% in some areas (Vo et al., 2002a).

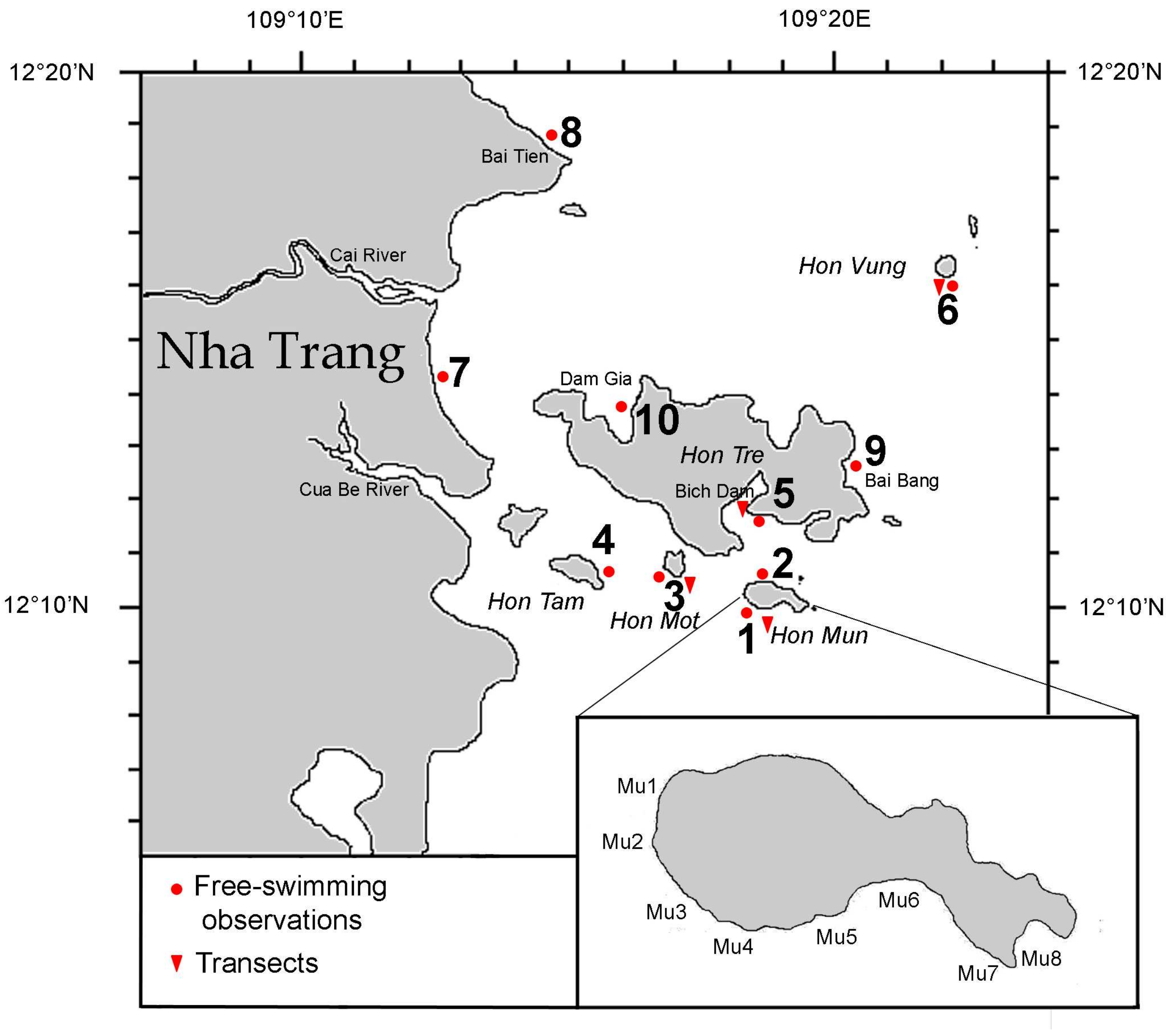

Fig. 3.1: Map of sites visited in Nha Trang Bay. 1: Hon Mun South, 2: Hon Mun North, 3:Hon Mot, 4: Hon Tam, 5: Bich Dam 6: Hon Vung, 7: Nha Trang, 8: Bai Tien 9: Bai Bang, 10: Dam Gia. Placement of transects around Hon Mun is shown in detail.

Table 3.1: Site descriptions and records of coral cover from previous surveys.

Site	General site description	Average amount of coral cover (%) found in recent surveys			
		Hard coral cover	Dead coral cover	Soft coral cover	Survey method
1 Hon Mun South	Semi-exposed. Fringing reef with high amounts of coral cover in some areas. Boulders and rocks covered by corals.	West 51-75 East 31-50	West 1-10 East 1-10	West 11-30 East 1-10	Manta tow*
2 Hon Mun North	Relatively well-developed reef flat, dead corals in some areas.	31-50	11-30	1-10	Manta tow*
3 Hon Mot	Patch reef comprised of boulders and rocks covered by corals.	31-50	-	-	Manta tow*
4 Hon Tam	Patch reefs, softer sediments, detritus. Bedrock.	18.4	3.8	0.3	Horizontal line transects†
5 Bich Dam	Sheltered patch reef. Bottom comprised of rocks and softer sediments. Dead corals.	11-30	11-30	-	Manta tow*
6 Hon Vung	Exposed. Offshore island surrounded by patch reef and sandy bottom.	19.4	0.9	1.6	Horizontal line transects†
7 Nha Trang	Sandy beach, no corals.	-	-	-	-
8 Bai Tien	Sheltered. Small slabs of corals surrounded by sand and mud	-	-	-	-
9 Bai Bang	Relatively well-developed reef flat. Some dead corals	35.0	5.4	1.3	Horizontal line transects†
10 Dam Gia	Sheltered. Muddy bay. Influenced by river runoff.	-	-	-	-

* : Vo et al. (2002b)
†: Vo et al. (2004)

Observations of echinoderms in non-reef localities (site 7 and 10) are also included in the results. Seagrass beds or mangroves were not visited, even though seagrass is found adjacent to site 10.

3.2 Sampling strategy

Transect surveys and free-swimming observations were found to be the best methods for the census of the macro echinoderms on the small patch reefs around the islands. Time constraints and logistical problems during fieldwork limited amount of sampling to a lower level than originally planned. Time available on the different sites varied; a sampling programme with equal amounts of sampling on each site could thus not be implemented.

3.2.1 Diving

Transect surveys were conducted by use of SCUBA diving, while free-swimming observations were made either with the aid of SCUBA or by free-diving. All SCUBA dives conducted are presented in Table 3.2. The author and the fellow student Hermanni Backer carried out the sampling. Dives lasted from 20 to 75 minutes and were made at depths down to 30 meters, free-dives were made down to 15 meters. All data were recorded directly onto pre-printed waterproof data sheets. Transport to the islands was provided by the Hon Mun Marine Protected Area Agency, by patrol boats belonging to the Vietnamese coast guard or by boat funded by Nha Trang Institute of Oceanography.

3.2.2 Transects

50 m long and 4 m wide ($200m^2$) belt transects centred along a line was chosen as the sampling unit in this survey. Transects were placed perpendicular to the shore and down the depth gradient.

A 50m long measuring tape with a lead weight in one end was stretched from the shallow to the deep end. Each transect was laid so that the shallow end stopped at a depth of about 4 meters, distance from shore at this point was noted. Pre-sampling observations had shown echinoderms to be very scarce at depths shallower than 4 meter. Surveying of transects commenced at the deep end. For each meter the observer moved along the transect line, an area of 2 meters to each side of the measuring tape was examined. The width of the belt transects was confirmed by use of a 2 meter long line placed at right angles to the measuring tape. Echinoderms having more than 50% of their circumference inside the belt transect were counted. Position (i.e. placement along transect line, and depth) and substrate type at place of finding for each individual was noted. Test sizes (diameter) of echinoids, major radius (measured from centre of disk to tip of arm) of asteroids and lengths of holothurians were measured to the nearest 0.5 cm by use of a ruler. This was done when time allowed. When more than 50% of the body of any individual was hidden this was noted. Swimming in a zig-sag manner while thoroughly investigating the substrate was important, and ensured that the individuals that were not completely hidden could be spotted. Stones were overturned when possible. Amount of live hard coral cover in each transect was estimated by use of a simplified version of the Line Intercept Transect technique described by English et al. (1997). Total length of tape overlaying live hard corals was summed up for the entire transect to a precision of 10%. When transects covered not only the reef flat but also the off-reef floor zone, any clear transition between reef and sandy/muddy substrate was noted.

Table 3.2: SCUBA dives conducted in Nha Trang Bay, spring 2003.

Dive #	Date	Site	Method	Time used (min)
1	15/3	1	Free-swimming observation	50
2	27/3	1	Free-swimming observation	20
3	28/3	3	Transect - Mo1	55
4	26/4	1	Transect - Mu1	40
5	28/4	1	Transect - Mu6	50
6	28/4	2	Free-swimming observation	45
7	29/4	3	Free-swimming observation	20
8	30/4	1	Transect - Mu5	50
9	6/5	1	Transect - Mu2	30
10	7/5	1	Transect - Mu3	60
11	8/5	1	Transect - Mu4	45
12	8/5	2	Free-swimming observation	30
13	9/5	1	Transect - Mu7	50
14	10/5	5	Transect - Tr1	45
15	10/5	4	Free-swimming observation	40
16	11/5	6	Transect - Vu1	50
17	19/5	1	Transect - Mu8	55
18	20/5	1	Horizontal visual survey	75

All transects were conducted between 9.00-15.00 hours. At daytime the ophiuroids behave cryptically and are usually hidden deep inside the corals, in coral rubble or between and under rocks. To overcome this problem destructive sampling could have been used, but would lead to unnecessary damage on the already vulnerable reefs. Collection of rubble and sand samples in nets was also tried out but proved unsuitable, and the method was abandoned. Abundances of ophiuroids could thus not be estimated and only a few were captured for species identification.

Placement of transects was originally "haphazard" on the reef areas, but on Hon Mun they were placed in a more systematic manner along the shore. A total of 11 transects was surveyed (Table 3.3), 8 of them were conducted on Hon Mun South. The area covered in all transects summed up to 2250 m^2. All but one of the transects were conducted in the manner described above: in transect Mo1 an area of 250m^2 (5*50m) instead of 200m^2 was covered.

Table 3.3: Transects conducted. Sites ordered in relation to west-east position in Nha Trang Bay.

Site	Number of transects	Area covered (m^2)	Transect names
3 (Hon Mot)	1	250	Mo1
5 (Bich Dam)	1	200	Tr1
1 (Hon Mun South)	8	1600	Mu1, ..., Mu8
6 (Hon Vung)	1	200	Vu1

3.2.3 Free-swimming observations

Free-swimming observations supplemented data from transects and made it possible to examine larger areas than those covered in the transects. In 6 of the 10 sites no transect surveys were carried out, here spot check and free-swimming observations were the only sampling methods used. All species encountered were noted. Average swimming speed used by the observer was calculated in order to estimate area covered in the free-swimming observations. Swimming speed was estimated from time spent covering 20 m long and ~4 m wide belts while observing echinoderms. 5 replicates on different locations were made. Given the total time spent at each site one then got a crude estimate of area covered. This method was used as a semi quantitative approach to estimating abundances of the echinoderms. In spot checks that lasted for only a few minutes no abundances were estimated.

On Hon Mun South an additional visual survey method was used, i.e. a horizontal depth stratified survey. Observations were made along the shoreline. The deep end of the reef (9-15 m) was surveyed for 45 minutes and the shallow end (4-8 meters) was surveyed for 30 minutes. Echinoderms inside a belt of approximately 4 m width were recorded while swimming. The method resembles Rapid Ecological Assessment methods (DeVantier et al., 1998) used in earlier surveys in Vietnam (Vo et al., 2002a).

3.2.4 Species identifications

All echinoderms were identified to the lowest taxonomic resolution feasible by reference to Clark and Rowe (1971), Irimura (1982), Shigei (1986), Coleman (1994) and Debelius (2001). Specimens that could not be identified to species right away were photographed (Canon Ixus 300 digital camera with housing) and collected when possible. In the tables given in the remainder of this thesis, taxa are ordered systematically according to the classification of Rowe and Gates (1995). The genera are listed alphabetically within families. Taxonomic decision for synonymy is based on Rowe and Gates (1995) and Lane et al. (2000), but see also Appendix 4.

3.3 Data analyses

3.3.1 Analyses of echinoderm community structure

The echinoderm fauna composition was analysed at several scales. Site specific and transect specific differences were investigated to the degree possible given the restrictions of the data material. Since the resolution of the sampling method was quite high ($4m^2$), substrate specific and depth specific differences, as well as microhabitat partitioning and small-scale abundances were described for some of the species.

Species counts from transects and the free-swimming observations were combined in order to give an inventory of species (taxa) found during the survey. Relative abundances were estimated for the different species at the different sites. Overall absolute densities were calculated for species encountered in transects. Number of individuals per 400 m^2 is given for easier comparisons with earlier studies in Nha Trang Bay.

A taxon sampling curve based on sampling-effort was produced. Species lists from transects and free-swimming observations were treated as separate entities of sampling effort (samples) and pooled. The relationship between species richness and sampling effort was presented by a rarefaction/smoothed curve (Gotelli and Colwell, 2001). The curve, calculated by re-sampling from the pooled data showed the expected number of taxa (species) with increasing sampling effort. The increase in species numbers at the end of the sampling period indicated how well sampled the area was.

Diversity in transects was estimated using a modification of the Simpson's index: $(D = 1 - \sum p_i^2)$ Where p_i is the proportion of the species i in the sample. The index ("Simpson's index of diversity") normalises diversity within a range from 0 to 1, and gives the probability that two randomly selected individuals in a sample are of different species. Values close to 1 indicate similar abundances of all species. This diversity measure was used because it is less sensitive to small numbers of species, or sample sizes than the Shannon–Wiener index (Routledge, 1979).

Species occurrences and abundances in samples (transects or subsamples of transects) were compared by use of multivariate techniques and routines as recommended by Clarke and Warwick (2001). The multivariate community analyses were performed to investigate similarity between samples. Data were stored in species-sample matrices, and analysed with the PRIMER 5 software package (Plymouth Marine Laboratory, UK). The data were standardised in order to balance for unequal sampling (i.e. by using percent contributions in each sample instead of abundances) and transformed to weight the contributions of common and rare species. Different data treatments were used on the species abundance lists in this survey. To calculate between-sample similarities the Bray-Curtis coefficient (Bray and Curtis, 1957) was used. Results were given in a similarity matrix, where between-sample similarities (percent) reflected the pattern of occurrences of each species across the given set of samples. High similarity values indicated that samples had co-occurring abundant species and rare species. When using species presence/absence lists with binary data (1 and 0) the Bray-Curtis coefficient gives results identical to the Sørensen (Dice) coefficient (Sørensen, 1948). Species presence/absence data was used when comparing species lists from the different sites in this study, and for comparisons of species inventories from different regions in the South China Sea (section 3.3.3).

Hierarchical cluster analyses (classification) were performed using group average sorting to reveal whether samples would fall into well defined groups. Results were presented graphically in dendrograms (cluster diagrams). In the dendrograms samples with pairwise high levels of similarity were fused into groups, and groups successively fused into larger clusters, at lower levels of similarity (see Clarke and Warwick, 2001). To further explore any inter-relationships between samples, non-metric Multidimensional Scaling (MDS) (Kruskal, 1964) was performed. Samples were ordinated in relation to inter-sample distances (dissimilarities) and their positions presented graphically in MDS plots.

In addition to analysing similarities between transects, changes in fauna composition along transects and down the depth contour were described. “Depth specific” differences were analysed by stratification of the transect data. Each transect was divided into two equal-sized subsamples, denoted as “shallower” (S) and “deeper” (D) segments (Fig 3.2). Parts of the belt transects were designated as S and D segments according to their position along the transect line, and thus to depth interval covered. Observations made along the shallower part of the transect line were separated from observations made along the deeper part of the transect line.

An interval of 2 (*4) meter separated the two segments from each other; observations made in this zone were left out from these.

S and D segments from all transects were compared by similarity analyses. Abundances in segments from transect Mo1 were adjusted down because of larger area sampled in this transect compared to that of the others. For subsequent statistical tests (see paragraph below) the two segments in each transect were considered as paired. In order to explore what species contributed to any grouping of S and D segments, similarity percentages analysis - SIMPER was used (analysis option within the software package PRIMER). The percentage contribution of each species to the average within-group (S or D) Bray-Curtis similarities, indicated whether the species was typical for this group or not. The overall contribution of each species to between-group dissimilarities, indicated to what extent the species was a good discriminator of one group from another.

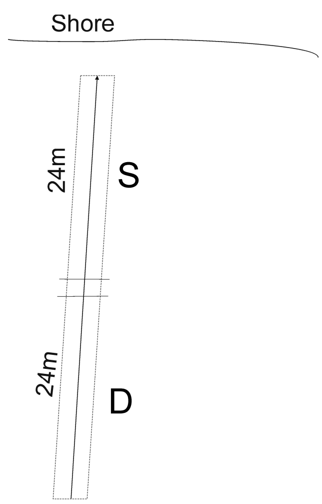

Fig 3.2: Stratification of transects into shallower (S) and deeper (D) segments.

3.3.2 Presentation of spatial patterns

The mapping of the positions of each of the individuals in the transects provided material for analyses of small-scale spatial patterns. On Hon Mun South it was possible to describe patterns in distribution not only with depth but also along the shoreline. Depth contours along the shore were presented graphically based on distance weighted least squares interpolation of all the depth measurements of the individuals. To model a two-dimensional "trend surface" showing densities of species of interest along the shoreline and with depth, the density data from the different transects were interpolated (linear interpolation) (see Burrough, 1987). The trend surface was combined with some general observations of the reef topography in order create a simple graphic presentation of spatial patterns.

3.3.3 Study of species occurrences in the South China Sea

In order to evaluate human effects on the echinoderm fauna in Nha Trang Bay, it is useful to compare results from this survey with data from relatively pristine areas with similar fauna. Historical species inventories were analysed in order to explore which areas in the South China Sea have echinoderm fauna similar to that recorded from the Khahn Hoa waters. Lane et al. (2000) compiled an inventory of echinoderms from the South China Sea (982 species in total). In their report they listed species occurrences from 7 regions/zones in the SCS (Fig. 3.3), along with the depth ranges of each species. Species occurrences in the different regions as given in Lane et al. (2000), and species lists from the Khahn Hoa Province (Dao, 2002) were compared with respect to occurrence of shallow-water (<200m) species of asteroids and echinoids (Table 3.4). The tables were updated according to Putchakarn and Sonchaeng (2004). Asteroids and echinoids were used in the analyses because their taxonomy is largely stabilized, and their distributions were expected to be more thoroughly investigated than for instance that of crinoids and holothurians. Similarities between the regions in the SCS were compared by use of Sørensen's coefficient.

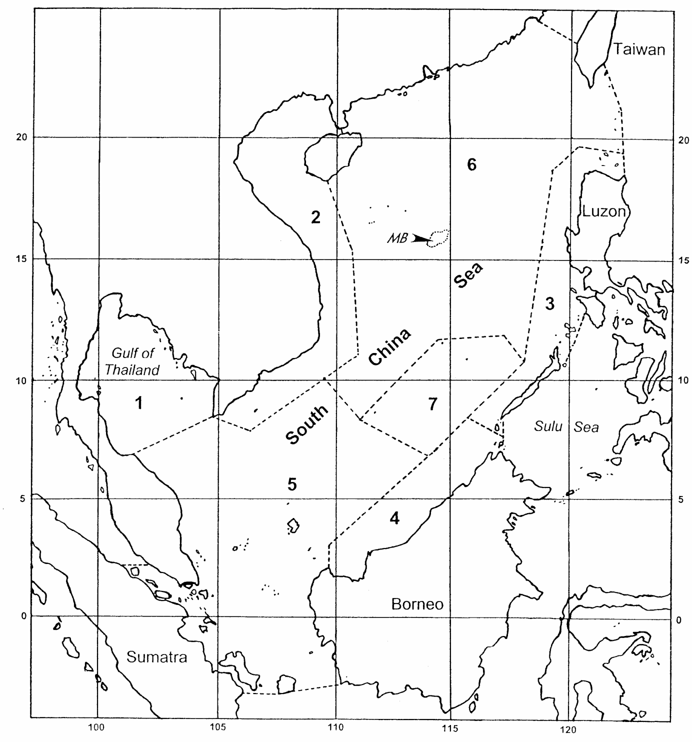

Fig. 3.3: Map of the South China Sea, different zones and boundaries of the South China Sea are marked with dashed lines, MB: Macclesfield Bank. (Map borrowed from Lane et al., 2000).

Table 3.4: Number of species of shallow water (<200m) asteroids and echinoids found in different zones in the South China Sea.

Region	Asteroids (128 sp. in total)	Echinoids (146 sp. in total)
Khahn Hoa	19	38
SCS1 (Gulf of Thailand)	24	59
SCS2 (Vietnam)	40	89
SCS3 (Phillipine waters)	73	107
SCS4 (Borneo waters)	17	48
SCS5 (Malaysia and open waters of Sunda shelf)	49	82
SCS6 (South China, open waters in northern SCS, Paracel Islands)	76	112
SCS7 (Spratly/Nansha islands)	27	32

3.3.4 Software and statistical tests

Excel 7.0 (Microsoft Corporation, USA) was used for all data tables, Statistica 5.5 (Statsoft inc., Tulsa, USA) was used for basic statistical tests and graphical presentations of spatial patterns. The programme package PRIMER 5 (Plymouth Marine Laboratory, UK) was used for all multivariate analyses of species lists.

To test for significant differences in mean body sizes of individuals from different sites, one-way ANOVA was used (Zar, 1984). Levene's test was used to check for homogeneity of variances. The Wilcoxon Signed-Rank test was used to test for significant differences in species numbers and abundances between deeper and shallower transect segments (S and D). In all statistical tests α (level of significance) was set to 0.05.

