NGHIÊN CỨU THÀNH PHẦN LOÀI, CẤU TRÚC QUẦN XÃ VÀ HIỆN TRẠNG RẠN SAN HÔ NHẰM ĐỀ XUẤT GIẢI PHÁP QUẢN LÝ ĐA DẠNG SINH HỌC Ở KHU BẢO TỒN BIỂN HÒN MUN, VỊNH NHA TRANG

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TÓM TẮT *Thành phần loài, cấu trúc quần xã và hiện trạng rạn san hô ở khu bảo tồn biển Hòn Mun (HMMPA) đã được khảo sát bằng phương pháp lặn có thiết bị từ tháng 5 – 7 năm 2002 tại 26 điểm thuộc 13 vị trí. Riêng thành phần san hô còn được nghiên cứu thêm ở 10 điểm thuộc 5 vị trí. Tổng cộng đã ghi nhận 350 loài san hô tạo rạn (64 giống, 15 họ, trong đó 40 loài và 1 giống được ghi nhận lần đầu cho khu hệ san hô Việt Nam), 220 loài cá rạn san hô (102 giống, 38 họ), 106 loài thân mềm, 18 loài da gai và 62 loài rong và cỏ biển.*

San hô tạo rạn ở vùng nghiên cứu được coi là rất đa dạng và chiếm tới hơn 40% tổng số loài trên thế giới và khoảng một nửa số loài của khu hệ Ấn Độ - Tây Thái Bình Dương. Nghiên cứu còn ghi nhận những loài chỉ mới được ghi nhận ở Ấn Độ Dương (Favites spinosa) hoặc có thể coi là chưa được mô tả. Tính đa dạng khác thường này là một chức năng sinh thái quan trọng của khu bảo tồn và liên quan đến sự khác nhau về điều kiện sống (ví dụ như ánh sáng, độ đục, mức độ lắng đọng trầm tích, ảnh hưởng của sông, mức độ chịu sóng gió) và sự liên kết với các vùng rạn san hô khác ở Biển Đông. Một số nhóm cá rạn san hô cũng khá đa dạng (họ cá Bướm), trong khi đó những nhóm có giá trị nuôi cảnh (họ cá Thia) hay thực phẩm (cá Mú, cá Hồng, cá Hè) khá nghèo về thành phần loài và số lượng. Điều đó chứng tỏ có sự khai thác quá mức trong khu vực. Cấu trúc thành phần loài thân mềm có sự thay đổi so với trước đây. Sự đa dạng của nhóm da gai đang giảm và gần như vắng mặt những loài kinh tế. Khá nhiều loài phân bố hẹp (chỉ xuất hiện dưới 10% số điểm nghiên cứu), thậm chí có nhiều loài hiếm gặp. Một số có thể coi là quần thể địa phương còn sót lại và tương đối hiếm do khai thác quá mức. Nếu quản lý tốt những quần thể này có thể phục hồi nhưng cần thời gian.

Thành phần loài san hô - nhóm chính tạo nên quần xã rạn san hô có cấu trúc thuộc vào 4 kiểu quần xã khác nhau và liên quan đến xu thế thay đổi tương tác đất liền - biển và khác biệt về điều kiện môi trường. Các quần xã được đặc trưng bởi các loài chỉ thị phân bố hẹp. Ngược lại, có khá nhiều loài phân bố rộng có thể bắt gặp trong vài quần xã. Phân tích thành phần loài tất cả các nhóm lại cho phép chia ra 3 kiểu quần xã khác biệt do những yếu tố như trên qui định.

Các vị trí có tính đa dạng cao nhất thuộc vùng Đông và Đông Bắc Hòn Tre

(quần xã san hô B) chiếm tới 50% tổng số loài. Một số vị trí có tính đa dạng cao, mang tính đại diện hoặc tiềm năng phục hồi đã được bảo vệ trong vùng lõi của khu bảo tồn (như Hòn Mun, Hòn Nọc và Hòn Cau). Các quần xã có ý nghĩa bảo tồn khác (như ở Đông Nam, Đông Bắc Hòn Miếu, Đông Nam Hòn Tằm, Tây Nam Hòn Một chưa được bảo vệ nghiêm ngặt và cần được chú ý khi xây dựng lại kế hoạch phân vùng. Cũng cần các hoạt động giám sát dài hơi sự thay đổi của các quần xã hiểu biết thêm về sinh thái học và tăng cường hiệu quả quản lý.