4. RESULTS

4.1 General findings

During this survey 35 different echinoderm taxa were observed, of which 26 could be identified to species (4 crinoids, 8 asteroids, 2 ophiuroids, 7 echinoids and 5 holothurians). A complete list of all echinoderm observations and relative abundances is presented in Table 4.1. The table gives an overview of site specific findings in the bay during the sampling period (see Fig. 3.1 for map). The shallow-water macro echinoderm fauna was to a large extent dominated by the locally very abundant and widely distributed sea urchin *Diadema setosum*. Species composition and abundances varied not only from site to site but also between transects and down depth gradients. So did factors like water movement, turbidity, underwater topography, substrate and amount of coral cover.

Table 4.1: Echinoderm observations in Nha Trang Bay April and May 2003. See footnote for details, underlined site names indicate transect surveys.

TAXA	**SITE**									
	<u>1</u>	**2**	**<u>3</u>**	**4**	**<u>5</u>**	**<u>6</u>**	**7**	**8**	**9**	**10**
CRINOIDEA										
Himerometridae										
Himerometra robustipinna (Carpenter, 1881)	++	++	++	+	.	+	.	.	+	.
Mariametridae										
Stephanometra sp.[1]	x	.	.	.	.	.	.	.	.	.
Colobometridae										
Cenometra bella (Hartlaub, 1890)	+	+	+	x	.	.	.	.	x	.
Comasteridae										
Comanthus parvicirrus (Müller, 1841)	+	+	+	.	x	.	.	.	+	.
Comaster sp.[2]	+	.	.	.	.	.	.	.	.	.
Phanogenia sp. [3]	+	.	.	.	.	.	.	.	.	.
Oxycomanthus bennetti (Müller, 1841)	++	++	+	.	.	++	.	.	+	.
ASTEROIDEA										
Acanthasteridae										
Acanthaster planci (Linnaeus, 1758)	+	++	++	x	++	x	.	.	x	.
Ophidiasteridae										
Linckia laevigata (Linnaeus, 1758)	+	++	++	x	++	x	.	x	+	.
Nardoa frianti Koehler, 1910	.	x	.	.	.	.	.	.	.	.
Pterasteridae										
Euretaster insignis (Sladen, 1882)	x	.	.	.	.	.	.	.	.	.
Oreasteridae										
Choriaster granulatus Lütken, 1869	x	.	.	.	+	.	.	.	.	.
Culcita novaeguineae Müller & Troschel, 1842	+	+	+	.	.	++	.	.	.	.
Protoreaster nodosus (Linnaeus, 1758)	.	.	.	.	.	.	.	.	x	.
Astropectinidae										
Astropecten monacanthus Sladen, 1883	x	.	.	+	.	.	.	.	.	.
Astropecten sp.	x	.	.	.	.	.	x	.	.	.

	1	2	3	4	5	6	7	8	9	10
OPHIUROIDEA										
Ophiotrichidae										
Macrophiothrix sp.	x	x	.	.	.	.	.	.	.	.
Ophiocomidae										
Ophiocoma scolopendrina (Lamarck, 1816)	.	.	.	.	.	.	.	x	.	x
Ophiomastix annulosa (Lamarck, 1816)	x	x	.	.	.	.	.	.	.	.
ECHINOIDEA										
Diadematidae										
Diadema savignyi Michelin, 1845	+	+	+	x	+	+	.	.	+	.
Diadema setosum (Leske, 1778)	+++	++	+++	++	++	+++	.	x	++	.
Echinothrix calamaris (Pallas, 1774)	+	+	+	+	+	x	.	.	x	.
Echinohtrix diadema (Linnaeus, 1758)	x	.	x	.	x	x	.	.	.	.
Toxopneustidae										
Toxopneustes pileolus (Lamarck, 1816)	+	.	.	.	++	+	.	.	+	.
Tripneustes gratilla (Linnaeus, 1758)	x	.	.	.	.	.	.	.	.	.
Clypeasteridae										
Clypeaster sp.	.	.	.	.	.	.	.	x	.	.
Loveniidae										
Lovenia elongata (Gray, 1845)	x	.	.	.	.	.	.	.	.	.
HOLOTHUROIDEA										
Holothuriidae										
Actinopyga sp.	x	.	.	.	.	.	.	.	.	.
Holothuria (Mertensiothuria) leucospilota (Brandt, 1835)	.	.	.	.	.	x	.	.	.	.
Pearsonothuria graeffei (Semper, 1868)	+	x	x	.	.	x	.	.	.	.
Stichopodidae										
Stichopus chloronotus Brandt, 1835	+	x	.	.	.	.	.	x	.	.
Thelenota ananas (Jaeger, 1833)	.	.	.	.	.	x	.	.	.	.
Synaptidae										
Synapta maculata (Chamisso & Eysenhardt, 1821)	+	.	++	++	.	.	.	.	.	.
Synaptidae indet.	+	.	+	+	.	.	.	.	.	.
Dendrochirotida indet.[4]	.	.	.	+	+	.	.	.	.	x

1: Probably *Stephanometra echinus* (A.H. Clark, 1908).
2: Probably *Comaster audax* (Rowe et. al. 1986) or *C. nobilis* (Carpenter, 1888).
3: Probably *Phanogenia gracilis* (Hartlaub, 1891).
4: Burrowing, only buccal tentacles and mouth visible.

x : Observed once
+ : ≤ 5 per 400 m^2
++ : 6 – 30 per 400 m^2
+++ : More than 30 per 400 m^2

4.2 Species-area relationship

The total sampling effort for the study amounts to about 17 hours of underwater observation (time used on transects and free-swimming observations combined). Estimated area covered in the survey is about 6450 m^2. Number of taxa (species) found at each site varied according to amount of sampling (Table 4.2). Hon Mun South was sampled more extensively than the other sites combined. On this particular reef it is estimated that about 1.1% of the main reef area (area with more than 40% coral cover) was surveyed by transects. The taxon sampling curve (Fig. 4.1) shows that at the end of the survey new species were found at a quite low rate, but that any asymptote was not reached.

Table 4.2: Sampling effort and observations of echinoderm taxa.

Site	**Sampling effort**		**Number of taxa recorded**
	Transects Area covered /m^2	Free-swimming observations* Approx. time used /minutes	
1 (Mu)	1600	220	28
2	-	80	15
3 (Mo)	250	25	14
4	-	50	11
5 (Tr)	200	20	11
6 (Vu)	200	15	13
7	-	20	1
8	-	30	5
9	-	50	11
10	-	15	2
Sum area covered	2250 m^2	~4200 m^2	

* SCUBA sureys and free-dives combined.

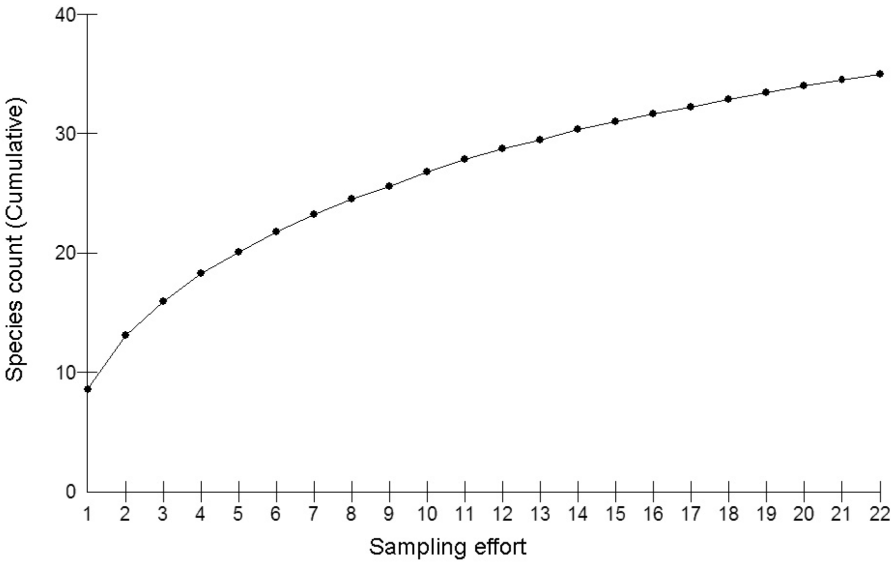

Fig. 4.1: Taxon sampling curve for survey of macro echinoderms in Nha Trang Bay, spring 2003. The rarefaction curve is based on re-sampled data from transects and free-swimming observations (sampling effort).

4.3 Echinoderm community structure

4.3.1 Fauna composition

In the transects and the horizontal visual survey, a total of 1225 specimens of crinoids, asteroids, echinoids and holothurians was recorded (8.8%, 2.7%, 87.8% and 0.7% of individuals, respectively). 19 species were found in the transects, of these, 10 were found less than 5 times in the transects combined. The dominant species in almost all transects was the sea urchin *Diadema setosum* (constituting 74% of all specimens counted). A dominance plot (Fig. 4.2) shows the relative numerical importance of *D. setosum*. When disregarding *D. setosum,* echinoids were still more abundant in most of the sites, crinoids were found more frequently than asteroids and holothurians occurred in very low numbers. This was a general trend on all reefs. Mean density of echinoderms over all transects was not particularly high (0.34 ind. m^{-2}), and heterogeneity was great (SD = 0.23). Standard deviation was higher than mean density for all but two of the species (*D. setosum* and *D. savignyi*). The coefficient of variation (SD/mean*100) in density for the different species in transects ranged from 79.6% to 331.7% (appendix, table A2.3). The rarest species had highest spatial variation.

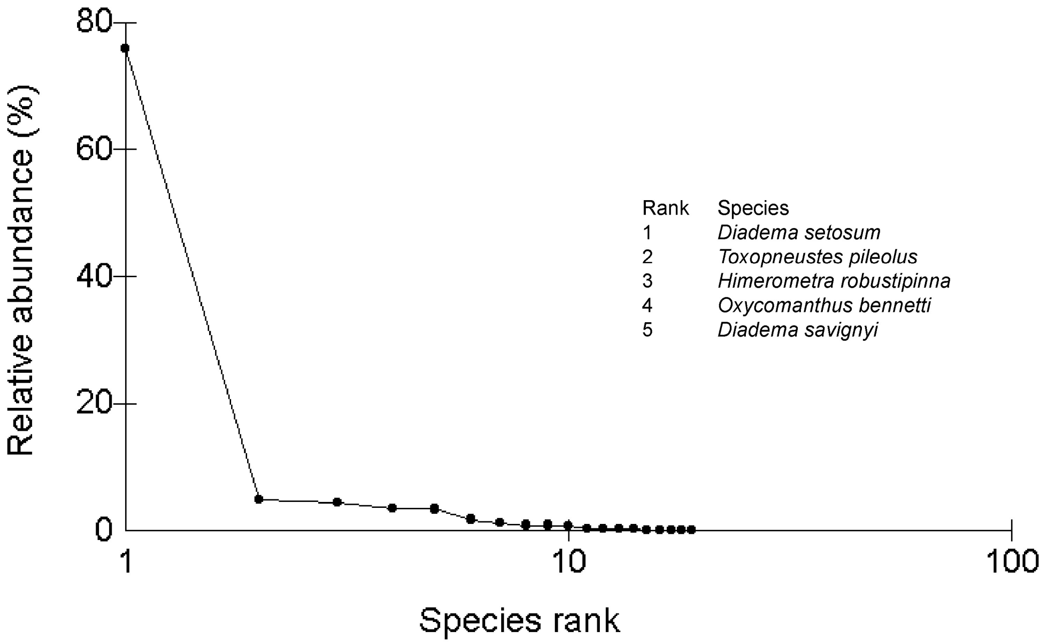

Fig. 4.2: *k*-dominance plot for transect data on macro echinoderms. n individuals = 784.

4.3.2 Comparisons between sites and transects

Registrations of species numbers and relative abundances on each site (Table 4.1) indicated some differences between the locations. Data material suitable for comparisons between sites is rather limited and biased. Cluster analysis on similarities calculated from species presence/absence data from the different sites (Fig. 4.3) mainly grouped sites in relation to observed species richness, and sampling effort. Most of the sites had many of the species in common, but the relative abundances of each species varied. This is not reflected in the dendrogram. Of the individual transects, the ones yielding highest number of taxa came from Bich Dam (site 5) and Hon Vung (site 6). The transect from Bich Dam had highest Simpson's index of diversity.

How the different echinoderm species contributed to the fauna composition in transects can be seen in a "Top-five" species list (Table 4.3). The composition varied with topography, substrate type and amount of coral cover in the different transects (Appendix, Table A1.1). Transect Mo1 had highest density of echinoderms. Transects Mu1 and Mu6 yielded only 3 and 4 specimens, respectively. All species found here are as a result included in the Top-five list. These two transects are omitted from the analyses below. A dendrogram resulting from cluster analysis of standardised abundances in the transects (Fig. 4.4) showed most transects to have similar relative species composition. Transects Mu2 and Tr1 differed from the others in having relatively lower abundance of *D. setosum* and relatively higher abundance of *Toxopneustes pileolus*.

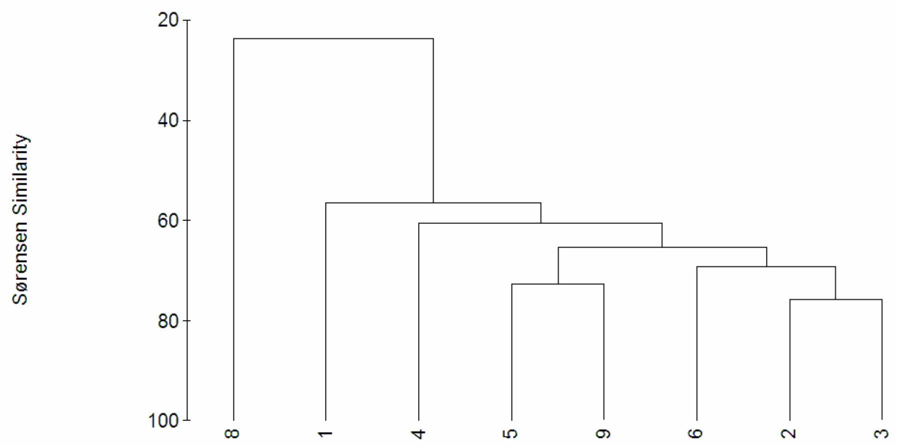

Fig. 4.3: Dendrogram resulting from group averaged cluster analysis of species presence/absence data from the different sites in the study. Sites with fewer than 5 observed taxa are omitted from the analysis (site 7 and 10).

Table 4.3: "Top-five" list with numerical abundance of the most common macro echinoderm species in the different transects. Total number of taxa, total number of specimens estimated densities of echinoderms and diversity in each transect is given.

		Site 3	Site 5	Site 1								Site 6
	Species	Mo1*	Tr1	Mu1	Mu2	Mu3	Mu4	Mu5	Mu6	Mu7	Mu8	Vu1
Crinoidea	*Comanthus parvicirrus*		1		1		1		1			
	Himerometra robustipinna	5				4	13	2	1	4	3	2
	Oxycomanthus bennetti	1				6	7			7	3	3
Asteroidea	*Acanthaster planci*	4			1	1						
	Choriaster granulatus		2									
	Culcita novaeguineae	1						2				3
	Linckia laevigata		5				1	1	1	3	2	1
Echinoidea	*Diadema savignyi*	8	2		3	2	5			1	3	2
	Diadema setosum	135	13	1	1	43	72	66	1	88	84	76
	Echinothrix calamaris		3	1		1					9	1
	Echinothrix diadema		1								1	1
	Lovenia elongata			1								
	Tripneustes gratilla				1							
	Toxopneustes pileolus		8		17		3	3		4	2	1
Holothuroidea	*Synapta maculata*	3										
Total number of taxa		10	11	3	7	6	10	7	4	9	9	11
Total number of specimens		161	37	3	25	57	107	78	4	111	109	92
Density of echinoderms (Ind. 400 m^{-2})		257.6	74	6	50	114	214	156	8	222	218	184
Simpson's index of diversity		0.29	0.80	0.67	0.51	0.41	0.52	0.28	0.75	0.36	0.40	0.31

* 250m^2 transect

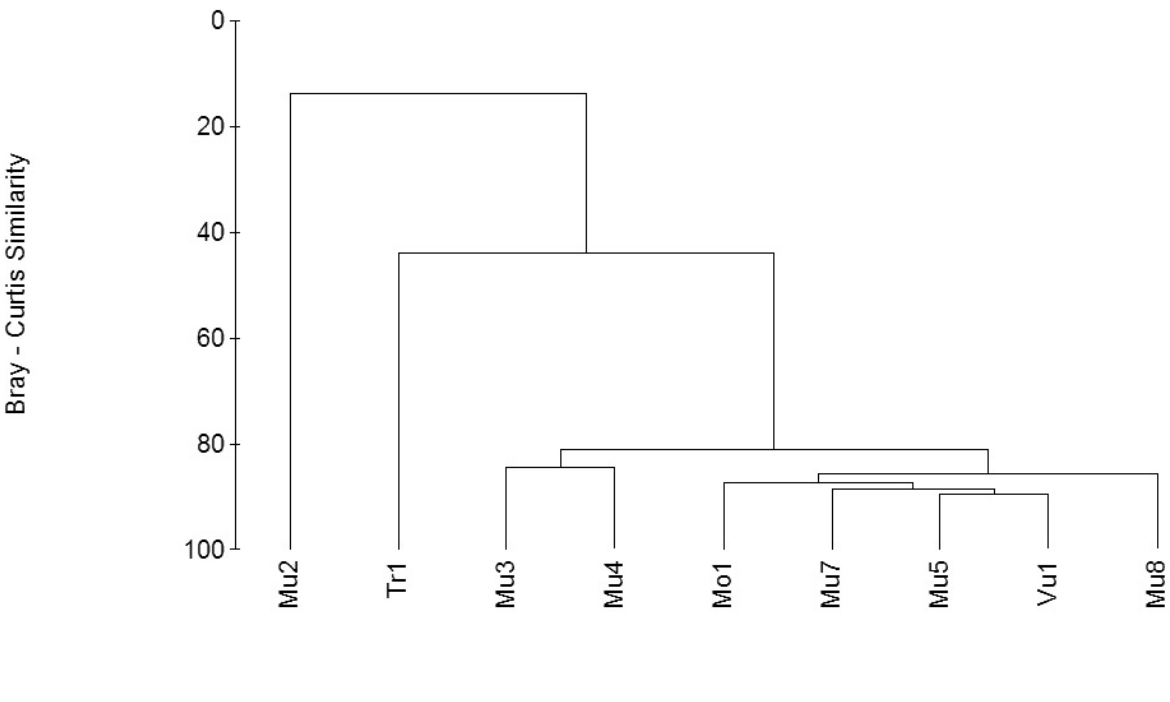

Fig. 4.4: Dendrogram resulting from group average cluster analysis of similarities calculated on standardised abundance data in transects.

4.3.3 Habitat specific observations

Registrations of substrate type at place of finding, and cryptic behaviour for individuals in transects is shown in Fig. 4.5 (13 species). Findings revealed daytime microhabitat preferences for the echinoderm species associated with the reef communities. Many of the species in the transects were found in direct association with rocks and stones or between patches or colonies of corals, and not so often on or in direct contact with live corals. The rocks were often covered by detritus, algal turf, ascidians and Porifera. When a specimen was found on a rock covered by fire corals (*Millepora*) this was noted as a finding on live coral. In the transects the echinoid species *Diadema savignyi*, *Echinothrix diadema* and *E. calamaris* were seen hiding in crevices in the reef, or under and between rocks more frequently than they were found out in the open.

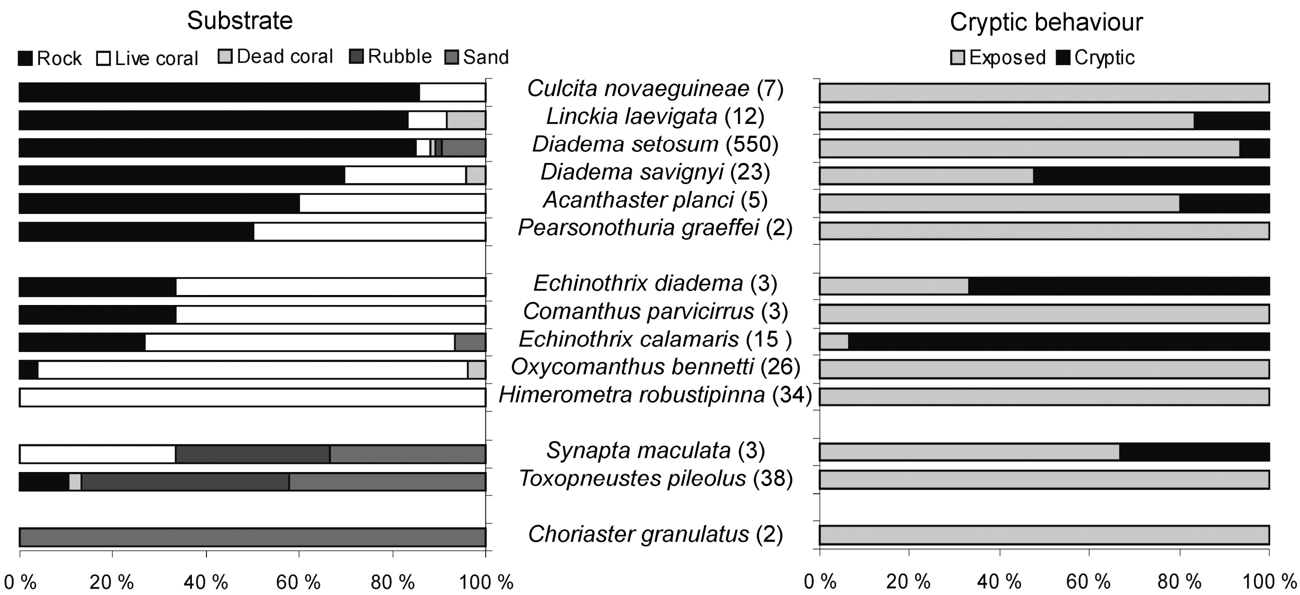

Fig. 4.5: Microhabitat preferences and cryptic behaviour for some of the species found in transects. Left: Relative number of observations of substrate types the species were found in direct association with. Species with similar observed preferences are grouped together. Total number of observations for each species is given in parentheses; species with only one observation are omitted. Right: Relative number of observations of behaviour, same grouping of species as to the left. Cryptic = hidden, exposed = more than 50% of body surface out in the open.

4.3.4 Depth specific observations

Histograms of all depth registrations made in transects (Fig. 4.6) show the distribution of fauna along the depth contours covered in this survey. Mean depth covered in transects (9.8 ± 3.4 m), did not coincide with mean depth for all of the different species (see paragraph 4.4).

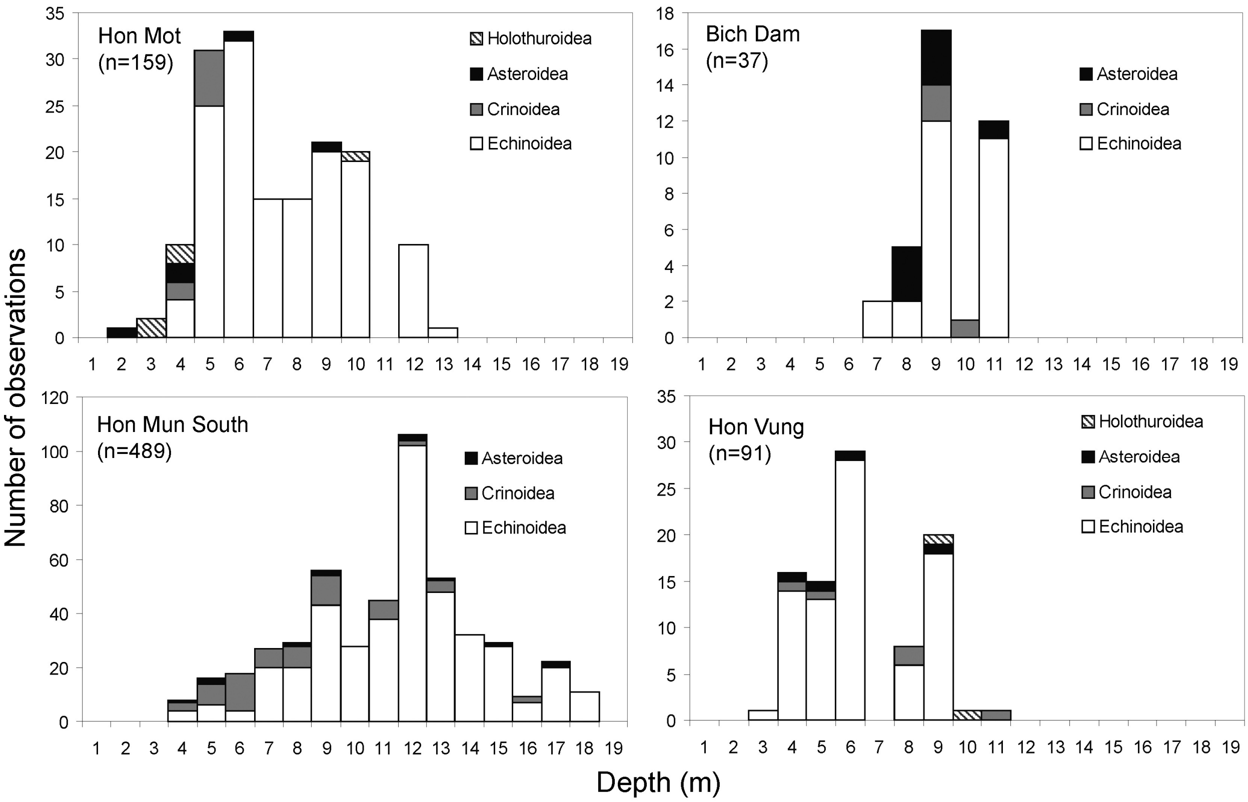

Fig. 4.6: Observed depth distribution of all macro echinoderms at different sites. Data obtained from 50 m long transects placed perpendicularly to the shore. No holothurians were observed in transects from Bich Dam or Hon Mun South.

Transects were stratified into shallower and deeper segments (Fig. 3.2) in order to explore in what depth interval (and part of reef) the different echinoderm species were most abundant. Data from S segments (mean depth ~7 m) and D segments (mean depth ~12 m) were compared by similarity analyses. Analyses were performed on both untransformed and double root (√√) transformed abundance data. Untransformed data-analysis is more sensitive to changes in abundances of the dominant species, while analyses on √√-transformations are more sensitive to changes in lower-abundance species. Both analyses showed some groupings according to depth interval covered (Fig. 4.7). Clustering of segments were however quite different in the two analyses. For a few of the transects both S and D segments were so different from others that they grouped together. The relatively high stress value (measure of "goodness of fit") associated with the MDS plot for √√-transformed data (0.2) indicated some difficulties in presenting the inter-relationships between samples in a 2-dimensional plot. In the analysis of untransformed data, *D. setosum* was responsible for most of the grouping of samples. Many of the D segments from Hon Mun South grouped together, this is shown to the left in the MDS plot (Fig. 4.7b, untransformed). These segments had highest abundance of *D.*

setosum. Analysis of √√-transformed data revealed contributions from the rarer species, and weighted down the contribution from *D. setosum*. The group at the bottom of the MDS plot for √√-transformed data contained many of the D segments, and was dominated by *Toxopneustes pileolus*. The group at the top contained many of the S segments and was in addition to being dominated by *D. setosum*, for large parts dominated by crinoids (*Himerometra robustipinna,* Crinoidea indet and *Oxycomanthus bennetti).* This group also contained transect segments with higher number of species. SIMPER analysis on untransformed data (Appendix, Table A3.2) showed the average within-group (S or D) similarities to be quite low (29.40% and 36.24%, for S and D, respecively). 90% of the average dissimilarity between the two groups (67.42%) was accounted for by *D. setosum*, *T. pileolus*, *H. robustipinna, O. bennetti*, Crinoidea indet., *Echinothrix calamaris* and *D. savignyi*. SIMPER analysis on √√-transformed data showed the average within-group similarities to be 44.48% and 44.51% for S and D, respectively.

When comparing data from all transects, more species were found in S segments, while more individuals were found in D segments, differences were however not significant. When disregarding *D. setosum*, there was a significant difference in number of individuals between S and D segments. Numbers were higher in S segments (Wilcoxon Signed Rank Test, $Z = 2.0769$, $p = 0.0127$). On Hon Mun South the abundance of *D. setosum* was found to be 3.8 times higher in D segments than in S segments.

Differences seen are further supported by the horizontal visual survey that was conducted on Hon Mun South (4-8m vs. 9-15m, see Appendix, Table A2.2). Abundance of *D. setosum* was 5.2 times higher in the deeper part (when adjusting for different times used in the two parts of the reefs), whilst the crinoids *H. robustipinna* and *O. bennetti* were recorded only from the shallower part. The deep survey followed the reef slope and the transition zone between reef and sandy/muddy sediment. Shallow observations were for the most part made on the main reef area or the reef flat.

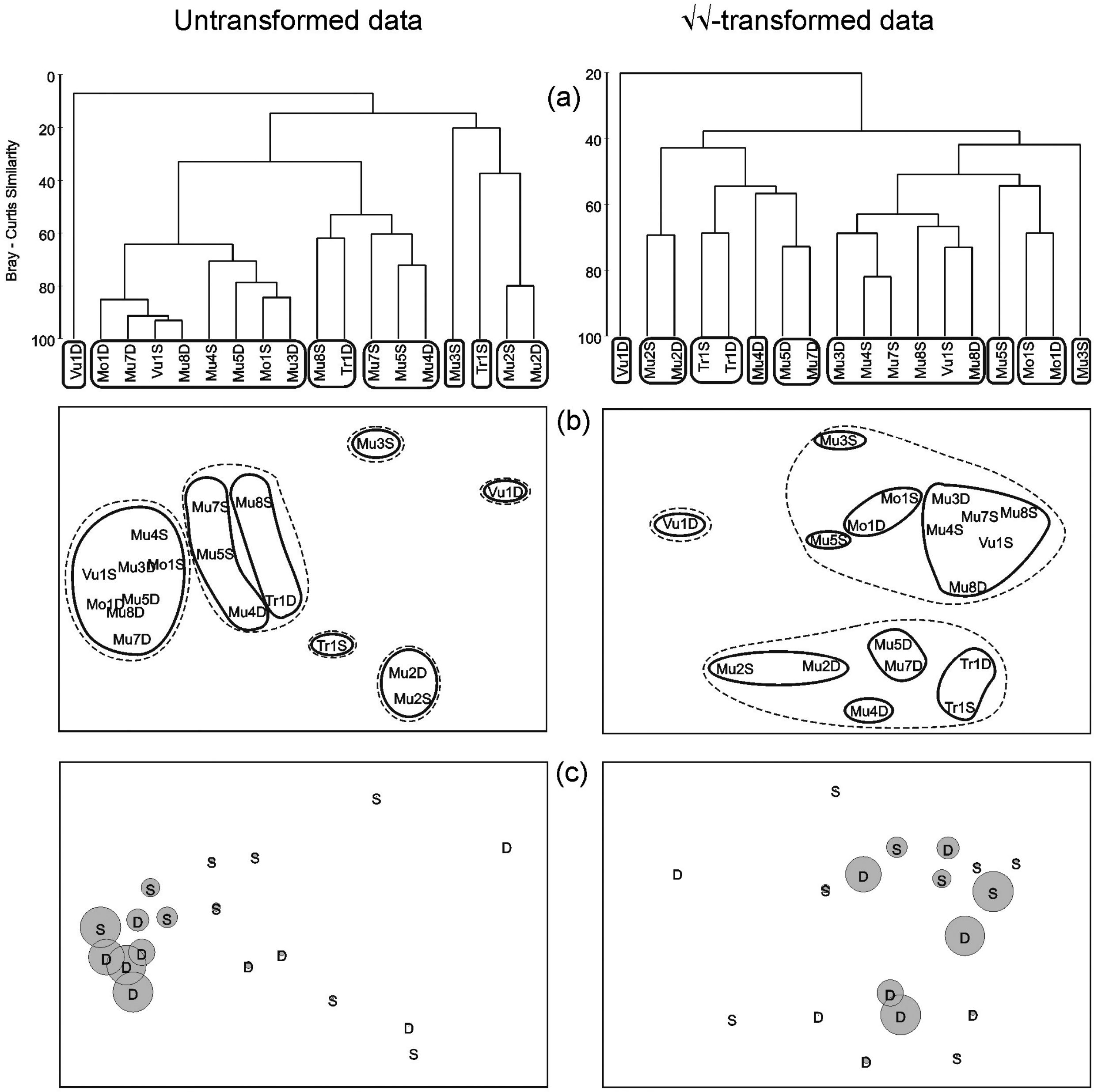

Fig. 4.7: Classification and ordination of shallower (S) and deeper (D) transect segments. All analyses are based on Bray - Curtis similarities calculated on either untransformed (left column), or √√-transformed (right column) abundance data. (a) Dendrograms resulting from group-averaged cluster analyses of similarities. Clusters formed at 60% similarity are encircled. (b) MDS plots showing groupings of transect segments. Clusters as seen from the dendrograms are encircled, dashed line: 40% similarity, continuous line: 60% similarity. (c) Same ordinations as above but showing abundances of *Diadema setosum* in the different transect segments (superimposed circles). Stress values in MDS plots: 0.11 (left) and 0.2 (right).

4.4 Densities, body sizes and spatial distributions for some of the species

4.4.1 Crinoidea

(7 taxa found, 84 individuals in transects).

Crinoids were widely distributed around the islands. Degree of cryptic behaviour varied between the different species. Some of the crinoids (e.g *Phanogenia* sp.) were hidden under rocks and in crevices in the reef. *Cenometra bella* was always seen attached to gorgonian sea whips (*Junceella* sp.) while *Oxycomanthus bennetti* and *Himerometra robustipinna* mostly aggregated on top of boulders covered by *Millepora.* They seemed to utilise the corals as perches for suspension feeding. Calculations from transects are given in Table 4.4.

Table 4.4: Transect data on crinoids.

Species	# Ind. in transects	Overall density Ind. 400 m^{-2} ± SD	Mean depth (m) ± SD
Comanthus parvicirrus	4	0.36 ± 0.81	10.50 ± 1.91
Himerometra robustipinna	34	6.00 ± 7.38	6.73 ± 1.74
Oxycomanthus bennetti	27	4.87 ± 5.91	8.62 ± 2.37
Phanogenia sp.	4	0.69 ± 1.32	13.67 ± 2.08

4.4.2 Asteroidea

(9 taxa found, 29 individuals in transects).

Asteroid numbers varied from 0 to 7 in transects, calculations from transects are shown in Table 4.5. *Linckia laevigata* was the most abundant species. *Acanthaster planci* was found in relatively low numbers in transects, but aggregations could be seen in some areas on Hon Mun North and Bich Dam. The species seemed to occur in moderately higher densities on Hon Mot (6.4 ind. 400 m^{-2}).

Table 4.5: Transect data on asteroids.

Species	# Ind. in transects	Overall density Ind. 400 m^{-2} ± SD	Major radius (cm) ± SD	Mean depth (m) ± SD
Acanthaster planci	5	0.95 ± 1.98	12.05 ± 4.04	5.00 ± 2.37
Choriaster granulatus	2	0.36 ± 1.21	16.00 ± 1.41	9.50 ± 2.12
Culcita novaeguineae	7	1.24 ± 2.04	10.00 ± 1.30	7.71 ± 4.46
Linckia laevigata	14	2.55 ± 3.11	13.33 ± 4.29	10.30 ± 3.40

4.4.3 Echinoidea

(10 taxa found, 664 individuals in transects).

Sea urchins were widely distributed around all islands, calculations from transects is shown in Table 4.6. *Toxopneustes pileolus* was usually found on patches of sand and rubble or on the off-reef floor. This species together with *Tripneustes gratilla* was found spawning in one of the transects, individuals clustered together and spawned into the water masses on one particular day with large waves (transect Mu2, conducted 6 May).

Table 4.6: Transect data on echinoids.

Species	# Ind. in transects	Overall density Ind. $400m^{-2}$ ± SD	Test diameter (cm) ± SD	Mean depth (m) ± SD
Diadema savignyi	26	4.44 ± 4.14	7.43 ± 1.12	8.79 ± 2.64
Diadema setosum	580	100.55 ± 80	5.21 ± 1.29	10.29 ± 3.41
Echinothrix calamaris	15	2.73 ± 5.39	8.10 ± 1.34	8.14 ± 1.56
Echinothrix diadema	3	0.55 ± 0.93	8.50 ± 1.50	6.50 ± 0.70
Lovenia elongata	1	0.18 ± 0.60	-	-
Tripneustes gratilla	1	0.18 ± 0.60	-	4.00
Toxopneustes pileolus	38	6.91 ± 10.21	8.73 ± 1.16	9.05 ± 3.50

Diadema setosum

Abundances, substrate preferences and spatial distribution

Density estimations based on transect data (Table 4.7) show that variation between transects was great, but that *D. setosum* numbers were relatively high at all sites. At Bich Dam the abundance was relatively low, but it was still the dominating species. The urchins were frequently found in close association with rocks and stones within the reef, but rarely on living corals (of 550 urchins 85% were found on, under or in direct contact with a rock or stone, 12 % were found out in the open i.e. on sandy bottom or on coral rubble while 4% were found directly on corals or inside the living reef framework). Associations with rock and stone were most noteworthy around Hon Mun and Hon Mot. The depth distribution of the urchins (Fig. 4.8) is in accordance with underwater topography, and observed distribution of corals on the different sites.

Table 4.7: Site specific calculations for *D. setosum* found in transects.

Site	# *D. setosum* counted	Relative number of *D. setosum*	Mean density Ind. m^{-2} ± SD	Mean depth (m) ± SD
Hon Mot	135	83.9%	0.54	7.5 ± 2.2
Bich Dam	13	34.2%	0.07	10.0 ± 1.6
Hon Mun South	356	71.8%	0.22 ± 0.19	12.2 ± 2.5
Hon Vung	76	82.6%	0.39	6.2 ± 1.8

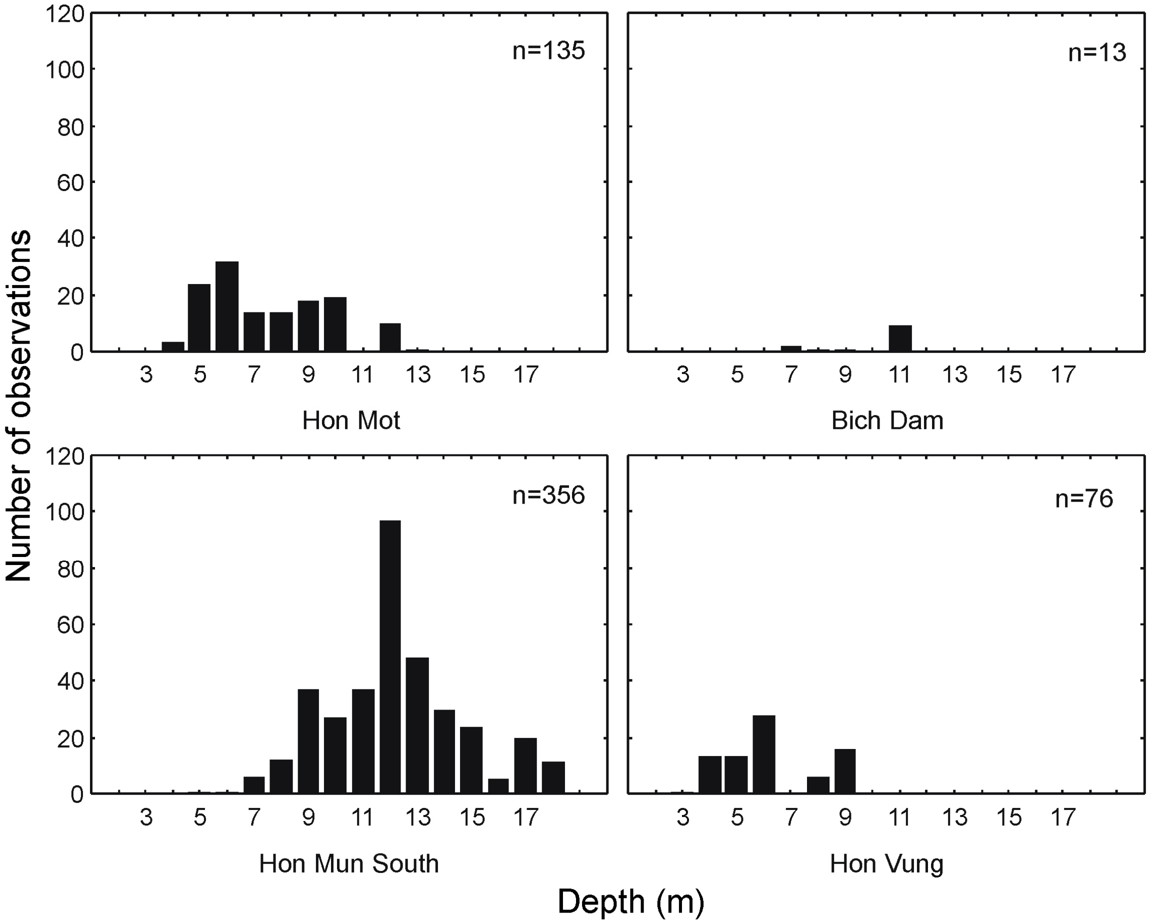

Fig. 4.8: Depth distribution of *D. setosum* on 4 sites.

The urchins were highly aggregated at small scales (Fig. 4.9). In most cases the individuals within each patch were in direct contact with at least one of the other animals. Patches consisted generally of 5-15 individuals. Calculations of sizes of patches from on-screen size calibrated images showed that the clumping of individuals often occurred on scales smaller than 1 m^2 (~0.3-1.0 m^2 for clumps consisting of 4 to 11 individuals, n images = 5). Sometimes transects traversed not only single patches but also parts of larger patches (>15 ind.). Larger aggregations consisting of smaller patches of individuals separated by short distances, were seen in some areas on the reefs.

The size of the main reef area on the Hon Mun South is estimated to be close to 0.1 km^2 (area with more than ~40% coral cover, calculated from transect data). Based on density estimates it is probable that somewhere between 20 000 and 30 000 individuals of *D. setosum* were present on, or adjacent to this reef area at the time of sampling (highest estimate is based on densities in transects Mu3, Mu4, Mu5, Mu7 and Mu8). The distributional pattern of the urchins is shown in Fig. 4.10. Density estimations as shown by the trend surface are calculated from mean densities in 8 m^2 quadrats along each transect, and interpolated between transects. Despite a rather crude interpolation a trend can be seen down the depth gradient and along the shoreline. The highest densities correspond to the observed transition zone between reef and sandy/muddy substrate at the end of the reef slope. Only a few urchins were found on the shallowest areas of the reef.

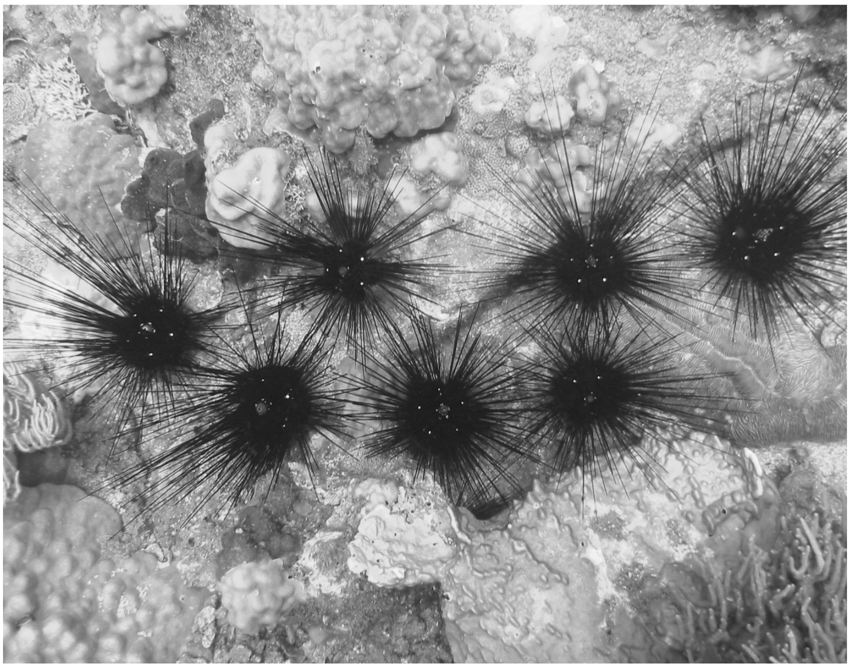

Fig. 4.9: Image showing small-scale aggregation of *Diadema setosum*. Size of patch estimated to be about 0.8m^2.