CORAL REEFS OF THE HON MUN MARINE PROTECTED AREA, NHA TRANG BAY, VIETNAM, 2002: SPECIES COMPOSITION, COMMUNITY STRUCTURE, STATUS AND MANAGEMENT RECOMMENDATIONS

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ABSTRACT *Species composition, community structure and status of the coral reef communities of Hon Mun Marine Protected Area (MPA) were assessed in standardized SCUBA swim-searches in 26 sites at 13 locations in May - July 2002. Corals were assessed in an additional 10 sites at 5 locations, because of their high diversity in MPA waters.*

In total, some 350 species of reef-building scleractinian corals (64 genera, 15 families, including distribution range extensions for some 40 species and 1 genus into Vietnam), 220 species of demersal fishes (102 genera, 38 families), 106 species of molluscs, 18 species of echinoderms and 62 species of algae and sea-grass were recorded. Recorded reef-building corals represents more than 40 % of the global and almost half the Indo-Pacific totals. The exceptional diversity is a function of the wide range of habitats in MPA waters in relation to mainland - offshore gradients and oceanographic connectivity with other reef areas of Vietnam and the South China Sea. Some groups of recorded ornamental reef-associated fishes also showed high diversity, although other groups, notably other commercially important fishes were relatively depauperate in species composition and locally scarce in abundance. Mollusc diversity, although similar in overall richness to previous surveys, showed major shifts in composition. For echinoderms diversity was lower than previously reported, and for several edible species, their absence or extremely low abundance also reflected the intense harvesting pressure.

A large suite of species had locally restricted distributions (occurring in < 10 % of sites overall), many of which were also locally rare in their sites of occurrence. At least some of these are unlikely to form locally viable *populations at present. Of these, some are highly desired commercially, and their local rarity in MPA waters is almost certainly attributable to over-collecting. It will require some years before local populations can recover, provided effective management of the fisheries occurs.*

The coral species in the MPA form 4 major community types broadly distributed in relation to the mainland - offshore gradient and prevailing environmental conditions. The corals, fish, molluscs, echinoderms and algae (combined) form 3 broad community types, again broadly distributed in terms of the mainland - offshore gradient and oceanography.

The most diverse individual locations at E. and N.E. Hon Tre (Coral community B) supported ca. half of total diversity. Several key locations in terms of diversity, representativeness, and replenishment already receive high levels of protection within MPA Core Zones. Other communities of special conservation significance are not in MPA Core Zones. These are recommended for protection in the forthcoming revision of the zoning plan. Monitoring of the longer-term ecological trajectories of these communities should provide insights both for community ecology and management effectiveness.

I. INTRODUCTION

An understanding of the biological structure and ecological function of natural communities is essential for successful conservation management planning, both in terms of the protection of key 'representative' areas, communities and species, and of regulating patterns of human use.

In most cases, managers opt for the 'multiple use' approach, trying to balance conservation and development issues in protected areas (Kenchington 1990). This approach has been implemented in many marine protected areas (MPAs) over the past three decades, including most of the larger marine parks (e.g. Australia's Great Barrier Reef), with varying levels of success (Alder 1996). In this approach, the careful selection of different zones is of paramount importance from both biodiversity and socio-economic standpoints, and the management agency must successfully address often-complex planning issues including use conflicts, effective surveillance and enforcement.

This multiple use approach has recently been implemented in the Hon Mun MPA, Nha Trang Bay, central-south Vietnam. The MPA encompasses ca. 130 km^2 of rich coastal waters, 9 islands with 6 local villages and some 6,000 local inhabitants. The area is renowned as one of the most biodiverse locations in Vietnam, with some 200 species of reef-building corals and reef-associated fishes already recorded (ref.). However, these rich and renewable marine resources are under severe pressure from both locals and outside fishermen, particularly following the depletion of marine resources in other areas, and also from developing tourism and coastal/river impacts (Vo *et al.* 2002).

The zoning plan of Hon Mun Protected Area, gazetted in April 2002, was established as a temporary measure to mitigate the impacts already identified, and prior to detailed socio-economic or biodiversity assessment of the MPA. These assessments are presently being conducted, as documented for marine biodiversity (species composition, community structure and status) herein, and will provide the basis for recommendations re revision of the temporary zoning scheme.