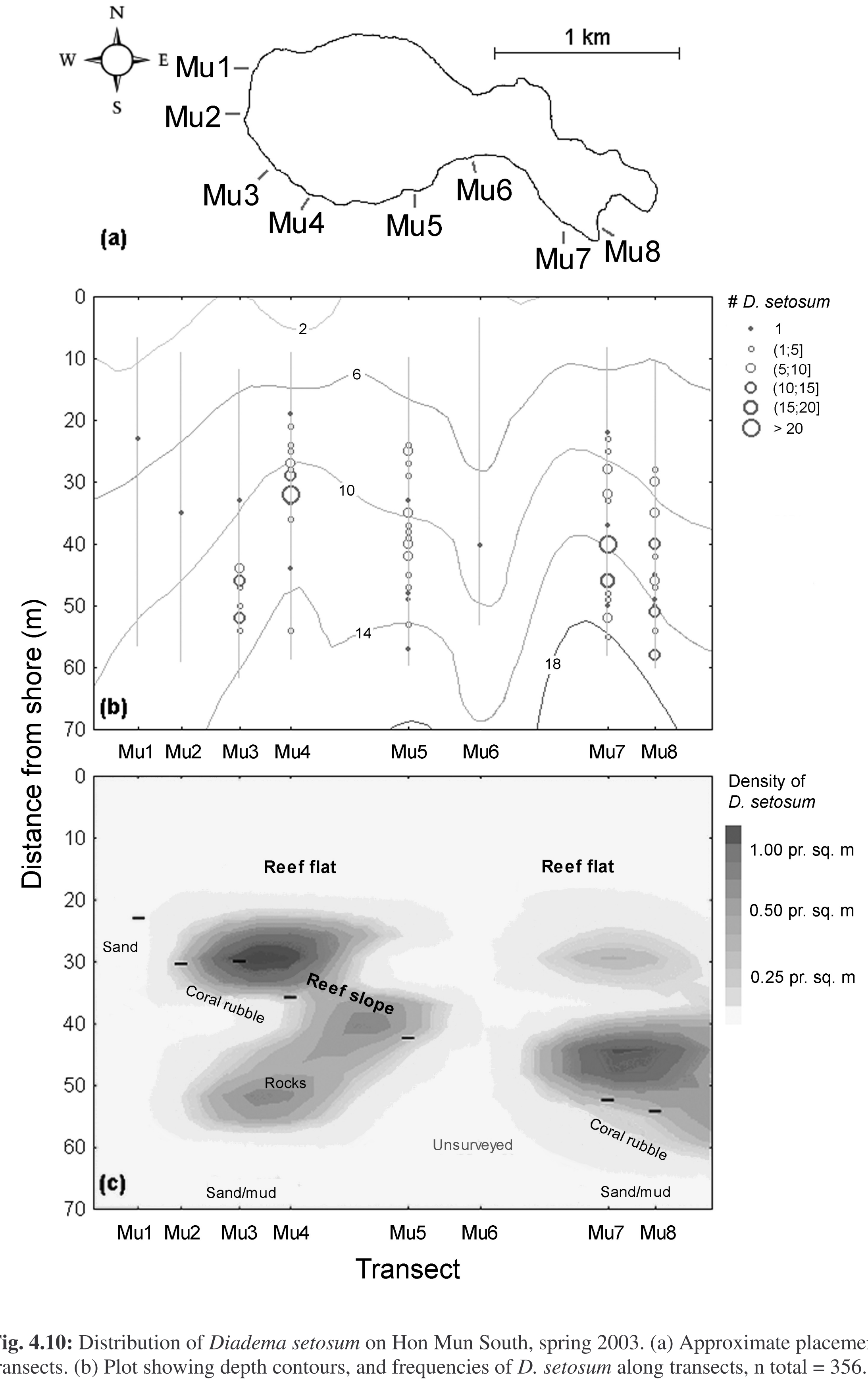

Fig. 4.10: Distribution of *Diadema setosum* on Hon Mun South, spring 2003. (a) Approximate placement of transects. (b) Plot showing depth contours, and frequencies of *D. setosum* along transects, n total = 356. Transects (vertical lines) are presented as if they were parallel to each other. (c) Trend surface based on interpolation of the abundance values in the transects. Horizontal lines symbolize transition between reef and sandy/muddy substrate. The vertical:horizontal scale ratio is about 1:30 in (b) and (c).

Sizes and population structure

Analyses of *D. setosum* test sizes (diameter) (Fig. 4.11 and 4.12) showed that mean size of individuals from Hon Vung was significantly larger than mean size of individuals from Hon Mun South and Hon Mot (one-way ANOVA, F=13.67, p< 0.05). No correlation was seen when comparing population densities with mean urchin diameter at the respective sites. Analyses of size data from Hon Mun showed no trend towards presence year groups (i.e. multiple peaks in frequencies of the test sizes).

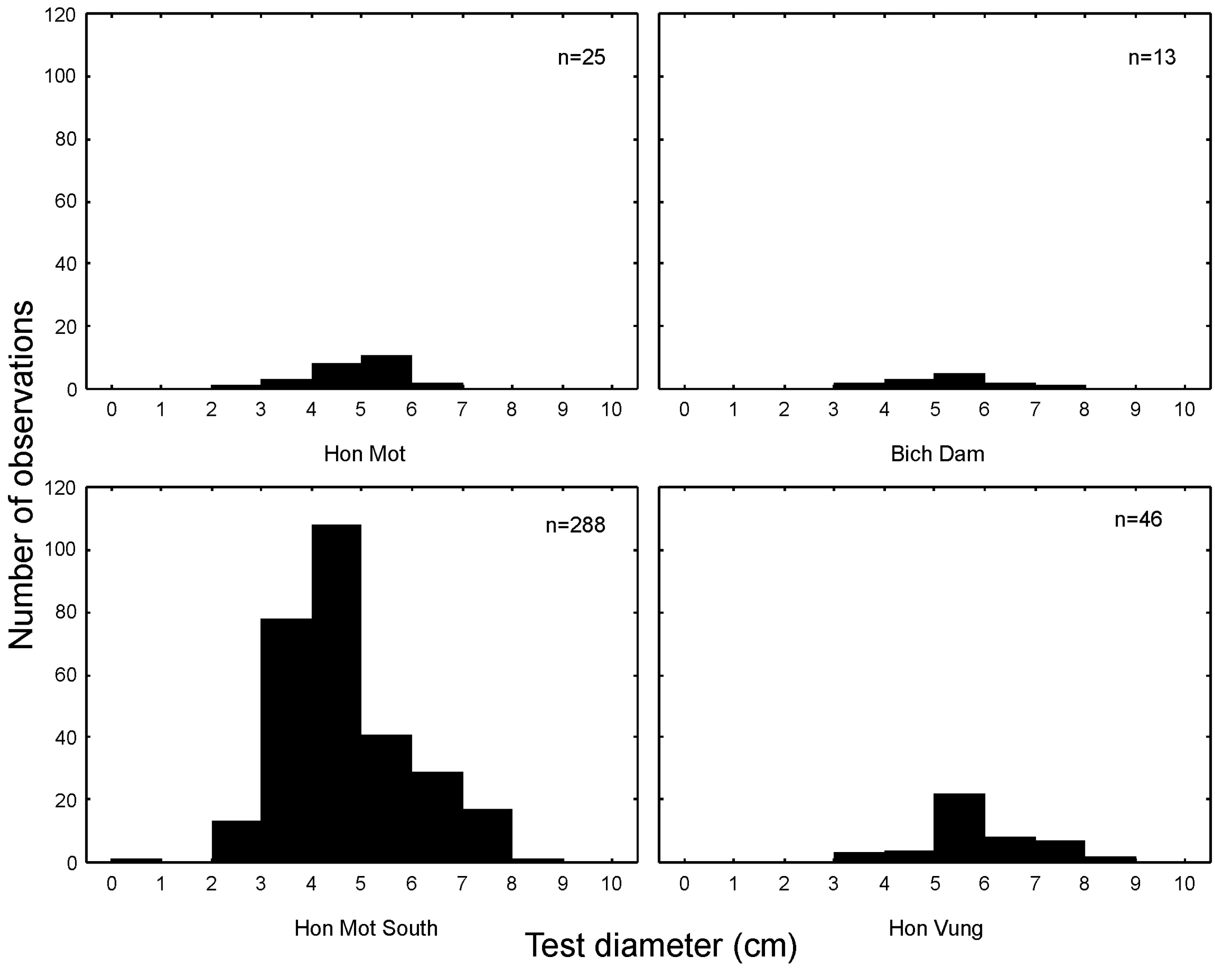

Fig. 4.11: Size-frequency histogram of *D. setosum* from 4 sites (0.5 cm size groups).

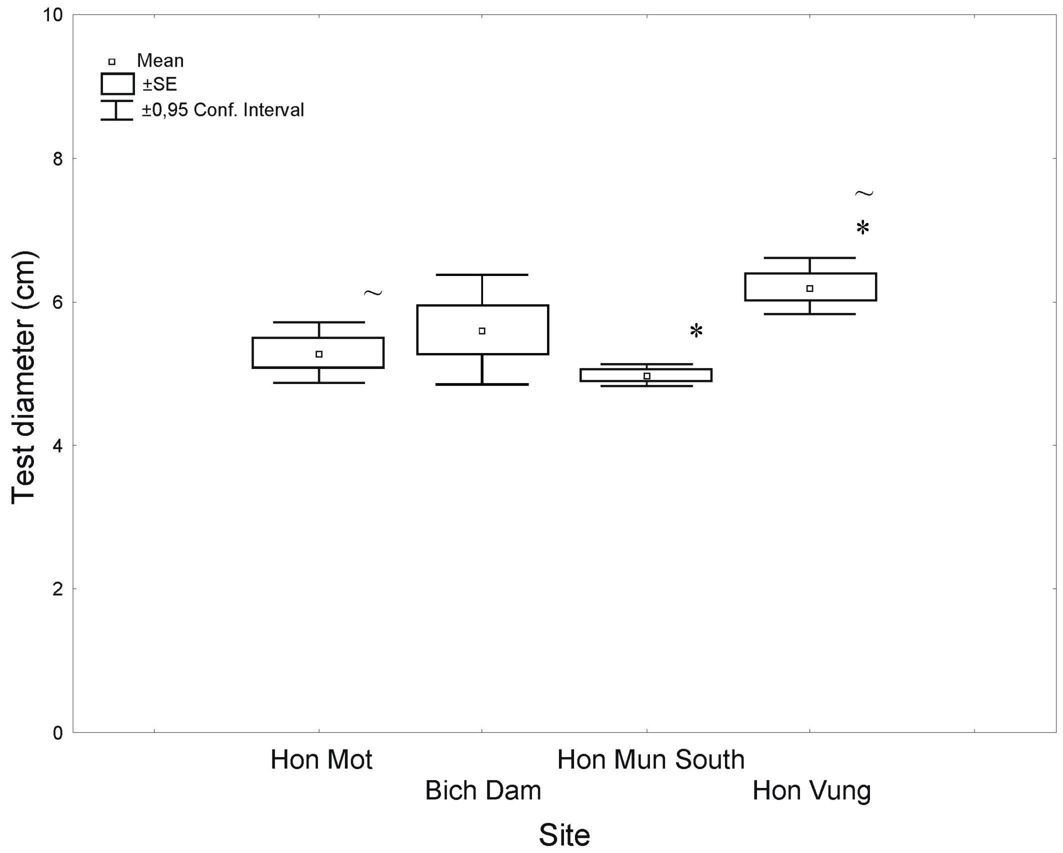

Fig. 4.12: Mean sizes of *D. setosum* on four sites. ~ and * indicate significant difference.

4.4.4 Holothuroidea

(8 taxa found, 7 individuals in transects).

Holothurians occurred very infrequently. In the transects they were only found on Hon Mot and Hon Vung (Table 4.8). *Synapta maculata* was always found in areas with high amounts of detritus.

Table 4.8: Transect data on holothurians.

Species	# Ind. in transects (Site)	Mean density Ind. $400m^{-2}$ ± SD	Body length (cm)	Mean depth (m) ± SD
Holothuria leucospilota	1 (Site 6)	0.18 ± 0.60	-	9.00
Pearsonothuria graeffei	2 (Site 3)	0.29 ± 0.96	30.0	7.00 ± 4.24
Synapta maculata	3 (Site 3)	0.44 ± 1.45	-	-
Thelenota ananas	1 (Site 6)	0.18 ± 0.60	19.0	10.0

4.5 Similarities between areas in the South China Sea

Species occurrences of shallow water asteroids and echinoids in different regions in the South China Sea, as presented by Lane et al. (2000), were compared by similarity analyses. The resulting dendrograms (Fig. 4.13), indicate that the area having most in common with the Khahn Hoa province is region 7, i.e. the Spratly (Nansha) islands. This region clustered together with Khahn Hoa in both analyses. The species list from Khahn Hoa is a subsample of species found in region 2. The similarity analysis for echinoids indicate that the subsample has a quite distinct fauna.

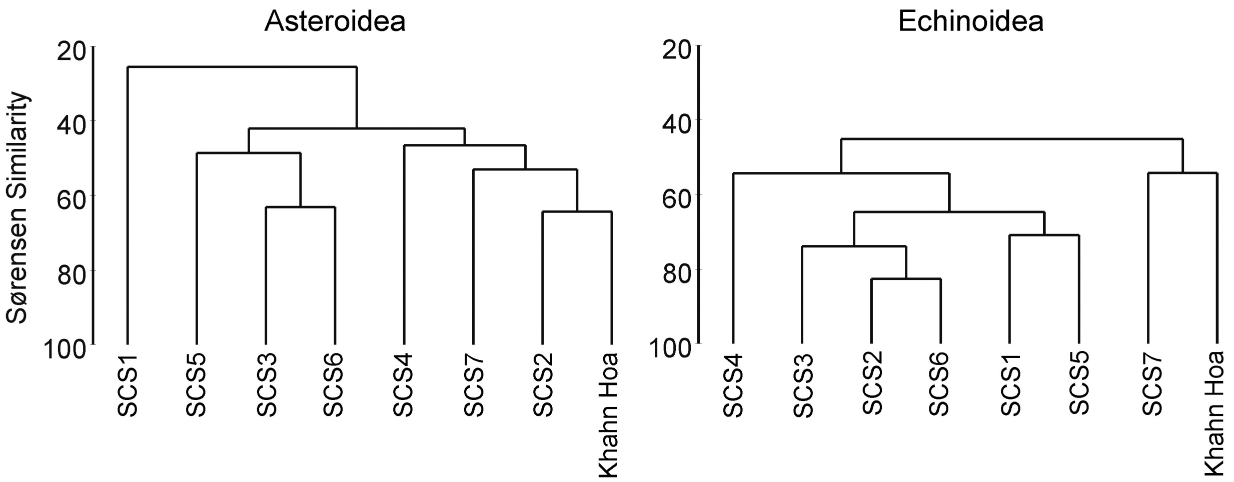

Fig. 4.13: Dendrogram resulting from group averaged cluster analysis of similarities calculated from occurences of shallow water (<200 m depth) asteroids and echinoids in different regions in the SCS (Fig. 3.3). Species occurrences are obtained from Lane et al. (2000), Dao (2002), and Putchakarn and Sonchaeng (2004).

5. DISCUSSION

5.1 Discussion of Material and Methods

5.1.1 Adequacy of sampling methods

The sampling design used in this study can be improved. The main improvement would be to survey replicate transects from the different sites. Preferably, more sites should also have been investigated by transect surveys. In this study comparisons of abundances of the different species were based on data from 8 transects from Hon Mun South, and 1 transect from each of the three other sites. For robust statistical analyses it is desirable that high (and equal) amounts of randomly allocated replicate samples from each site are collected (see Green, 1979; Hurlbert 1984). This can however not always be obtained when doing fieldwork.

In this study 50m*4m belt transects were used in order to obtain detailed data for many of the species. An elaborate methodological study by Mapstone and Ayling (1998) showed that, for visually assessing the abundance of discrete benthic organisms, such as corals and many mobile invertebrates, 50-60m x 4-5m benthic belt transects often provide the least biased density estimates. Conducting several long and narrow transects are also expected to be more cost-effective than using wider transects in order to cover larger areas, and are likely to be easier to use given the logistical constraints associated with diving. One of the weaknesses with the 50 meter long transects was that they sometimes traversed not only the reef area but also the off-reef floor. In areas with a clear transition zone between the reef and the off-reef floor, the length of the transects should probably have been adjusted so that smaller parts of the off- reef floor was sampled. Since use of smaller sampling units normally result in increased precision of estimates with aggregated distributions of organisms (Elliot, 1971), more precise density estimations of the most abundant species on the reefs could probably have been obtained by using numerous smaller transects or quadrats. These should preferable be placed at random on the reefs. In instances where only a few small samples are to be taken, or large scale environmental patterns exist, stratified random allocation of sampling units is generally recommended (Green, 1979). Small quadrats have often been used in studies where the aim was to estimate densities of the more abundant echinoderm species (e.g. Carpenter, 1981; Hay, 1984; Mokady et al., 1996; McClanahan, 1998; Carreiro-Silva and McClanahan, 2001), but long and narrow transects have also provided valuable data in some surveys (Grignard et al., 1996; Engelhardt et al., 1999; Miller et al., 2003).

In this study transects were placed perpendicular to the shore. The positioning of transects across the available reef profile and depth range was expected to ensure the collection of representative samples that truly reflected the range of environmental conditions that existed at each site. Miller and Ambrose (2000) found line transects laid across the depth profile to approach or exceed the accuracy of the best stratified quadrat efforts in their small-scale littoral studies. In contrast to depth-stratified sampling (i.e. where two fixed depths have been pre-selected for transect placement), sampling across the depth contour probably avoids possible problems of missing data. Depth stratified transect sampling is commonly used in monitoring surveys as an efficient way of estimating densities in deep and shallow parts of the reefs. Results from this study show that distributions of the species were heterogeneous not only across the depth contour but also along the shoreline (e.g. Fig. 4.10). Thus, density estimates will be strongly influenced by size, shape and positioning of sampling units. Within the scope of this study, and within the limitations imposed by diving and logistics, the choice of sampling unit proved to be useful. The 50 m long transects covering the whole reef profile, along with mapping of each of the specimens, made it possible to examine small-scale, and depth-specific patterns in distribution. The relatively large area covered in each transects made it possible to estimate abundances of the rarer taxa. A major disadvantage though, with the detailed observations made is that they are quite time consuming.

The free-swimming observations conducted in this survey provided semi-quantitative estimates of the abundances at different sites, where transect surveys could not be performed. Free-swimming observations of this kind will always have some degree of bias towards subjective perceptions of patterns. Semi-quantitative abundances estimated from this survey are meant to be descriptive, and were not used in any statistical analyses. In terms of biodiversity assessment, free-swimming methods have been shown to yield more species than traditional quantitative methods. Rather than being restricted to a defined quadrat area or transect line, observers are allowed to actively search for new species records at each site (DeVantier et al., 1998). In this survey similarity analyses on species presence/absence data from the different sites showed sites to group together according to sampling effort, and thus species richness. The use of equal amounts of time in the free-swimming observations at each site would have made comparisons more reliable, and it would have been easier to say if sites differed in species richness or not.

Since many echinoderms are nocturnal feeders (Endean, 1973; Carpenter, 1981; Vail, 1987; Coleman, 1994), sampling at nighttime would probably have resulted in observation of more species and individuals. Due to the nature of the substrate on the reefs, and the fact that many species, and especially juveniles (Yamaguchi, 1973) are cryptic, it is probable that densities calculated in this survey are considerable underestimates. Smaller species and juveniles probably existed in higher densities on the reefs than was observed. When specimens were buried deeply within the rubble or under rocks, they were not looked for. During this study the tests of 2 species of burrowing irregular sea urchins were found lying on top of the sediments (*Echinocyamus crispus* Mazzetti, 1984 and *Metalia spatagus* (Linnaeus, (1758)), thus indicating the presence also of these macro echinoderm species on the reef areas.

5.1.2 Sampling effort

Total area covered in this survey (~6450m^2) was by no means extensive compared to many other studies on shallow water echinoderms (e.g. Paterson, 1994; Engelhardt 1999; Miller, 2003). The area covered in this study is very similar to that covered by Vo et al. (2002b), where a species inventory was compiled from an area of about 6500m^2 in a total of 26 transects from 13 locations. Earlier studies in Nha Trang bay has focused on estimating indicator species like *Diadema* sp. or *Acanthaster planci*, either semi-quantitatively, or by means of seven 1 m^2 quadrats placed at two depths at different monitoring sites. Kalashnikov (1989) investigated distributions and population densities of holothurian species around islands in Vietnam, but did not describe how densities were estimated. This study is probably the first of its kind being done on estimating abundances of the rarer macro echinoderm species on reefs in Vietnam.

5.2 Discussion of the results

26 species from 23 genera and 15 families were found during this survey. The macro echinoderm fauna on reefs in Nha Trang Bay was dominated by the sea urchin *Diadema setosum.* Community structure varied greatly along the depth contour and between transects.

5.2.1 Species found

The taxon sampling curve (Fig. 4.1) shows that species richness was still increasing at the end of the survey, it is highly likely that further sampling will reveal additional macro echinoderm species.

The first reports on the echinoderms in Nha Trang Bay is from 1952, since then a total of 143 species have been recorded (Dawydoff, 1952; Cherbonnier, 1960; Cherbonnier, 1961; Loi and Sach, 1965; Loi, 1967; Nguyen et. al., 1978; Levin and Dao, 1989; Dao, 1991; Nguyen and Nguyen, 1993; Dao, 1994; Dao, 2001). 23.8% of the crinoid, asteroid, echinoid and holothuroid species recorded from earlier studies in the bay were found in this survey. The asteroid *Euretaster insignis* is a new record for Nha Trang Bay but not for the Khahn Hoa province where a total of 165 species have been listed (Dao, 2002). Biodiversity surveys conducted in later years, where reefs in the bay have been investigated by standardised methods, reports 27 species (Cheung and Vo, 1993) and 18 species (Vo et al., 2002b) of echinoderms. No crinoids were reported from these surveys. According to Dao (2002) 6 species of crinoids have been found in Khahn Hoa waters, while a total of 45 species are reported from Vietnam (Dao, 1994). Meyer and Macurda (1977) noted that the most diverse fauna of extant crinoids occurs in the coral reefs of the tropical Indo-Pacific. The taxonomy of recent crinoids is not stabilised (Ausich and Kammer, 2001). It is highly probable that more than 6 species of crinoids can be found in Khahn Hoa waters, and it would be rewarding to conduct detailed studies on taxonomy and ecology of this group.

5.2.2 Diversity and rare species

It is seen from the dominance plot (Fig 4.2) that the five most common species accounted for about 90% of the total number of individuals in transects. Of the 26 species registered during the survey, 7 were observed once. The results show that the majority of the macro echinoderm species on reefs in Nha Trang Bay are relatively rare. The overwhelming contribution from *Diadema setosum* to the fauna composition can in terms of evenness be said to indicate low biodiversity. However, similar patterns are commonly seen in nature (Fisher et al., 1943; McArdle, 1990). Paterson (1994), found most of the asteroid species in his survey to be rare, while only a few species were common, and noted this to be a general trend in reef ecosystems. What species is dominating at a reef at any given time is governed by several factors. Food available, amount of coral cover, sediment types, presence of predators, degree of wave exposure, heterogeneity in larval settlement and seasonal variations are some examples. The Simpson's diversity index varied between transects, as an effect of the relative high, and fluctuating numbers of *D. setosum,* and low number of species. The transect from Bich Dam (Tr1) had highest evenness, and was not completely dominated by *D. setosum*, as most of the other transects were. *D. setosum* density was found to be in the range

0.07-0.54 ind. m^{-2} in this survey. On reefs in the Indo-West pacific it is commonly found to be the dominant species. Density estimates have been reported to be in the range of 0.0-1.1 ind. m^{-2} in Kenya (Carreiro-Silva and McClanahan, 2001), 0.004-0.38 ind. m^{-2} in Singapore (Grignard et al., 1996), 1.7-3.1 ind. m^{-2} on reefs in Sulawesi, Indonesia, 0.18-17 m^{-2} in Papua New Guinea, 4-38 ind. m^{-2} in Thailand (Birkeland, 1989). Clearly the density estimates in this survey are not particularly high. It must be noted that due to differences in sampling methods, densities between different reefs in the Indo-West pacific are not directly comparable.

5.2.3 Microhabitat preferences: differences between transects and between depth intervals

A mosaic of bottom types and microhabitats was covered in the transects. The high amount of heterogeneity is reflected by the fact that standard deviation was smaller than the overall mean density for only 2 species, and that the lowest coefficient of variation was calculated to be 79.6%.

From the "Top 5" list (Table 4.3) it is evident that many of the transects had quite similar relative composition of echinoderm fauna. Still, some differences were observed. The differences recorded on Hon Mun South can be explained by the properties of the different transects (Appendix, Table A1.1). Transects Mu1 and Mu6 yielded very few individuals. Both transects covered shallower depths than that of the other transects (4-7 m). It is probable that effects from waves, and low substrate complexity were reasons why densities were so low. Mu1 was placed in an area with very low coral cover (5-15%), and much sand. Mu6 had high coral cover (60-70%), and was placed over a reef flat in a cove sometimes subject to concentrated wave action. Transects Mu2 and Tr1 (Bich Dam) differed from the others in having relatively higher abundance of *Toxopneustes pileous*, and lower numbers of *D. setosum*. Both had coral cover of about 10-20% and sediment consisting of mainly rubble and sand. From observations of habitat preferences (Fig. 4.5) it is evident that *T. pileolus* preferred these substrates. The two transects also had very little amount of rocks in them, which was seen to bee preferred by *D. setosum*. The rest of the transects in the survey were quite similar, and were dominated by *D. setosum* and the crinoids *Himerometra robustipinna* and *Oxycomanthus bennetti*.

Analyses of species abundances in shallower and deeper transect segments indicated some differences in species composition along the depth contour. This was seen from the similarity analyses of both untransformed and √√-transformed abundance data. Thus indicating some depth specific differences in abundance both for the most common species (*D. setosum*) and for the rarer species. Clustering of individual segments was however quite different in the two analyses, and within-group (S and D) similarities as given by the SIMPER analyses were relatively low. Three D segments containing many *D. setosum* clustered together with S segments in the analysis of √√ transformed data, this because the segments also contained relatively high number of crinoids. Differences seen between D and S segments are explained by the distribution of corals and sediment types. Areas with good coral cover were found at depths above 12 meters. The substrate consisting of predominantly live coral and coral rubble changed to finer sediments as depth increased. Sometimes the transects traversed not only the reef framework but also the off-reef floor in the deep parts. It is seen from the multivariate analyses of species abundances in S and D segments that D segments generally have higher abundances of *D. setosum* and *Toxopneustes pileolus*, while in the S segments higher densities of *Himerometra robustipinna* and *Oxycomanthus bennetti* are normally found. The D segments on Hon Mun South covered the reef slope where many *D. setosum* aggregated, while in the shallow parts the crinoids *H. robustipinna* and *O. bennetti* were found most frequently. S segments from Hon Mot (Mo1) and Hon Vung (Vu1) clustered together with D segments from Hon Mun in the analyses of untransformed abundance data. In these transects corals were generally confined to patches in the shallower segments. The individuals of *D. setosum* found here aggregated around the patches of corals, and occurred only in small numbers in deeper segments, as is revealed by Fig 4.8.

D. setosum had a peak abundance at about 12 m on Hon Mun South. Grignard et al. (1996) found highest densities of *D. setosum* to occur at depths of 1-4 meters on reefs in Singapore, and noted this to be a general tendency of *D. setosum* in the Indo West Pacific Ocean. Reasons for the distribution were found to be high amounts of sedimentation and thereby high turbidity. As an effect, the algae preffered as food for the urchins were confined to the shallowest parts of the reefs. Dotan (1990) found *D. setosum* in the Red Sea to avoid areas with strong water movement. It is likely that waveaction was a structuring force determining the depth distribution seen on Hon Mun South at the time of sampling. Mokady et al. (1996) found *D. setosum* to to be most abundant over the reef slope, on reefs in the Red Sea. The preference towards rocks and the heterogeneous substratum found at the reef slope in this study can be explained by the urchins feeding preferences. Pearse and Arch (1969) noted that individuals of *Diadema* probably are omnivorous scavengers that feed on silt, detritus and algae scraped off rocks. The distribution can also be explained by the fact that aggregating in areas with heterogeneous (rocky) substratum will reduce the risk of mortality from predators, e.g. from predatory gastropods (Levitan and Genovese, 1989) or fish (McClanahan, 1998).

A strong thermocline, probably induced by weak local upwelling, was sometimes recorded on Hon Mun South. Currents carrying water masses with distinctly colder temperature were recorded at a depth of about 9-13 m. Some of the more cryptic crinoids (e.g. *Phanogenia* sp. *Comaster* sp. tended to aggregate around this thermocline. It is likely that the crinoids utilized these local circulation patterns for feeding (see Meyer and Macurda, 1980; Meyer et al, 1984).

5.2.4 Site specific differences

No significant differences in species abundances between sites can be revealed on the basis of the data obtained in this survey. The heterogeneity seen between transects reflected the high amount of small-scale variations in substrate that exists at each site. Larger scale differences in for instance coral cover, underwater topography, amount of rocky substrate, and water movement clearly will influence the echinoderm fauna composition at each site. In Nha Trang Bay the reef communities change naturally along gradients from terrestrial influenced conditions to oceanic conditions, and this will probably be a major structuring force of what can be found of echinoderms at each site.

Grignard et al. (1996) found *D. setosum* to increase in density as distance to shore increased, on sediment-stressed coral reefs in Singapore. In this study the lowest abundance of the species was found at the most sheltered site in the survey, Bich Dam. This site is probably exposed to higher amount of sedimentation, and the seafloor was covered by more detritus than in other sites, this can be a reason for the low numbers observed. The crinoids *Himerometra robustipinna* and *Oxycomanthus bennetti* were not found at Bich Dam. It has been shown that crinoids are sensitive to sedimentation (Fabricius, 1994), and that they prefer areas with currents (Meyer and Macurda, 1980; Meyer et al., 1984).

Individuals of *D. setosum* were found to be significantly larger at Hon Vung than at Hon Mun South and Hon Mot in this survey. Vo et al. (2003) noted cover of algae turf and fleshy algae to be highest at Hon Vung, thus it is probable that the larger size of the urchins found here is an effect of higher avaliability of food for the urchins at this site. Mean test diameter did not seem to be correlated with population density across sites, this might suggest that population densities are well below trophic carrying capacity, and that competition between the urchins is minimal (Levitan, 1988). However, since algae cover on Hon Vung seemed to be higher, it is probable that this site will support higher densities of urchins of larger sizes. High amounts of algae were also found around the island Hon Mieu at the mouth of the Cua Be river, but densities of *D. setosum* seemed to be lower here (Vo et al., 2003). Something that probably can be ascribed to lower salinity at this location.

The asteroid *Culcita novaeguineae* seemed occur at highest densities around the exposed Island Hon Vung in this study. Glynn and Krupp (1986) also found this species to be most abundant at the most exposed sites on Hawaii.

5.2.5 Pristine areas in the South China Sea with similar fauna?

The similarity analysis on species occurrences in the South China Sea (Fig. 4.13) indicates that Khahn Hoa has echinoid and asteroid fauna somewhat similar to that of the Spratly archipelago. I have not been able to find any analyses of spatial distributions in the SCS on similar data, but it seems feasible that the echinoderm fauna around the south-central part of Vietnam will have a rather distinct fauna compared to that of other parts of the country. The Spratly Islands and Khahn Hoa province are located around similar latitudes, and Khahn Hoa is more exposed to the open ocean than the northern and southern parts of the country. In addition, the Mekong delta (south) and the Gulf of Tonkin (north) are influenced by runoff from large rivers. It has been shown that coral communities in the northern and central parts of the country are quite similar, while coral communities in the southernmost parts are similar to that of the Gulf of Thailand (Latypov, 2001; Latypov 2003). Latypov (2005) reported Central and South Vietnam reefs to be most similar in species composition, and found them to be quite comparable to Spratly reefs. The innermost islands in Nha Trang bay are influenced by river runoff. Still, it is probable that relatively pristine areas with echinoderm fauna similar to that known from islands in Nha Trang Bay, can be found on the islands in the open parts of the South China Sea. It must be noted that the fauna in the SCS has never been comprehensively studied (Lane et al., 2000), and that further sampling is needed in order to fully establish patterns in the distribution for the echinoderms in the SCS.

Jeng (1998) conducted a small survey on the shallow water echinoderm fauna around the relatively pristine Taiping Island in the Spratly archipelago. The Island being of the same size as Hon Mun was studied at 7 sites for a total of approximately 8.5 hours. A total of 39 echinoderm species was recorded (5 crinoids, 8 asteroids, 7 ophiuroids, 6 echinoids and 13 holothuroids). Of the 39 species, 14 were found in the current surveys in Nha Trang Bay (38% of the species in this survey).

5.3 General Discussion

5.3.1 Effects from the echinoderms on reefs in Nha Trang Bay

Sea urchins are important in controlling the balance between algae and corals, this was well-documented in the Caribbean where mass mortality of *Diadema antillarum* lead to dominance of reefs by fleshy and filamentous algae (Lessios, 1988; Miller et al., 2003). Sea urchins can also contribute to the erosion of reef carbonate when their abundances are high. Mokady et al. (1996) reported total rates of bioerosion from urchins to be in the range of 0.5-0.9 kg $CaCo_3$ m^{-2} $year^{-1}$ on reefs in the Red Sea. Carreiro-Silva and McClanahan (2001) reported total rates of bioerosion to vary between ~0.05 kg $CaCo_3$ m^{-2} $year^{-1}$ on protected reefs and ~1.2 kg $CaCo_3$ m^{-2} $year^{-1}$ on unprotected reefs in Kenya. When combining the rates of bioerosion of individuals of *D. setosum* proposed by Carreiro-Silva and McClanahan (2001), with the observed densities of this species on Hon Mun South from this study, it can be estimated that ~0.15 kg $CaCo_3$ m^{-2} $year^{-1}$ might be eroded by this species at this site. It is evident that *D. setosum* have the potential of limiting the reef growth in Nha Trang Bay. *E. calamaris* and *E. diadema* are also well-known bioeroders. Since they are larger than *D. setosum*, and are normally found in crevices in the reefs and in direct contact with corals, it is probable that rates of bioerosion from individuals of these will be higher than that that from of individuals of *D. setosum.* The majority of specimens of *D. setosum* was observed on or in direct contact with rocks in this study, and seemed to graze on these. This might indicate low rates of erosion of the reef framework from this species. However, since the urchins are nocturnal feeders, and normally are not moving during daytime (Lawrence and Hughes-Games, 1972; Ogden et al. 1976), their distribution and behaviour can be rather different during night. It would be rewarding to perform studies of gut contents of urchins in the bay, in order to determine their rates of algae grazing, and possible bioerosion.

The corallivorous crown-of-thorns starfish *Acanthaster planci* was found at a mean density of 0.95 ind. 400 m^{-2} in this survey (transect data). Vo et al., (2002a) reported *A. planci* to have occurred at “outbreak” densities on some reef areas in Nha Trang Bay in the recent years. In areas in the bay with high densities, individuals have been collected annually as a means of preventing future outbreaks. Engelhardt et al. (1999) used a threshold density of

1.2 ind. 400 m^{-2} of adult *A. planci* ("maximum diameter"≥ 26 cm) when classifying reefs in Australia as sustaining actively outbreak populations or not. In the same study a threshold value of 4 ind. 400 m^{-2} of juveniles (max. diam. ≤ 13 cm) was expected to lead to outbreak populations within the next 18-24 months. Transect data from the present survey indicated a relatively high density of *A. planci* on Hon Mot (6.4 ind. 400 m^{-2}, Appendix, Table A2.3), high densities of this species were also observed at Hon Mun North, and Bich Dam. However, the data obtained in this study do not open up for detailed analyses of sizes and densities between sites. It is important to monitor densities, as well sizes of this species in Nha Trang Bay in order to predict any potential threat from this species on the different reefs. It should though be acknowledged that it is generally difficult to give precise quantitative expressions to an *A. planci* infestation (Endean, 1973). Individuals are normally aggregated over small areas, and patterns in the behaviour of the starfish (cryptic behaviour, feeding behaviour) are highly variable both at temporal, local and regional scales (De'ath and Moran, 1998). The causes for the outbreaks of *A. planci* and the dynamics of outbreaks are not fully understood. Still, it is evident that when abundant, the presence of this species will have dramatic effects on the reef communities. Outbreaks will lead to high mortality of corals, and some coral species seem to be preferred over others. In general, *A. planci* seem to prefer to feed on acroporid and pocilloporid corals, while poritids and favids are strongly avoided (Pratchett, 2001). Biggs and Eminson (1977) reported dead portions on coral following attacks by *A. planci* to be rapidly colonized by algae. The presence of macroalgae has been shown to affect densities of fishes (Choat and Ayling, 1987). Clearly, predation by *A. planci* on corals, and subsequent changes in the coral/algae ratio will affect the local communities of fish, and invertebrates as well.

Culcita novaeguinea is another well-known corallivorous seastar found on reefs in Nha Trang Bay. Feeding behaviour of this species was described by Glynn and Krupp (1986). In their study they found the asteroid to selectively feed on young pocilloporid corals and to avoid poritids as also is common for *A. planci.* Thus the combined effects from feeding of these two species will probably have an effect on the coral community structure and local coral species richness, also when abundances are relatively low.

The effects of holothurians on coral reefs are not well studied. It is clear that they feed on detritus, rework the sediments, and break up any initial stratification in these (Bakus, 1973). Moriarty (1985) found *Holothuria atra* to consume about 10 to 40 % of bacterial carbon in sediments, and proposed that they play an important role in the carbon cycle on coral reef flats. The species *Pearsonothuria graeffei* and *Synapta maculata* were seen feeding on the detritus and mucus covering live corals during this study. Since many corals have symbiotic algae (zooxanthellae) living in their tissues, and get energy from these, it is probable that the removal of detritus and precipitated sediments will be a benefit for the corals due to increased photosynthetic activity in the algae. It might also be that the removal of detritus can have negative effects, since some of the coral species feed on this detritus.

5.3.2 Effects from humans on the echinoderms

20 echinoderm species with known commercial value are recorded from Khahn Hoa waters (value according to McElroy, 1990; Schoppe, 2000; Dao, 2002; personal observation). Of these, 6 were found during this survey (Table 5.1), but apart from *D. setosum* each species was recorded in low numbers.

Table 5.1: Echinoderms with commercial value recorded from Khahn Hoa waters (occurrences from Dao, 2002).

	Species	Use*	Ind. found in this survey
Asteroidea	*Protoreaster nodosus*	S	1
Echinoidea	*Diadema setosum*	***F***	>1000
	Heterocentrotus mammillatus (Linnaeus 1758)	***S, O***	-
	Mespilia globulus (Linnaeus 1758)	F	-
	Tripneustes gratilla	***F***	1
Holothuroidea	*Actinopyga echinetes* (Jaeger, 1833)	***F***	-
	Actinopyga lecanora (Jaeger, 1833)	F	-
	Actinopyga mauritania (Quoy & Gaimard, 1833)	***F***	-
	Bohadschia argus (Jaeger, 1833)	F	-
	Bohadschia marmorata (Jaeger, 1833)	F	-
	Bohadschia tenuissima Semper, 1868	F	-
	Holothuria (Halodeima) atra Jaeger, 1833	***F***	-
	Holothuria (Halodeima) edulis Lesson, 1830	F	-
	Holothuria (microthele) nobilis Selenka, 1867	***F***	-
	Holothuria (Metriatyla) scabra Jaeger, 1833	***F***	-
	Holothuria (Thymiosycia) impatiens (Forskål, 1775)	F	-
	Pearsonothuria graeffei	F	5
	Stichopus chloronotus	F	4
	Stichopus hermanni Semper, 1868	F	-
	Thelenota ananas	***F***	1
	Thelenota anax H.L. Clark, 1921	F	-

*F: Used as food, S: Used for souvenirs, O: Other value. Bold italic letters indicate high commercial value in Vietnam (according to Dao, 2002).

The sea cucumber fishery in Vietnam has increased substantially over the last decades. Loi and Sach (1965) studied holothurians in Nha Trang Bay and found many of the species to be common and widely distributed. This seemed to be the case up until 1990, and one of the highest priced commercial species of today, *Holothuria scabra* was found in high densities on many reef locations (Dao, 1991). Several tons of *H. scabra* could be collected daily on reefs in the southern parts of the Khahn Hoa province in the autumn at that time (Dao, 2002). A decade later, many of the commercially important species were becoming rare (Dao, 2002). Similar trends have been seen in many countries in Asia. Schoppe (2000) for instance, reported exports of beche-de-mer in the Philippines to have increased by 850% between the years 1977 to 1996, with a subsequent depletion of sea cucumber stocks, and smaller sizes of individuals.

During this survey only a few species of edible holothurians were recorded. The only species with high commercial value (*Thelenota ananas*) was found around the offshore island Hon Vung. Vo et al. (2003) also found edible holothurians to be very rare, and observed highest densities of sea cucumbers on the reefs of Hon Cau and Hon Vung (mean density: 1 per 400 m^2). Strehlow (2004) expected each fishing boat in Nha Trang Bay to catch about 600 *Holothuria scabra* per year (did no say how many boats), and noted that the single largest expense the fishermen has, is that of fuel for their boats. It is likely that the islands located further off to sea are less exposed to the beche-de-mer fishery. Jeng (1998), in his 8.5 hour study around Taiping Island, in the Spratly archipelago, found 13 species of holothurians. 8 of the species recorded in his survey have commercial value. This is in sharp contrast to the 3 commercially valuable species found in this 17 hour survey, - a difference that in part illustrates the impact from the sea cucumber fishery in the coastal waters of Vietnam.

The commercially important sea urchins *Heterocentrotus mammilatus* and *Mespilia globulus* were not found in this survey; *Tripneustes gratilla* was recorded only once. The impact from human harvest of these species is largely undescribed. Still, it is highly probable that these species are heavily exploited and are becoming locally extinct. Dao (2002) reported *H. mammilatus* to be harvested for the souvenir and traditional medicine market, and noted that gonads from *T. gratilla* have been exported from Nha Trang since 1992.The local fishermen also collect *Diadema setosum* for their gonads, or use them as fodder for caged lobsters. Anecdotes indicate that 10 years ago, *D. setosum* occured frequently at the near shore zones of the reefs in the bay, and injured many of the swimming tourists (Dao Tan Ho personal communication). In this survey, most individuals were found in deeper waters, and on Hon Mun South they were nearly absent close to shore. The local villagers normally collect the urchins by snorkelling and spearfishing. Reef-top gathering in the Red Sea has been shown to be an important factor controlling the distribution of commercially valuable molluscs (Ashword et al., 2004). A similar scenario might be that human harvest in the shallow parts of the reefs in Nha Trang Bay is a governing factor of the depth distribution of some of the species, including perhaps that of *D. setosum*. Yet another effect from human harvest might be that selective removal of the largest individuals can influence the size distribution of the targeted species. Individuals of *D. setosum* were found to be smaller at Hon Mun South than at Hon Vung in this survey. It would be interesting to monitor the sizes of *D. setosum* inside and outside the core zones of Hon Mun MPA.

Abundances of commercially valuable sea urchins on reefs in Nha Trang Bay have not been quantified in earlier studies (i.e. no publications in english). The highly poisonous sea urchin *Toxopneustes pileolus* was found in relatively high densities on most reefs in this survey. Since this species is rarely collected for food, its densities can perhaps be used as a measure of what can expected to be found, if human harvest was negligible. At least for some of the species (e.g. *Tripnesustes gratilla*).