II. METHODS

Rapid Ecological Assessment (REA) surveys were conducted using SCUBA at 26 sites in 13 locations around all islands in June 2002 (Fig. 1). For corals, an additional 10 sites at 5 locations were surveyed. Eighteen survey locations were chosen to provide a representative range of coral reef communities in terms of the environmental gradients, based on the results of prior habitat assessment (Vo *et al*. 2002), thus maximizing taxonomic inventories in MPA waters in the limited time available for the assessment. Survey locations were recorded with a portable GPS unit (WGS84).

At each location, two sites in different depth ranges were surveyed independently (deep slope site: ca. 20 m - 8 m below low tide level) and shallow slope site (ca. 7 m - 2m depth), because of strong depth-related gradients in species composition in some taxa. Throughout this report, the terms 'location' and 'site' are used consistently in the above manner. The survey method was a form of Rapid Ecological Assessment (R.E.A.) where the species composition and relative abundance of the various taxonomic groups were carefully assessed during ca 45 min. meandering SCUBA survey swims at each site.

Each swim covered an area of approximately 250 m^2 (5m width across the reef slope and 50 m length along slope). Although 'semi-quantitative', this method has proven far superior to more traditional quantitative methods (transects, quadrates) in terms of biodiversity assessment, allowing the specialist to actively search for new species records at each site, rather than being restricted to a defined quadrate area or transect line (DeVantier et al. 1998). For example, for corals the present method has routinely returned a two- to three-fold increase in coral species records in comparison with line transects conducted concurrently at the same sites in the Red Sea and Great Barrier Reef (DeVantier pers. comm.)

1. Taxonomic inventories

Detailed inventories of corals, fish, macro-benthos and algae were compiled during each swim. Taxa were identified *in situ* to the following levels:

- Stony (hard) corals - species wherever possible (Veron and Pichon 1976, 1980, 1982, Veron *et al.*, 1977, Veron and Wallace 1984, Veron 1986, 1990, 2000, Hoeksema 1989, Wallace and Wolstenholme 1998, Wallace 1999), otherwise genus and growth form (e.g. *Porites* sp. of massive growth-form);

- Soft corals, zoanthids, corallimorpharians, anemones and some macro-algae - to genus or higher taxonomic level (Colin and Arneson 1995, Goslinger *et al.* 1996, Fabricius and Alderslade 2000);

- Other sessile macro-benthos, such as sponges - to higher taxonomic level, usually phylum plus growth-form (Colin and Arneson 1995, Goslinger *et al.* 1996);

-Fishes - to species wherever possible, focused on reef-associated taxa in 38 families;

- Molluscs and echinoderms - to species or genus;

- Macro-algae and seagrasses - to species or genus for macro-algae. Turfing and crustose coralline forms were not recorded, as accurate field identification, even to genus level, for many groups is not possible.

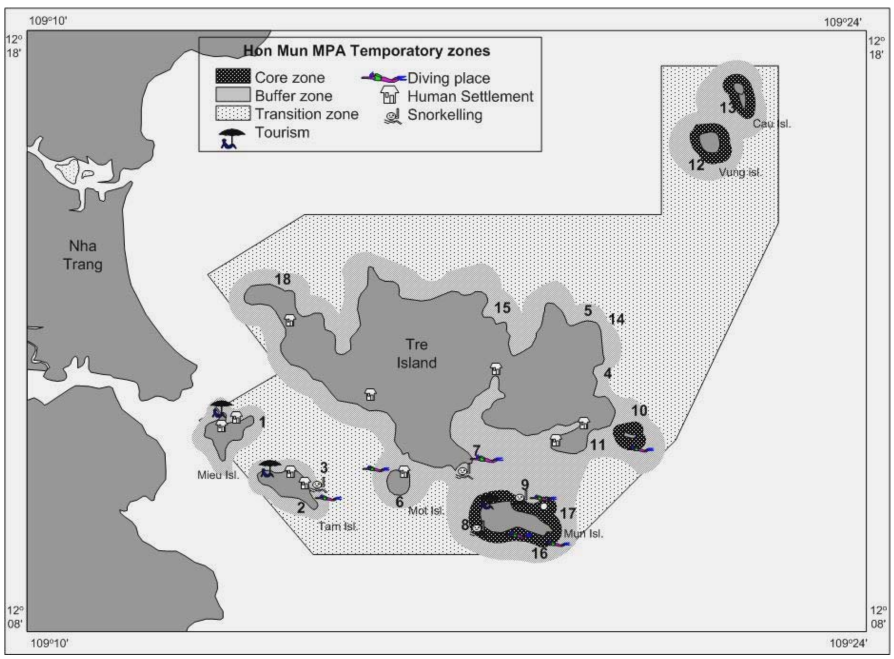

Figure 1: **Hon Mun MPA Temporary Zones and 18 survey locations, 2002**

At the end of each swim, the inventories were reviewed, and each species was ranked in terms of its relative abundance in the community (Table 1). These ordinal ranks are similar to those long employed in vegetation analysis (Barkman et al. 1964, van der Maarel 1979, Jongman *et al*. 1997). The ranks were not identical among the different taxonomic groups (Table 1) because of differences among the specialists in their standard ranking systems, in terms of maintaining comparability with other surveys.