The waters of Nha Trang Bay are heavily overfished (Vo et al., 2002a). It has been well-documented that fishing will have indirect effects on benthic invertebrates (Pinnegar et al., 2000). Removal of predatory fish like triggerfish (Balistidae) and wrasses (Labridae) has been shown to result in higher density of sea urchins and competitive exclusion of weaker competitors such as herbivorous fish. This can result in reefs characterised by denser populations of larger sea urchins, fewer and smaller fishes and reduced coral cover, as seen in Kenya (McClanahan and Muthiga, 1988). Triggerfish are easily fished because of their aggressive behaviour (Jennings and Kaiser, 1998). On Hon Mun one of the most important predators (*Balistapus undulatus*) could be found at a mean density of 1-3 individuals 500 m^{-2} in August 2003, individuals were smaller than 20 cm (Ngyen Van Long personal communication). This low number corresponds with the fact that most of the fish targeted for food are rare in Nha Trang waters, and that large fish (>20 cm) are seldomly observed (Vo et al. 2003). The competitors of the urchins, the herbivorous fishes (e.g. parrotfishes: Scaridae and surgeonfishes: Acanthuridae) are also fished. It is probable that grazing urchins probably will have increased survival because of this release in competitive pressure. McClanahan (1992) proposed that sea urchins probably will persist at lower levels of algal biomass and productivity than herbivorous fishes, and thereby will out-compete them. As a result, once an urchin-dominated community is established, it is unlikely that herbivorous fishes can re-establish themselves (Jennings and Kaiser, 1998). Scaridae and Acanthuridae seemed to occur at relatively high densities on most locations in Nha Trang Bay in August 2003 (Vo et al., 2003). Any effects from competition between herbivorous fish and sea urchins, or effects from predation are not easy to quantify. However, with the implementation of Hon Mun MPA, these effects can hopefully be studied in the light of the decreased fishing pressure inside of the core zones of the MPA.

Fishing and other extractive activities are not the only human induced factors with the potential of influencing echinoderm abundances in Nha Trang Bay. In fact, most anthropogenic effects on coral reefs (reviewed by Hatcher et al. 1989) will influence the communities of echinoderms in one way or the other. The effects from increased sedimentation and nutrients input as well as direct causes of coral mortality are probably the main factors that will influence on the fauna composition of echinoderms in the bay. High amounts of sediments and nutrients come from river runoff in Nha Trang Bay, and have increased in recent years due to human activities (Vo et al., 2002a Pavlov et al., 2004). Crinoids will be adversely affected by increased sedimentation (Fabricius, 1994). Walker and Ormond (1982) reported *D. setosum* to occur at higher densities in areas exposed to sewage and phosphate pollution, compared to that of control areas. Coral mortality and subsequent increase in algal biomass can lead to increased numbers of grazing urchins. Vo et al. (2002) noted reef communities on the north side of Hon Tre to have been degraded because of dynamite fishing and river runoff in the last decades, and that amount of algae had increased because of this. Diving tourists contribute to a steady amount of coral mortality. Brodie et al. (2005) claimed that increased nutrient inputs and subsequent increase in phytoplankton would lead to higher survival of *A. planci* larvae, and thereby would lead to increased outbreaks of this species. Pavlov et al. (2004) found remains of the herbicide "Agent orange" that was used as a defoliant during the Vietnam war, to be present in sediments at high densities in Nha Trang Bay. In their study they proposed this to be a main factor of the mortality of corals in the bay. Clearly, a multitude of human activities have potential effects on the reef communities in Nha Trang Bay, and thereby also on the echinoderm populations. The more indirect effects from human activities on the echinoderms are however not easily measured.

Without earlier data to compare with it is difficult to say if the echinoderm fauna composition has changed during the last years, either due to human activities or natural disturbances. Comparisons with echinoderm densities from other areas less subject to human activities are often obscured by differences in sampling methods and differences in environmental characteristics between the areas. Evidently, the monitoring programmes currently being conducted on reefs in Nha Trang Bay have great value.

5.3.3 Possible effects from protection of habitats

The establishment of Hon Mun Marine Protected Area is certainly a step in the right direction when it comes to conserving the heavily exploited marine resources of Nha Trang Bay. Even though any clear effects from protection probably will be confined to the relatively small core zones in the MPA. This survey was conducted one year after protection commenced. It is unlikely that any changes in the composition of echinoderm fauna had occurred during this short timespan. Over time however, enforcement of the "no-take" zones in the MPA can have several effects on the echinoderm fauna. This clearly will depend on the success in keeping harvesting activities at a minimum.

Populations of commercially valuable species of holothurians, asteroids and echinoids in the core zones of the MPA have the potential of being replenished by pelagic larvae transported into the reef areas. It is likely that species numbers and abundances will increase on the protected reefs. If management is successful, these populations might also serve as a source of larvae for other reefs in the bay (Botsword et al., 2003). Recruitment of species and individuals on the reefs will depend on current systems transporting the larvae, duration of larval stages, and densities of larvae in the water masses. With the commercially valuable species being rare close to shore, it is reasonable to believe that the majority of larvae will have to be transported into the MPA from offshore reefs.

It is probable that protection will lead to increase in densities and sizes of reef fishes in the core zones of the MPA. Elevated densities of predatory fish will clearly influence the echinoderms. Fish predators have been proposed to control the abundances of *Acanthaster planci* and thereby also prevent outbreaks of this species (Sweatman, 1995). Several studies have shown overfished reefs to be characterized by having high sea urchin densities, while reefs less subject to fishing generally have low urchin densities (Hay, 1984; Roberts, 1995). The most striking example of this was seen in Kenya where urchin densities were 100 times higher on unprotected than protected reefs (McClanahan and Shafir, 1990). Yet another effect from increase in densities of predatory fish seen in Kenya might be changes in the composition of urchin fauna. McClanahan (1998) proposed a gradient in peak abundances of different species with increased predation pressure. In his study, competitive subordinate species generally confined to crevices in the reefs seemed to have increased abundances (wet weight, kg/ha) with increased levels of predation. The competitive dominant species (in terms of food resources) seemed to be closely controlled by predation and was a weaker competitor for the resource of "predator-free space". On reefs in Nha Trang Bay *Diadema setosum* was clearly the competitive dominant urchin species. *D. setosum* numbers will probably be closely controlled by predation if fish densities (triggerfish and wrasse) are elevated. The more cryptic species *D. savignyi*, *Echinothrix calamaris* and *E. diadema* will perhaps be less affected by predation, and might even increase in abundances (or sizes). Since *D. setosum* is collected by humans it is also feasible to believe that numbers of this species will increase within the core zone. Thus masking any effects from increased predation from fish.

The positive effects from protection of habitats have been recorded in a number of studies, especially for fish. The success in conserving threatened species is however often linked with the size of the marine reserve. The effects of protection from small no-catch zones such as the core zones of Hon Mun MPA are sometimes found to be limited (Edgar and Barrett, 1999; McClanahan, 1999). Uthicke and Benzie (2000) in their studies on the Great Barrier Reef, found densities of the sea cucumber *Holothuria nobilis* to be 4 to 5 times higher, and sizes of individuals to be larger, on protected reefs than those not protected. In their study the clearest effects were seen on the largest protected reefs. They also found that the proximity to tourist attractions might enhance the effect of protection. It is likely that the presence of high numbers of tourists on Hon Mun, in Nha Trang Bay can have similar benefits. Illegal fishing seems however to be a potential problem in Nha Trang Bay. During the present survey illegal harvest and dynamite fishing was observed several times. There is none the less hope for, that over time, awareness of the importance of the protected areas will increase among the local fishermen.

5.4 Concluding remarks

The objective of this study was to obtain background information on the macro echinoderm fauna in Nha Trang Bay, at the onset of protection of habitats. Major findings can be summarized as follows:

- A total of 32 different macro echinoderm taxa was recorded during this survey (7 crinoids, 9 asteroids, 7 echinoids and 8 holothurians). See Table 4.1.

- *Diadema setosum* comprised 74% of individuals in transects, and had an overall mean density of 100.55 ± 80 (SD) ind. 400 m^{-2}. Mean density of other species was in the range 0.18-6.9 ind. 400m^{-2}.

- Mean diameter of *Diadema setosum* was found to be significantly higher at Hon Vung than Hon Mun South and Hon Mot. This can be linked with the fact that more algae have been observed at this site.

- The corallivorous seastar *Acanthaster planci* was found in relatively low densities in this study. Surveys over large areas are however needed in order to evaluate any eventual threat from this species.

- The crinoids *Himerometra robustipinna* and *Oxycomanthus bennetti* were generally confined to the shallow parts of the reefs. *Diadema setosum* and *Toxopneustes pileolus* did generally dominate at the deeper parts. The distribution of the different species on the reefs is explained by their microhabitat preferences (Fig. 4.5). At larger scales the composition echinoderm fauna will be governed by mainland-offshore gradients such as sedimentation, salinity and distance from human populations.

- Commercially valuable species normally found in pristine areas, were nearly absent from the reefs. Clearly, the macro echinoderm fauna in Nha Trang Bay was strongly influenced by human activities at the onset of protection of habitats.

Information obtained in this survey will hopefully be useful when planning future monitoring programmes. Results from the core zone in the MPA; Hon Mun South, are most detailed, and can open up for interesting follow-up studies.

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APPENDIX 1 - Transect properties and survey times

Table A1.1: Properties of the different transects.

Site	Transect	Transect specifications				
		Distance from shore at end (m)	Slope angle (degrees)	Depth covered (m)	Hard coral cover (%)	Substrate other than hard corals
3	Mo1	3	~15	2-14	20-30	Boulders, rocks, pebbles, coral rubble
5	Tr1	7	~5	6-12	10-20	Pebbles, rubble, sand/silt
1	Mu1	6	~10	4-7	5-15	Sand
	Mu2	8	~10	4-10	10-20	Sand, coral rubble
	Mu3	10	~15	4-14	20-30	Boulders, rocks, rubble, sand
	Mu4	7	~15	7-15	30-40	Rocks, coral rubble, sand/silt
	Mu5	7	~15	5-15	40-50	Boulders, rocks, coral rubble, sand/silt
	Mu6	4	~5	4-7	60-70	Coral rubble
	Mu7	5	~20	6-18	40-50	Rocks, coral rubble, sand/silt
	Mu8	8	~15	6-17	40-50	Rocks, coral rubble, sand/silt
6	Vu1	10	~15	3-12	20-30	Rubble, sand

Table A1.2: Table of swimming speed calculations. Calculated in 5 replicates (20m*~4m) from various locations.

Replicate #	Date	Time used (min.)	Approx. area surveyed per minute (m^2)
1 (Hon Mun)	15/3 - 03	10.25	7.80
2 (Hon Mun)	27/3 - 03	9.75	8.21
3 (Bich Dam)	10/5 - 03	10.00	8.00
4 (Hon Tam)	10/5 - 03	9.50	8.42
5 (Hon Mun)	20/5 - 03	11.00	7.27
	Mean	10.10	7.92
	SD	0.58	0.44

APPENDIX 2 - General observations and calculations

Table A2.1: Table of all individuals encountered in the different transects.

Transect	Species	Depth (m)	Distance from shore (m)	Size* (cm)	Habitat†
Mo1	*Diadema setosum*	13	52	5	R
Mo1	*Diadema setosum*	12	51	4,5	CR
Mo1	*Diadema setosum*	12	51	2,5	DC
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	12	49	-	S
Mo1	*Diadema setosum*	10	48	-	-
Mo1	*Diadema setosum*	10	48	-	-
Mo1	*Diadema setosum*	10	48	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	10	45	-	-
Mo1	*Diadema setosum*	9	42	-	R
Mo1	*Diadema setosum*	9	42	-	R
Mo1	*Diadema setosum*	9	42	-	R
Mo1	*Diadema setosum*	9	42	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	40	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	9	38	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	8	36	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	7	35	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	8	34	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	33	-	R
Mo1	*Diadema setosum*	6	32	-	R
Mo1	*Diadema setosum*	6	32	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	31	-	R
Mo1	*Diadema setosum*	6	26	-	R
Mo1	*Diadema setosum*	6	26	-	R
Mo1	*Diadema setosum*	6	26	-	R
Mo1	*Diadema setosum*	6	25	-	R
Mo1	*Diadema setosum*	6	25	-	R
Mo1	*Diadema setosum*	6	25	-	R
Mo1	*Diadema setosum*	6	25	-	R
Mo1	*Diadema setosum*	6	25	-	R
Mo1	*Diadema setosum*	7	25	-	R
Mo1	*Diadema setosum*	7	24	-	R
Mo1	*Diadema setosum*	7	24	-	R
Mo1	*Diadema setosum*	7	24	3,5	R
Mo1	*Diadema setosum*	6	23	4	R
Mo1	*Diadema setosum*	6	23	5	R
Mo1	*Diadema setosum*	6	22	4	R
Mo1	*Diadema setosum*	6	22	5	R
Mo1	*Diadema setosum*	5	18	5	R
Mo1	*Diadema setosum*	5	18	5	R
Mo1	*Diadema setosum*	5	18	5	R
Mo1	*Diadema setosum*	5	18	6	R
Mo1	*Diadema setosum*	5	18	6	R
Mo1	*Diadema setosum*	5	18	6	R
Mo1	*Diadema setosum*	5	17	6	R
Mo1	*Diadema setosum*	5	17	4,5	R
Mo1	*Diadema setosum*	4	15	6	R
Mo1	*Diadema setosum*	5	15	6	R
Mo1	*Diadema setosum*	5	14	6	R
Mo1	*Diadema setosum*	5	14	6	R
Mo1	*Diadema setosum*	4	14	6,5	R
Mo1	*Diadema setosum*	5	14	6	R
Mo1	*Diadema setosum*	4	14	7	R
Mo1	*Diadema setosum*	5	12	6	R
Mo1	*Diadema setosum*	5	12	6	R
Mo1	*Diadema setosum*	5	12	-	R
Mo1	*Diadema setosum*	5	12	-	R
Mo1	*Diadema setosum*	5	12	-	R
Mo1	*Diadema setosum*	6	12	-	R
Mo1	*Diadema setosum*	6	12	-	R
Mo1	*Diadema setosum*	6	10	-	R
Mo1	*Diadema setosum*	6	10	-	R
Mo1	*Diadema setosum*	6	10	-	R
Mo1	*Diadema setosum*	5	10	-	R
Mo1	*Diadema setosum*	5	9	-	R
Mo1	*Diadema setosum*	7	9	-	R
Mo1	*Diadema setosum*	5	9	-	R
Mo1	*Diadema setosum*	5	9	-	R
Mo1	*Diadema setosum*	5	9	-	R
Mo1	*Diadema setosum*	5	9	-	DC
Mo1	*Diadema savignyi*	12	49	-	R
Mo1	*Diadema savignyi*	10	-	-	DC
Mo1	*Diadema savignyi*	9	36	-	R
Mo1	*Diadema savignyi*	9	36	-	R
Mo1	*Diadema savignyi*	9	-	-	HC
Mo1	*Diadema savignyi*	9	-	-	HC
Mo1	*Diadema savignyi*	6	24	-	HR
Mo1	*Diadema savignyi*	4	15	-	R
Mo1	*Culcita novaeguineae*	4	14	-	R
Mo1	*Acanthaster planci*	9	43	13	R
Mo1	*Acanthaster planci*	6	26	-	-

Mo1	*Acanthaster planci*	4	14	9	R
Mo1	*Acanthaster planci*	2	6	-	C
Mo1	*Synapta maculata*	6	-	-	HC
Mo1	*Synapta maculata*	5	-	-	RB
Mo1	*Synapta maculata*	5	-	-	S
Mo1	*Pearsonothuria graeffei*	10	43	-	C
Mo1	*Pearsonothuria graeffei*	4	13	30	R
Mo1	*Himerometra robustipinna*	5	27	-	DC
Mo1	*Himerometra robustipinna*	5	27	-	DC
Mo1	*Himerometra robustipinna*	5	27	-	C
Mo1	*Himerometra robustipinna*	5	27	-	C
Mo1	*Himerometra robustipinna*	5	27	-	C
Mo1	Crinoidea indet.	9	38	-	-
Mo1	Crinoidea indet.	5	19	-	HR
Mo1	Crinoidea indet.	4	4	-	HR
Tr1	*Diadema setosum*	11	50	6	R
Tr1	*Diadema setosum*	11	50	6,5	R
Tr1	*Diadema setosum*	11	50	8	R
Tr1	*Diadema setosum*	11	42	3,5	HC
Tr1	*Diadema setosum*	11	42	3,5	HC
Tr1	*Diadema setosum*	11	41	6	HC
Tr1	*Diadema setosum*	11	41	7	HR
Tr1	*Diadema setosum*	11	41	5,5	HR
Tr1	*Diadema setosum*	11	41	6	HR
Tr1	*Diadema setosum*	9	25	5	HR
Tr1	*Diadema setosum*	8	15	5	HC
Tr1	*Diadema setosum*	7	7	6	R
Tr1	*Diadema setosum*	7	7	5	R
Tr1	*Diadema savignyi*	11	50	7	HR
Tr1	*Diadema savignyi*	11	42	8	HR
Tr1	*Echinothrix calamaris*	9	38	9,5	S
Tr1	*Echinothrix calamaris*	9	37	6	HR
Tr1	*Echinothrix calamaris*	9	28	9	HR
Tr1	*Echinothrix diadema*	9	31	8,5	C
Tr1	*Linckia laevigata*	9	37	13	DC
Tr1	*Linckia laevigata*	9	23	14	HR
Tr1	*Linckia laevigata*	9	19	15	HC
Tr1	*Linckia laevigata*	8	15	12	R
Tr1	*Linckia laevigata*	8	15	-	R
Tr1	*Comanthus parvicirrus*	9	31	-	HC
Tr1	*Choriaster granulatus*	11	46	15	S
Tr1	*Choriaster granulatus*	8	10	17	S
Tr1	*Toxopneustes pileolus*	9	37	7,5	CR
Tr1	*Toxopneustes pileolus*	9	36	9	CR
Tr1	*Toxopneustes pileolus*	9	35	10	RB
Tr1	*Toxopneustes pileolus*	9	32	9,5	RB
Tr1	*Toxopneustes pileolus*	9	31	8	RB
Tr1	*Toxopneustes pileolus*	9	23	9	RB
Tr1	*Toxopneustes pileolus*	9	21	8	R
Tr1	*Toxopneustes pileolus*	8	18	13	RB
Tr1	Crinoidea indet.	9	25	9	CR
Tr1	Crinoidea indet.	10	25	-	HR
Tr1	*Comanthus parvicirrus*	9	20	-	R
Mu1	*Diadema setosum*	5	23	-	S
Mu1	*Echinothrix calamaris*	5	17	-	HC
Mu1	*Lovenia elongata*	20	50	-	S
Mu2	*Diadema setosum*	7	35	3	HR
Mu2	*Diadema savignyi*	7	35	1	-
Mu2	*Diadema savignyi*	5	22	-	-
Mu2	*Diadema savignyi*	5	22	-	C
Mu2	*Tripneustes gratilla*	4	18	8,5	CR
Mu2	*Acanthaster planci*	4	19	10	C
Mu2	*Toxopneustes pileolus*	8	40	9	S
Mu2	*Toxopneustes pileolus*	8	40	8,5	CR
Mu2	*Toxopneustes pileolus*	8	38	8,5	S
Mu2	*Toxopneustes pileolus*	8	37	8	S
Mu2	*Toxopneustes pileolus*	8	37	9,5	S
Mu2	*Toxopneustes pileolus*	8	37	7	S
Mu2	*Toxopneustes pileolus*	7	35	8,5	CR
Mu2	*Toxopneustes pileolus*	7	35	7	S
Mu2	*Toxopneustes pileolus*	6	33	8,5	S
Mu2	*Toxopneustes pileolus*	6	32	8,5	S
Mu2	*Toxopneustes pileolus*	6	31	8	DC
Mu2	*Toxopneustes pileolus*	5	22	9	CR
Mu2	*Toxopneustes pileolus*	5	21	8,5	CR
Mu2	*Toxopneustes pileolus*	5	21	9	S
Mu2	*Toxopneustes pileolus*	4	19	9,5	R
Mu2	*Toxopneustes pileolus*	4	18	8	S
Mu2	*Toxopneustes pileolus*	4	18	8,5	R
Mu2	Crinoidea indet.	7	36	-	-
Mu2	Crinoidea indet.	4	20	-	-
Mu3	*Diadema setosum*	13	54	6,5	R
Mu3	*Diadema setosum*	13	54	6,5	R
Mu3	*Diadema setosum*	13	54	7	S
Mu3	*Diadema setosum*	13	54	5,5	S
Mu3	*Diadema setosum*	13	52	3	HR
Mu3	*Diadema setosum*	13	52	3,5	R
Mu3	*Diadema setosum*	13	52	4	R
Mu3	*Diadema setosum*	13	52	4	R
Mu3	*Diadema setosum*	13	52	5	R
Mu3	*Diadema setosum*	13	52	5	R
Mu3	*Diadema setosum*	13	52	7	R
Mu3	*Diadema setosum*	13	52	4	S
Mu3	*Diadema setosum*	13	52	6	S
Mu3	*Diadema setosum*	13	52	6	S
Mu3	*Diadema setosum*	13	52	8	S
Mu3	*Diadema setosum*	13	52	4	S
Mu3	*Diadema setosum*	13	50	4,5	R
Mu3	*Diadema setosum*	13	50	5	R
Mu3	*Diadema setosum*	13	50	6	HR
Mu3	*Diadema setosum*	12	47	5	R
Mu3	*Diadema setosum*	12	47	5	R
Mu3	*Diadema setosum*	12	47	6,5	C
Mu3	*Diadema setosum*	12	46	5	HC
Mu3	*Diadema setosum*	12	46	6,5	R
Mu3	*Diadema setosum*	12	46	6,5	HC
Mu3	*Diadema setosum*	12	46	5,5	R
Mu3	*Diadema setosum*	12	46	6,5	R
Mu3	*Diadema setosum*	12	46	6,5	HC
Mu3	*Diadema setosum*	12	46	6,5	R
Mu3	*Diadema setosum*	12	46	8	C
Mu3	*Diadema setosum*	12	46	3,5	R
Mu3	*Diadema setosum*	12	46	5,5	R
Mu3	*Diadema setosum*	12	46	5,5	R
Mu3	*Diadema setosum*	12	46	7,5	R
Mu3	*Diadema setosum*	11	44	4	HR
Mu3	*Diadema setosum*	11	44	4	R
Mu3	*Diadema setosum*	11	44	4	R
Mu3	*Diadema setosum*	11	44	4	R
Mu3	*Diadema setosum*	11	44	4	R
Mu3	*Diadema setosum*	11	44	5	HR
Mu3	*Diadema setosum*	11	44	5	HR
Mu3	*Diadema setosum*	11	44	5	HR
Mu3	*Diadema setosum*	9	33	6,5	C
Mu3	*Diadema savignyi*	11	44	8	HC
Mu3	*Diadema savignyi*	9	37	8,5	HC
Mu3	*Echinothrix calamaris*	7	27	-	HC
Mu3	*Acanthaster planci*	5	18	18	HR
Mu3	*Himerometra robustipinna*	7	28	-	C
Mu3	*Himerometra robustipinna*	7	28	-	C
Mu3	*Himerometra robustipinna*	5	18	-	C
Mu3	*Himerometra robustipinna*	5	18	-	C
Mu3	*Oxycomanthus bennetti*	13	50	-	C
Mu3	*Oxycomanthus bennetti*	11	45	-	C
Mu3	*Oxycomanthus bennetti*	11	42	-	C
Mu3	*Oxycomanthus bennetti*	11	40	-	C
Mu3	*Oxycomanthus bennetti*	10	32	-	C
Mu3	*Oxycomanthus bennetti*	9	28	-	C
Mu4	*Diadema setosum*	15	54	3	HR
Mu4	*Diadema setosum*	15	54	6	R
Mu4	*Diadema setosum*	14	44	4	HR
Mu4	*Diadema setosum*	14	36	4,5	R
Mu4	*Diadema setosum*	14	36	3,5	HR
Mu4	*Diadema setosum*	12	33	5	R
Mu4	*Diadema setosum*	12	33	5	R
Mu4	*Diadema setosum*	12	33	3	R
Mu4	*Diadema setosum*	12	33	4	R
Mu4	*Diadema setosum*	12	33	5	R
Mu4	*Diadema setosum*	12	33	5	R
Mu4	*Diadema setosum*	12	33	7	R
Mu4	*Diadema setosum*	12	33	4	R
Mu4	*Diadema setosum*	12	32	3	R
Mu4	*Diadema setosum*	12	32	3,5	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	4,5	R
Mu4	*Diadema setosum*	12	32	4,5	R
Mu4	*Diadema setosum*	12	32	5	R
Mu4	*Diadema setosum*	12	32	3	R
Mu4	*Diadema setosum*	12	32	3,5	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	4	R

Mu4	*Diadema setosum*	12	32	4,5	R
Mu4	*Diadema setosum*	12	32	4,5	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	5	R
Mu4	*Diadema setosum*	12	32	5	R
Mu4	*Diadema setosum*	12	32	5	R
Mu4	*Diadema setosum*	12	32	5,5	R
Mu4	*Diadema setosum*	12	32	6	R
Mu4	*Diadema setosum*	12	32	5	R
Mu4	*Diadema setosum*	12	32	4	R
Mu4	*Diadema setosum*	12	32	8	R
Mu4	*Diadema setosum*	10	29	4	R
Mu4	*Diadema setosum*	10	29	4	R
Mu4	*Diadema setosum*	10	29	7	R
Mu4	*Diadema setosum*	10	29	4	R
Mu4	*Diadema setosum*	10	29	4	R
Mu4	*Diadema setosum*	10	29	5	R
Mu4	*Diadema setosum*	10	29	5	R
Mu4	*Diadema setosum*	10	29	5	R
Mu4	*Diadema setosum*	10	29	4,5	R
Mu4	*Diadema setosum*	10	29	4,5	R
Mu4	*Diadema setosum*	10	29	6	R
Mu4	*Diadema setosum*	10	29	8,5	R
Mu4	*Diadema setosum*	9	28	4,5	R
Mu4	*Diadema setosum*	9	28	5	R
Mu4	*Diadema setosum*	9	28	5	R
Mu4	*Diadema setosum*	9	28	5	R
Mu4	*Diadema setosum*	9	27	3,5	R
Mu4	*Diadema setosum*	9	27	4,5	R
Mu4	*Diadema setosum*	9	27	4	R
Mu4	*Diadema setosum*	9	27	5	R
Mu4	*Diadema setosum*	9	27	7	R
Mu4	*Diadema setosum*	9	27	8	R
Mu4	*Diadema setosum*	9	25	4	R
Mu4	*Diadema setosum*	9	25	4	R
Mu4	*Diadema setosum*	9	25	4	R
Mu4	*Diadema setosum*	9	25	4	R
Mu4	*Diadema setosum*	9	25	4	R
Mu4	*Diadema setosum*	9	24	6	CR
Mu4	*Diadema setosum*	9	24	4	HR
Mu4	*Diadema setosum*	9	24	5	HR
Mu4	*Diadema setosum*	9	21	4	DC
Mu4	*Diadema setosum*	9	21	4	DC
Mu4	*Diadema setosum*	9	21	5	DC
Mu4	*Diadema setosum*	9	21	5	DC
Mu4	*Diadema setosum*	9	19	5	R
Mu4	*Diadema savignyi*	12	32	6	R
Mu4	*Diadema savignyi*	9	27	5	R
Mu4	*Diadema savignyi*	9	25	7,5	R
Mu4	*Diadema savignyi*	9	21	6,5	HC
Mu4	*Diadema savignyi*	7	8	9	HR
Mu4	*Toxopneustes pileolus*	15	46	10	S
Mu4	*Toxopneustes pileolus*	14	39	7	S
Mu4	*Toxopneustes pileolus*	14	36	7,5	S
Mu4	*Linckia laevigata*	9	20	23	R
Mu4	*Himerometra robustipinna*	9	25	-	C
Mu4	*Himerometra robustipinna*	9	20	-	C
Mu4	*Himerometra robustipinna*	9	20	-	C
Mu4	*Himerometra robustipinna*	9	20	-	C
Mu4	*Himerometra robustipinna*	9	19	-	C
Mu4	*Himerometra robustipinna*	9	19	-	C
Mu4	*Himerometra robustipinna*	6	8	-	C
Mu4	*Himerometra robustipinna*	6	8	-	C
Mu4	*Himerometra robustipinna*	6	7	-	C
Mu4	*Himerometra robustipinna*	6	7	-	C
Mu4	*Himerometra robustipinna*	6	7	-	C
Mu4	*Himerometra robustipinna*	6	7	-	C
Mu4	*Himerometra robustipinna*	6	7	-	C
Mu4	*Oxycomanthus bennetti*	9	25	-	C
Mu4	*Oxycomanthus bennetti*	9	20	-	C
Mu4	*Oxycomanthus bennetti*	8	15	-	C
Mu4	*Oxycomanthus bennetti*	6	7	-	C
Mu4	*Oxycomanthus bennetti*	6	7	-	C
Mu4	*Oxycomanthus bennetti*	6	7	-	C
Mu4	*Oxycomanthus bennetti*	6	7	-	C
Mu4	Crinoidea indet.	5	7	-	R
Mu4	Crinoidea indet.	5	8	-	-
Mu4	Crinoidea indet.	5	8	-	-
Mu4	Crinoidea indet.	4	7	-	-
Mu4	Crinoidea indet.	4	7	-	HR
Mu4	Crinoidea indet.	4	7	-	-
Mu5	*Diadema setosum*	15	57	4,5	R
Mu5	*Diadema setosum*	14	53	5	R
Mu5	*Diadema setosum*	14	53	6	R
Mu5	*Diadema setosum*	13	49	4,5	R
Mu5	*Diadema setosum*	13	48	1	HR
Mu5	*Diadema setosum*	12	47	5,5	R
Mu5	*Diadema setosum*	12	47	6	R
Mu5	*Diadema setosum*	12	45	3,5	HR
Mu5	*Diadema setosum*	12	45	3,5	HR
Mu5	*Diadema setosum*	12	45	3,5	HR
Mu5	*Diadema setosum*	12	45	3,5	HR
Mu5	*Diadema setosum*	12	45	6	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	12	42	5,5	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	12	42	5	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	12	42	5,5	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	12	42	4,0	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	12	42	3,5	R
Mu5	*Diadema setosum*	11	40	5	R
Mu5	*Diadema setosum*	11	40	5	R
Mu5	*Diadema setosum*	11	40	5.5	R
Mu5	*Diadema setosum*	11	40	6	R
Mu5	*Diadema setosum*	11	40	3,5	HR
Mu5	*Diadema setosum*	11	40	3,5	HR
Mu5	*Diadema setosum*	11	40	3,5	HR
Mu5	*Diadema setosum*	11	39	-	S
Mu5	*Diadema setosum*	11	39	-	S
Mu5	*Diadema setosum*	11	39	-	S
Mu5	*Diadema setosum*	11	39	-	S
Mu5	*Diadema setosum*	11	38	-	S
Mu5	*Diadema setosum*	11	38	-	R
Mu5	*Diadema setosum*	11	38	-	R
Mu5	*Diadema setosum*	11	38	-	R
Mu5	*Diadema setosum*	11	38	-	R
Mu5	*Diadema setosum*	11	37	-	R
Mu5	*Diadema setosum*	11	37	-	R
Mu5	*Diadema setosum*	11	37	-	R
Mu5	*Diadema setosum*	11	37	-	R
Mu5	*Diadema setosum*	9	35	-	S
Mu5	*Diadema setosum*	9	35	-	S
Mu5	*Diadema setosum*	9	35	-	S
Mu5	*Diadema setosum*	9	35	-	S
Mu5	*Diadema setosum*	9	35	-	S
Mu5	*Diadema setosum*	9	35	-	C
Mu5	*Diadema setosum*	9	35	-	C
Mu5	*Diadema setosum*	9	33	6,5	R
Mu5	*Diadema setosum*	8	29	-	R
Mu5	*Diadema setosum*	8	29	-	R
Mu5	*Diadema setosum*	8	27	-	R
Mu5	*Diadema setosum*	8	27	-	R
Mu5	*Diadema setosum*	8	27	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	8	25	-	R
Mu5	*Diadema setosum*	7	24	-	R
Mu5	*Diadema setosum*	7	24	-	R
Mu5	*Diadema setosum*	7	24	-	R
Mu5	*Diadema setosum*	7	24	-	R
Mu5	*Linckia laevigata*	13	48	4	-
Mu5	*Culcita novaeguineae*	8	32	10	C
Mu5	*Culcita novaeguineae*	5	19	9	R
Mu5	*Himerometra robustipinna*	5	20	-	C
Mu5	*Himerometra robustipinna*	5	16	-	C
Mu5	*Toxopneustes pileolus*	12	45	10	S
Mu5	*Toxopneustes pileolus*	8	32	9,5	S
Mu5	*Toxopneustes pileolus*	8	32	8	CR
Mu5	Crinoidea indet.	11	37	-	R
Mu5	Crinoidea indet.	11	37	-	R
Mu5	Crinoidea indet.	9	33	-	R
Mu5	Crinoidea indet.	8	27	-	R
Mu6	*Diadema setosum*	9	35	-	C
Mu6	*Comanthus parvicirrus*	11	43	-	-
Mu6	*Himerometra robustipinna*	6	25	-	C
Mu6	*Linckia laevigata*	10	40	-	-
Mu7	*Diadema setosum*	18	55	7	R

Mu7	*Diadema setosum*	18	55	5,5	R
Mu7	*Diadema setosum*	18	55	3	R
Mu7	*Diadema setosum*	18	55	3	R
Mu7	*Diadema setosum*	18	52	5	R
Mu7	*Diadema setosum*	18	52	6	R
Mu7	*Diadema setosum*	18	52	3	R
Mu7	*Diadema setosum*	18	52	3	R
Mu7	*Diadema setosum*	18	52	3,5	R
Mu7	*Diadema setosum*	18	52	3,5	R
Mu7	*Diadema setosum*	18	52	6	R
Mu7	*Diadema setosum*	17	50	5	R
Mu7	*Diadema setosum*	17	49	4,5	R
Mu7	*Diadema setosum*	17	49	4	HC
Mu7	*Diadema setosum*	17	49	5	HC
Mu7	*Diadema setosum*	17	48	3,5	R
Mu7	*Diadema setosum*	17	48	7	R
Mu7	*Diadema setosum*	17	48	5	R
Mu7	*Diadema setosum*	15	46	7,5	R
Mu7	*Diadema setosum*	15	46	4	R
Mu7	*Diadema setosum*	15	46	7,5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	4	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	4,5	R
Mu7	*Diadema setosum*	15	46	4,5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	6	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	46	5	R
Mu7	*Diadema setosum*	15	41	7,5	CR
Mu7	*Diadema setosum*	14	40	4,5	R
Mu7	*Diadema setosum*	14	40	4,5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	4,5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	4,5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	4	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5,5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	5	R
Mu7	*Diadema setosum*	14	40	6	R
Mu7	*Diadema setosum*	14	40	6	R
Mu7	*Diadema setosum*	14	40	6	R
Mu7	*Diadema setosum*	14	40	6	R
Mu7	*Diadema setosum*	14	40	7	R
Mu7	*Diadema setosum*	13	37	5	R
Mu7	*Diadema setosum*	12	33	7	R
Mu7	*Diadema setosum*	12	33	5	R
Mu7	*Diadema setosum*	12	33	4	R
Mu7	*Diadema setosum*	14	32	5	R
Mu7	*Diadema setosum*	12	32	4,5	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	12	32	7	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	12	32	5	R
Mu7	*Diadema setosum*	10	28	6,5	CR
Mu7	*Diadema setosum*	10	28	4	R
Mu7	*Diadema setosum*	10	28	5	R
Mu7	*Diadema setosum*	10	28	4	R
Mu7	*Diadema setosum*	10	28	5,5	R
Mu7	*Diadema setosum*	10	28	6	R
Mu7	*Diadema setosum*	10	28	6,5	R

Mu7	*Diadema setosum*	9	25	4,5	R
Mu7	*Diadema setosum*	9	25	5,5	R
Mu7	*Diadema setosum*	10	23	6	R
Mu7	*Diadema setosum*	10	23	5	R
Mu7	*Diadema setosum*	7	22	5,5	R
Mu7	*Diadema savignyi*	9	27	7	R
Mu7	*Linckia laevigata*	12	35	12	R
Mu7	*Linckia laevigata*	12	35	11	R
Mu7	*Linckia laevigata*	9	25	13,5	R
Mu7	*Culcita novaeguineae*	17	48	8,5	R
Mu7	*Himerometra robustipinna*	7	20	-	C
Mu7	*Himerometra robustipinna*	7	20	-	C
Mu7	*Himerometra robustipinna*	7	19	-	C
Mu7	*Himerometra robustipinna*	6	5	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	8	24	-	C
Mu7	*Oxycomanthus bennetti*	7	17	-	C
Mu7	*Toxopneustes pileolus*	16	43	10,5	CR
Mu7	*Toxopneustes pileolus*	16	43	8,5	CR
Mu7	*Toxopneustes pileolus*	15	41	8	CR
Mu7	*Toxopneustes pileolus*	15	41	9	R
Mu7	*Comanthus parvicirrus*	13	37	-	C
Mu7	*Phanogenia sp.*	13	37	-	HR
Mu7	Crinoidea indet.	-	55	-	HR
Mu8	*Diadema setosum*	17	58	3,5	HR
Mu8	*Diadema setosum*	17	58	3,5	R
Mu8	*Diadema setosum*	17	58	6	R
Mu8	*Diadema setosum*	17	58	5	R
Mu8	*Diadema setosum*	17	58	6	R
Mu8	*Diadema setosum*	17	58	6	R
Mu8	*Diadema setosum*	17	58	7	R
Mu8	*Diadema setosum*	17	58	5	R
Mu8	*Diadema setosum*	17	58	4.5	R
Mu8	*Diadema setosum*	17	58	8	R
Mu8	*Diadema setosum*	17	58	2,5	R
Mu8	*Diadema setosum*	17	58	2,5	R
Mu8	*Diadema setosum*	17	58	4	R
Mu8	*Diadema setosum*	16	54	5	R
Mu8	*Diadema setosum*	16	54	6	R
Mu8	*Diadema setosum*	16	54	7	R
Mu8	*Diadema setosum*	16	54	8	R
Mu8	*Diadema setosum*	16	54	5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	6	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	51	5,5	R
Mu8	*Diadema setosum*	13	50	6	CR
Mu8	*Diadema setosum*	13	49	4,5	R
Mu8	*Diadema setosum*	12	47	5	R
Mu8	*Diadema setosum*	12	47	4	HC
Mu8	*Diadema setosum*	12	47	3,5	R
Mu8	*Diadema setosum*	13	46	5	R
Mu8	*Diadema setosum*	13	46	5	R
Mu8	*Diadema setosum*	13	46	5	CR
Mu8	*Diadema setosum*	13	46	4	CR
Mu8	*Diadema setosum*	13	46	5	R
Mu8	*Diadema setosum*	13	46	7	R
Mu8	*Diadema setosum*	13	46	7,5	R
Mu8	*Diadema setosum*	13	46	7,5	R
Mu8	*Diadema setosum*	13	46	7,5	R
Mu8	*Diadema setosum*	13	46	7,5	R
Mu8	*Diadema setosum*	13	45	2,5	HR
Mu8	*Diadema setosum*	12	42	5	R
Mu8	*Diadema setosum*	12	42	6,5	R
Mu8	*Diadema setosum*	12	42	6,5	R
Mu8	*Diadema setosum*	12	42	5	R
Mu8	*Diadema setosum*	12	42	8	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R

Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	12	40	-	R
Mu8	*Diadema setosum*	11	35	7,5	R
Mu8	*Diadema setosum*	11	35	6,5	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	11	35	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	10	30	-	R
Mu8	*Diadema setosum*	9	28	-	R
Mu8	*Diadema setosum*	9	28	-	R
Mu8	*Diadema setosum*	9	28	-	R
Mu8	*Diadema savignyi*	15	54	7	HR
Mu8	*Diadema savignyi*	9	28	7,5	R
Mu8	*Diadema savignyi*	7	30	8	HR
Mu8	*Echinothrix calamaris*	12	49	-	HC
Mu8	*Echinothrix calamaris*	10	32	8	HR
Mu8	*Echinothrix calamaris*	7	26	-	HC
Mu8	*Echinothrix calamaris*	7	26	-	HC
Mu8	*Echinothrix calamaris*	7	26	-	HC
Mu8	*Echinothrix calamaris*	7	26	-	HC
Mu8	*Echinothrix calamaris*	7	25	-	HC
Mu8	*Echinothrix calamaris*	7	25	-	HC
Mu8	*Echinothrix calamaris*	7	25	-	HC
Mu8	*Echinothrix diadema*	7	20	7	HC
Mu8	*Linckia laevigata*	17	55	12	R
Mu8	*Linckia laevigata*	15	53	14,5	R
Mu8	*Himerometra robustipinna*	12	45	-	C
Mu8	*Himerometra robustipinna*	7	27	-	C
Mu8	*Himerometra robustipinna*	5	16	-	C
Mu8	*Oxycomanthus bennetti*	13	45	-	C
Mu8	*Oxycomanthus bennetti*	11	40	-	C
Mu8	*Oxycomanthus bennetti*	9	30	-	C
Mu8	*Phanogenia sp.*	16	54	-	HR
Mu8	*Phanogenia sp.*	12	41	-	-
Mu8	*Toxopneustes pileolus*	12	47	8,5	CR
Mu8	*Toxopneustes pileolus*	12	46	7,5	CR
Vu1	*Diadema setosum*	9	32	8	R
Vu1	*Diadema setosum*	9	32	5,5	R
Vu1	*Diadema setosum*	9	32	7	R
Vu1	*Diadema setosum*	9	32	8	R
Vu1	*Diadema setosum*	9	32	8	R
Vu1	*Diadema setosum*	9	33	9	R
Vu1	*Diadema setosum*	9	33	5	R
Vu1	*Diadema setosum*	9	33	7	R
Vu1	*Diadema setosum*	9	33	7	R
Vu1	*Diadema setosum*	9	33	7	R
Vu1	*Diadema setosum*	9	33	7	R
Vu1	*Diadema setosum*	9	33	7	R
Vu1	*Diadema setosum*	9	33	6	R
Vu1	*Diadema setosum*	9	33	6	R
Vu1	*Diadema setosum*	9	33	6	R
Vu1	*Diadema setosum*	9	33	6	R
Vu1	*Diadema setosum*	8	28	6	S
Vu1	*Diadema setosum*	8	25	8	R
Vu1	*Diadema setosum*	8	25	7	R
Vu1	*Diadema setosum*	8	25	6	R
Vu1	*Diadema setosum*	8	25	5	R
Vu1	*Diadema setosum*	8	25	7	CR
Vu1	*Diadema setosum*	6	23	6	S
Vu1	*Diadema setosum*	6	23	6	S
Vu1	*Diadema setosum*	6	23	6	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	-	S
Vu1	*Diadema setosum*	6	23	3,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	7,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,0	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	5,5	R
Vu1	*Diadema setosum*	6	23	8	R
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	23	-	S
Vu1	*Diadema setosum*	5	20	9	S
Vu1	*Diadema setosum*	5	20	8	S
Vu1	*Diadema setosum*	3	20	3,5	S
Vu1	*Diadema setosum*	4	14	3,5	R
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema setosum*	4	12	-	-
Vu1	*Diadema savignyi*	4	14	9	HR
Vu1	*Echinothrix calamaris*	9	31	8	HR
Vu1	*Echinothrix diadema*	6	25	10	HR
Vu1	*Linckia laevigata*	4	10	16	R
Vu1	*Culcita novaeguineae*	9	36	12	R
Vu1	*Culcita novaeguineae*	6	23	9,5	R
Vu1	*Culcita novaeguineae*	5	23	11	R
Vu1	*Himerometra robustipinna*	8	26	-	DC
Vu1	*Himerometra robustipinna*	8	26	-	DC
Vu1	*Oxycomanthus bennetti*	11	52	-	DC
Vu1	*Oxycomanthus bennetti*	5	20	-	R
Vu1	*Oxycomanthus bennetti*	4	12	-	C
Vu1	*Thelenota ananas*	10	41	19	R
Vu1	*Toxopneustes pileolus*	9	35	10,5	S
Vu1	*Holothuria leucospilota*	9	25	-	S

*Sizes are given as: test diameter for echinoids, major radius (from centre of disc to tip of arms) for asteroids and body lenght for holothuroians.