For the corals, a visual estimate of the total amount of injury (dead surface area) present on colonies of each species at each site was made, in increments of 0.1, where 0 = no injury and 1 = all colonies dead. The approximate proportion of colonies of each taxon in each of three size classes was also estimated. The size classes were 1 - 10 cm diameter, 11 - 50 cm diameter and > 50 cm diameter.

For taxonomically difficult species of hard corals, where field verification of specific identity was not possible, photographs were taken (Olympus digital camera) and small representative specimens (approximately 100 cm^3) were sampled from the colonies. The samples were carefully taken *in situ* to minimize disturbance to the coral and the site, and for most species usually represented only a small portion (approximately 5 - 10 cm longest axis of sample) of the respective colony.

Corals for which identification remained uncertain following laboratory inspection of photographs and specimens were shipped for expert confirmation by Dr. J.E.N. Veron (Australian Institute of Marine Science) and Dr. C.C. Wallace (Museum of Tropical Queensland) under a CITES Export Permit from the Govt. of Vietnam.

Table 1: **Relative abundance categories for the taxonomic inventories, Hon Mun MPA**

Relative abundance ranks			
Corals	**Fish**	**Macro-benthos**	**Algae**
0: absent	0: absent	0: absent	0: absent
1: rare	1: rare (1-2 individuals)	1: uncommon	1: uncommon
2: uncommon	2: uncommon (3-5 individuals)		
3: common	3: common (6-20 individuals)	2: common	2: common
4: abundant	4: very common (21-50 individuals)		
5: dominant	5: abundant (51-100 individuals)	3: abundant	3: abundant
	6: very abundant (> 100 individuals)		

2. Benthic cover and reef development

Because the cover of sessile benthos form the structural basis of the reef communities, an assessment of cover of the substrate by the major sessile benthic groups (corals and algae), and amount of reef development, was made at each site (after Done 1982, Sheppard and Sheppard 1985, DeVantier *et al.* 1998). At completion of each survey swim, six ecological and six substratum attributes were assigned to 1 of 5 standard categories (Table 2), based on an assessment integrated over the length of the swim (after Done 1982, Miller & De'ath 1995, DeVantier *et al.* 1998).

Average cover of stony corals, dead corals, soft corals, turf algae, macro-algae and coralline algae overall in the sites was calculated using the mid-point % cover of the rank category of each site (e.g. rank 1: cover = 6 %, rank 2: 20 %, rank 3: 40 %, rank 4: 63 %, rank 5: 88 %).

The sites were also classified arbitrarily on the degree of reef development (DeVantier *et al.* 1998), exposure to wave energy, sedimentation (particle sizes ranging from very fine to moderately coarse), blast fishing impact, poison fishing impact, anchoring impact, bleaching impact, crown-of-thorns seastars predation, *Drupella* snails predation, coral diseases (Table 3).

Table 2: **Ranked categories of benthic attributes and % cover categories, Hon Mun MPA**

Attribute		**% cover category**	
Ecological	Physical	Rank	%
Stony coral	Hard substrate	0	not present
Dead standing coral	Continuous pavement	1	1 - 10 %
Soft coral	Large blocks (diam. > 1 m)	2	11 - 30 %
Coralline algae	Small blocks (diam. < 1 m)	3	31 - 50 %
Turf algae	Rubble	4	51 - 75 %
Macro-algae	Sand	5	76 - 100 %

Table 3: **Categories for environmental variables and ecological impacts, Hon Mun MPA**

Attribute	**Rank / category**
Reef Development (rank)	1: coral community 2: Incipient reef 3: small reef flat (< 50 m width) 4: large reef flat (> 50 m width)
Exposure (rank)	1: sheltered 2: semi-sheltered 3: semi-exposed 4: exposed
Sediments (rank)	0: no sediment; 1: minor (thin layer) sediment deposition; 2: moderate sediment deposition (thick layer), but substrate can be cleaned by fanning off the sediment; and 3: major sediment deposition (thick, deep layer), and substrate cannot be cleaned by fanning (after Fabricius 2001).