†Habitat: Rock (R), Coral (C), Dead coral (DC), Sand (S), Coral Rubble (CR), Rubble (RB), Hidden under rock (HR), Hidden in coral (HC).

APPENDIX 2 - Continued

Table A2.2: Summary of species observations in transects, and the horizontal visual survey on Hon Mun South.

Species	Transects											Horizontal visual survey	
	Mo1	Tr1	Mu1	Mu2	Mu3	Mu4	Mu5	Mu6	Mu7	Mu8	Vu1	Deep (45 minutes)	Shallow (30 minutes)
Crinoidea													
Comanthus parvicirrus		2						1	1			4	2
Crinoidea indet.	1	1		2		6	4		1			11	1
Himerometra robustipinna	5				4	13	2	1	4	3	2		4
Oxycomanthus bennetti	1				6	7			7	3	3		2
Phanogenia sp.	1								1	2			
Asteroidea													
Acanthaster planci	4			1	1								
Choriaster granulatus		2											
Culcita novaguineae	1						2		1		3	1	2
Linckia laevigata		5				1	1	1	3	2	1		1
Echinoidea													
Diadema savignyi	8	2		3	2	5			1	3	2	7	5
Diadema setosum	135	13	1	1	43	72	66	1	88	84	76	317	39
Echinothrix calamaris		3	1		1					9	1		
Echinothrix diadema		1								1	1		
Lovenia elongata			1										
Toxopneustes pileolus		8		17		3	3		4	2	1	27	17
Tripneustes gratilla				1									
Holothuroidea													
Holothuria leucospilota											1		
Pearsonothuria graeffei	2												1
Synapta maculata	3												
Thelenota ananas											1		

Table A2.3: Densities calculated from transect data (ind. 400 m^{-2}).

Species	Mo1	Tr1	Mu1	Mu2	Mu3	Mu4	Mu5	Mu6	Mu7	Mu8	Vu1	Mean	SD	Coeff. of var. (%)
Crinoidea														
Comanthus parvicirrus		4						2	2			0.73	1.35	185.40
Crinoidea indet.	1,6	2		4		12	8		2			2.69	3.94	146.26
Himerometra robustipinna	8				8	26	4	2	8	6	4	6.00	7.38	122.93
Oxycomanthus bennetti	1,6				12	14			14	6	6	4.87	5.91	121.30
Phanogenia sp.	1,6								2	4		0.69	1.32	190.42
Asteroidea														
Acanthaster planci	6,4			2	2							0.95	1.98	209.22
Choriaster granulatus		4										0.36	1.21	331.66
Culcita novaguineae	1,6						4		2		6	1.24	2.04	165.26
Linckia laevigata		10				2	2	2	6	4	2	2.55	3.11	122.18
Echinoidea														
Diadema savignyi	12.8	4		6	4	10			2	6	4	4.44	4.14	93.31
Diadema setosum	216	26	2	2	86	144	132	2	176	168	152	100.55	80.00	79.57
Echinothrix calamaris		6	2		2					18	2	2.73	5.39	197.52
Echinothrix diadema		2								2	2	0.55	0.93	171.27
Lovenia elongata			2									0.18	0.60	331.66
Toxopneustes pileolus		16		34		6	6		8	4	2	6.91	10.21	147.81
Tripneustes gratilla				2								0.18	0.60	331.66
Holothuroidea														
Holothuria leucospilota											2	0.18	0.60	331.66
Pearsonothuria graeffei	3.2											0.29	0.96	331.66
Synapta maculata	4.8											0.44	1.45	331.66
Thelenota ananas											2	0.18	0.60	331.66

APPENDIX 3 - Stratification of transects into shallower and deeper segments.

Table A3.1: Species list for shallower (S) and deeper (D) segments of transects*

Species	Mo1S†	Tr1S	Mu2S	Mu3S	Mu4S	Mu5S	Mu7S	Mu8S	Vu1S	Mo1D†	Tr1D	Mu2D	Mu3D	Mu4D	Mu5D	Mu7D	Mu8D	Vu1D
Acanthaster planci	2.4		1	1						0.8								
Choriaster granulatus		1									1							
Comanthus parvicirrus		1														1		
Crinoidea indet.	1.6	1	1	4	6	1				0.8		1			3	1		
Culcita novaeguineae	0.8					1			2							1		1
Diadema savignyi	1.6		2		4		1	2	1	4.8	2	1	2				1	
Diadema setosum	39.2	4		1	35	16	12	9	77	68	9	1	42	13	50	76	75	
Echinothrix calamaris		1		1				8	1		2						1	
Echinothrix diadema		1						1	1									
Himerometra robustipinna	4				13	2	4	2	2								1	
Holothuria leucospilota									1									
Linckia laevigata		4			1		1		1		1				1	2	2	
Lovenia elongata																		
Oxycomanthus bennetti	2.4			2	7		7	1	2				4				2	1
Pearsonothuria graeffei	0.8									0.8								
Phanogenia sp.	0.8															1	2	
Synapta maculata																		
Thelenota ananas																		1
Toxopneustes pileolus		4	8								3	9		3	1	4	2	1
Tripneustes gratilla			1															
Total number of taxa	9	8	5	5	6	4	5	6	9	5	6	4	3	2	4	7	8	4
Total number of specimens	53.6	17	13	9	66	20	25	24	88	75.2	18	12	48	16	55	86	86	4

*S: Area along 24 m. of transect line lying closest to the shore; D: Area along 24 m. of transect line lying at the deep end of transect.
†: Abundances are adjusted due to larger area covered in this transect (abundances from 120 m^2 adjusted to abundances in 96 m^2).

APPENDIX 3 – Continued

Table A3.2: Results from SIMPER analysis of Bray-Curtis similarities calculated on untransformed and √√-transformed abundance data in shallower and deeper transect segments. Cut off level for low contributions: 90%.

Untransformed data						
Group S. Average similarity: 29.40						
Species	Av.Abund	Av.Sim	Sim/St. Dev.	Contrib%	Cum.%	
Diadema setosum	21.47	18.40	1.02	62.58	62.58	
Himerometra robustipinna	3.00	2.44	0.73	8.31	70.90	
Crinoidea indet.	1.71	2.22	0.70	7.54	78.43	
Oxycomanthus bennetti	2.38	2.19	0.62	7.46	85.89	
Diadema savignyi	1.29	1.52	0.63	5.16	91.05	
Group D. Average similarity: 36.24						
Species	Av.Abund	Av.Sim	Sim/St. Dev	Contrib%	Cum.%	
Diadema setosum	37.11	30.33	0.97	83.67	83.67	
Toxopneustes pileolus	2.56	4.00	0.69	11.03	94.70	
Groups S & D. Average dissimilarity = 67.42						
	Group S	Group D				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/St. Dev.	Contrib%	Cum.%
Diadema setosum	21.47	37.11	40.41	1.60	59.94	59.94
Toxopneustes pileolus	1.33	2.56	6.00	0.72	8.90	68.84
Himerometra robustipinna	3.00	0.11	3.76	0.84	5.58	74.42
Oxycomanthus bennetti	2.38	0.64	2.88	0.64	4.28	84.02
Echinothrix calamaris	1.22	0.33	2.57	0.49	3.81	87.84
Diadema savignyi	1.29	1.20	2.17	0.96	3.22	91.06
√√-transformed data						
Group S. Average similarity: 44.48						
Species	Av.Abund	Av.Sim	Sim/St. Dev.	Contrib %	Cum.%	
Diadema setosum	21.47	14.85	1.62	33.38	33.38	
Himerometra robustipinna	3	5.99	0.81	13.47	46.85	
Crinoidea indet.	1.71	5.78	0.81	12.99	59.84	
Oxycomanthus bennetti	2.38	5.59	0.8	12.56	72.4	
Diadema savignyi	1.29	5.09	0.81	11.45	83.85	
Echinothrix calamaris	1.22	1.99	0.44	4.48	88.33	
Linckia laevigata	0.78	1.79	0.44	4.03	92.36	
Group D. Average similarity: 44.51						
Species	Av.Abund	Av.Sim	Sim/St. Dev	Contrib%	Cum.%	
Diadema setosum	37.11	22.49	1.53	50.52	50.52	
Toxopneustes pileolus	2.56	10.82	1.06	24.31	74.83	
Diadema savignyi	1.2	4.33	0.59	9.72	84.55	
Crinoidea indet.	0.64	2.42	0.43	5.43	89.98	
Linckia laevigata	0.67	2.07	0.44	4.64	94.62	
Groups S & D. Average dissimilarity = 58.89						
	Group S	Group D				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/St. Dev.	Contrib%	Cum.%
Diadema setosum	21.47	37.11	7.62	1.22	12.94	12.94
Toxopneustes pileolus	1.33	2.56	6.56	1.38	11.13	24.07
Himerometra robustipinna	3	0.11	6.13	1.26	10.4	34.47
Oxycomanthus bennetti	2.38	0.78	5.44	1.18	9.25	43.72
Crinoidea indet.	1.71	0.64	4.87	1.12	8.27	51.99
Diadema savignyi	1.29	1.2	4.51	1.07	7.66	59.65
Echinothrix calamaris	1.22	0.33	3.94	0.89	6.69	66.35
Linckia laevigata	0.78	0.67	3.9	1.02	6.61	72.96
Culcita novaeguineae	0.42	0.22	2.95	0.8	5	77.96
Acanthaster planci	0.49	0.09	2.89	0.75	4.9	82.86
Echinothrix diadema	0.33	0	2.16	0.69	3.66	86.52
Phanogenia sp.	0.09	0.33	1.72	0.63	2.93	89.45
Choriaster granulatus	0.11	0.11	1.3	0.49	2.21	91.67

APPENDIX 4 - On the species identifcations

Due to conspicuous colour patterns and morphological traits that can be lost under conservation it is often easier to identify specimens *in situ* than after they have been preserved. In this study most asteroids and echinoids were easily distinguished from each other. There is however some confusion about species identifications and distributions of the diadematid echinoids in the literature. Morphological characters used for *in situ* identifications in this survey will be described in some detail in order to clarify some newer findings. and for pointing out some colour variations not mentioned in traditional identification literature. In this study *D. setosum* was distinguished from *D. savignyi* on the basis of a dichotomy in colour patterns as used by Pearse and Arch (1969): *D. setosum* has got an orange ring around the anal cone. 5 conspicious rings around the interambulacrals above the ambitus (mid part of urchin where circumference is largest). and a pattern of iridescent blue dots around the periproct (anal opening) and down the interambulacrals; *D. savignyi* lacks the orange ring. has inconspicuous white spots during day (visible at night according to Coppard and Campbell. 2005). and a striking pattern of iridescent blue lines. Hybrids with mixtures of these traits (3 morphotypes) are known to occur. but are rare (Lessios and Pearse. 1996). If any hybrids were encountered in this study they were identified as either of the two species they resembled most. Presence of hybrids could have been investigated by examination of pedicellariae. but was not done in the scope of this study. One hybrid is known to fit the description of *D. paucispinum* A. Agassiz. 1863. In the South China Sea this species is only recorded from Malaysia and Indonesia (Lane et al.. 2000). The two species of the genus *Echinothrix* initially proved difficult to identify in the field in this study. *E. calamaris* is known to have a variety colour morphs. one white morph that is easily identified. and darker morphs that can be more difficult to distinguish from the black-spined *E. diadema* (see Clark. 1925). *E. calamaris* have horizontally verticillate interambulacral spines. naked median lines with green iridophores (cells with iridescent crystals) down the interambulacra and a swollen periproctal cone with white platelets present in the membrane; *E. diadema* have longitudinal ridges down the interambulacral spines (which flare distally). no median lines down the interambulacra and an anal cone that is only slightly swollen (as in species of *Diadema*) with no white platelets (Coppard and Campbell. 2004; S.E. Coppard personal communication). In this study most individuals were found to be *E. calamaris*. Dark red colour morphs were very similar to *E. diadema* but were differentiated from this on the basis of the swollen periproctal cone (sometimes lacking most of the white platelets normally seen) and the tapering interambulacral spines known from this colour morph. There is always a chance that hybridisation between the two species might occur. studies on Fiji however. showed that each species had very distinct breeding cycles at different phases of the moons cycle (Coppard and Campbell. 2005).

Since colour variation is common in crinoids. colour patterns are not reliable characters for species identification (Jeng. 1998). This in combination with cryptic behaviour and fragile bodies makes them difficult to identify in the field. Some of the crinoids not identified to species level in this study are thought to belong to the genus *Stephanometra*. *Comaster* and *Phanogenia*. The genus *Stephanometra* is in need of revision (C.G. Messing personal communication). and the genus *Comaster* has recently been revised (Messing. 1998). The name *Comaster bennetti* as used in recent reports from Vietnam (e.g. Dao. 2002) is according to Rowe et al. (1986) a synonym for *Oxycomanthus bennetti.* One of the species found in this study was thought to be *Comaster audax* (Rowe et. al. 1986) or *C. nobilis* (Carpenter. 1888). both used to be placed in *Comanthina*. The species considered to be *Phanogenia gracilis* in this study used to be called *Comaster gracilis* or *Comaster multifidus* (Müller. 1841). but the latter name does not apply to this species any longer (Messing. 1998). Crinoidea indet. as used in the species lists in this survey probably were constituted by *Stephanometra* sp. and *Comaster* sp.

Holothurians identified to species in this study were distinguished on basis of their characteristic colouration or other conspicuous morphological traits (*Holothuria leucospilota*. *Stichopus chloronotus*. *Thelenota ananas*. *Pearsonothuria graeffei*) and by examination of ossicles from the body wall (*Synapta maculata*). The species *P. graeffei* has been reported in recent articles from Vietnam (Dao. 2002) as *Bohadschia graeffei*. *P. graeffei* as used in this study is in accordance with Levin et al. (1984). Kerr et al. (2005) used molecular methods and found *Pearsonothuria* (consisting of only *P. graeffei*) to be a sister group of *Bohadschia*. Samyn et al. (2005) reviewed a number of morphological studies and supports this view.

PLATES

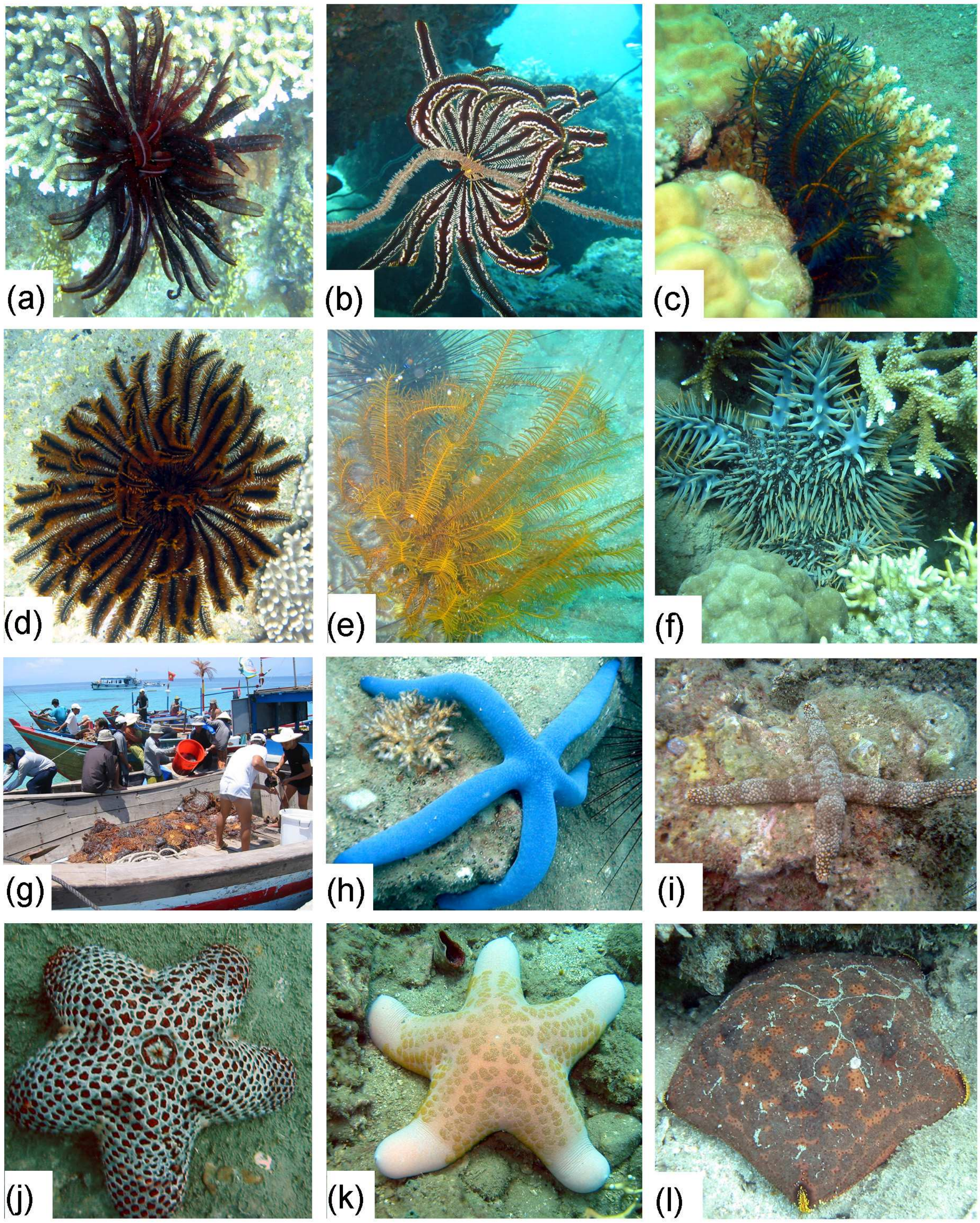

Fig P1: (a) *Himerometra robustipinna*; (b) *Cenometra bella*; (c) *Comanthus parvicirrus*; (d) *Oxycomanthus bennetti*; (e) *Phanogenia* sp.; (f) *Acanthaster planci*; (g) Collection of *A. planci* by local villagers; (h) *Linckia laevigata*; (i) *Nardoa frianti*; (j) *Euretaster insignis*; (k) *Choriaster granulatus*; (l) *Culcita novaeguineae*.

PLATES

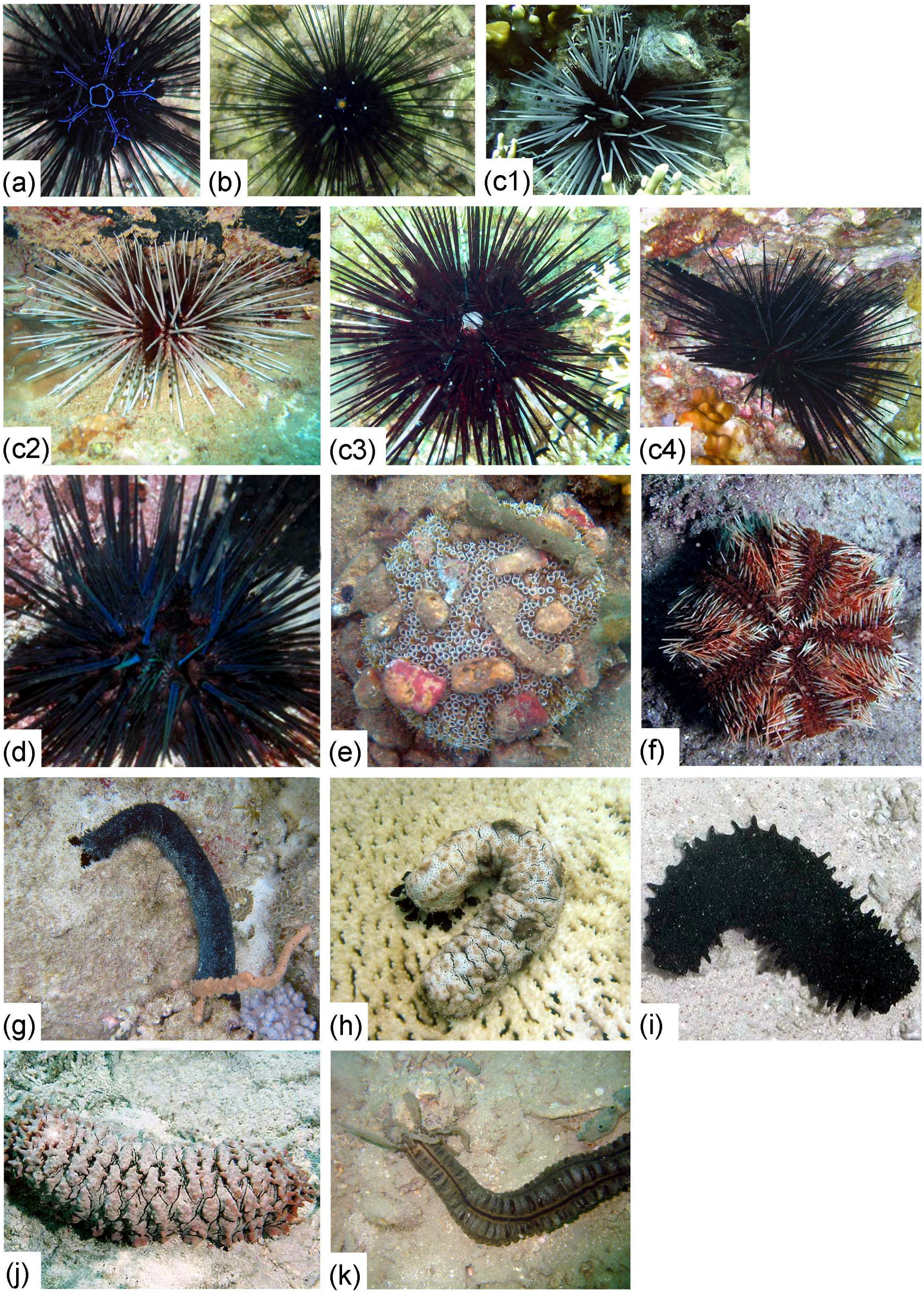

Fig. P2: (a) *Diadema savignyi*; (b) *Diadema setosum*; (c1)-(c4) *Echinothrix calamaris*; (d) *Echinothrix diadema*; (e) *Toxopneustes pileolus*; (f) *Tripneustes gratilla*¸(g) *Holothuria leucospilota*; (h) *Pearsonothuria greaeffei*; (i) *Stichopus chloronotus*; (j) *Thelenota ananas*; (k) *Synapta maculata*.