Blast fishing (rank)	0: absent; 1: minor - 1 crater 2: moderate - 2-5 craters, 3: severe - > 5 craters
Poison fishing (rank)	0: absent; 1: minor - 1 coral showing symptoms 2: moderate - 2-5 corals showing symptoms 3: severe - > 5 corals showing symptoms
Anchoring (rank)	0: absent; 1: minor - 1 damaged coral 2: moderate - 2-5 damaged corals, 3: severe - > 5 damaged corals
Crown-of-thorns seastars	Counts in each site, providing a crude estimate of population density (area of each site ~ 250 m^2)
***Drupella* snails (rank)**	0: absent; 1: minor - present on 1 coral 2: moderate - present on 2-5 corals, 3: severe - present on > 5 corals
Bleaching (rank)	0: absent; 1: minor - partial bleaching on 1 or a few corals 2: moderate - partial and/or total bleaching on < 1/2 corals present 3: severe - total bleaching on > 1/2 corals present
Coral diseases (rank)	0: absent; 1: minor - present on 1 coral 2: moderate - present on 2-5 corals, 3: severe - present on > 5 corals

The depths of the sites (maximum and minimum in m), average angle of reef slope to the horizontal (estimated visually to the nearest 10 degrees), and underwater visibility (to the nearest m) were also recorded. The presence of any unique or outstanding biological features, such as particularly large corals or unusual community compositions, bleached corals (partial or total loss of pigments on living corals), coral predators, other cause(s) of coral mortality were also recorded (Table 3). All data were input to EXCEL for storage and preliminary analyses.

3. Data Analysis

Groups of sites were defined according to their ecological and environmental characteristics and community type (species composition and relative abundance). Relationships among sites, community types and the ecological and environmental site-descriptor variables were explored using Redundancy Analysis - a type of Principal Components Analysis that correlates environmental variables with the structure in the community data (Jongman *et al.* 1995).

3.1. Ecological and environmental site variables:

The ecological variables included cover of hard coral, dead standing coral, soft coral, macro-algae, coralline algae and turf algae. The environmental variables included exposure, slope angle, degree of reef development, water clarity, temperature. Prior to analysis the data were transformed (square-root). PCA biplots were used to illustrate the relationships among sites in terms of the ecological (cover) and environmental variables.

3.2. Coral reef replenishment index (CI):

The presence of high species richness, abundance and cover of hard and soft corals may afford some sites greater importance than others in terms of their role as reproductive sources for local replenishment of populations. A local replenishment index, *CI* which rates sites based on a combination of their total coral cover and individual taxon rank abundance scores was calculated for each site:

$$CI = \sum A_i H_i / 100$$

Where A_i = abundance rank for the ith coral, fish, macro-benthos and algal taxon at a given site (as in Table 1), and H_i = sum of ranks of hard coral and soft cover categories at the site (1-5, as in Table 2). This index gives highest scores to sites that have high species richness and abundance of reef species and cover of corals.

3.3. Local rarity index (RI):

The presence of rare species may afford some sites greater importance than others in terms of the conservation of regional biodiversity. An index, *RI*, to indicate the relative importance of rare versus common hard and soft corals was calculated for each site:

$$RI = \sum A_i / P_i$$

Where A_i = abundance rank for the ith coral species at a given site (1-5, as in Table 1), and P_i = the proportion of all sites in which the species was present. This index gives highest values to sites which are least representative or most unusual faunistically (ie. with high abundance of taxa which are rare in the data set).

3.4. Community types:

Site groups defined by community type were generated by hierarchical cluster analysis using abundance ranks of all sessile benthic taxa in the inventories. The species abundance data were fourth-root transformed prior to analysis. Initial clustering used Euclidean Distance and complete linkage to generate cluster site groups of similar community composition and abundance. These initial clusters were refined using K-means clustering, to maximize homogeneity within the initial groups derived from the hierarchical clustering. The data were plotted using PCA, and the groups defined by K-means clustering were outlined as hulls. The species that best characterized each community group (key indicator taxa) were determined, based on relative abundance and fidelity to the community types (after Dufrene & Legendre 1997, DeVantier *et al.* 2000a). Species showing little fidelity to particular communities were also determined. The statistical significance of differences in key ecological variables among the different coral community types was examined using one-way Analysis of Variance.

3.5. Coral injury:

Each coral species in the sites was assigned a score for its level of injury, from 0 – 1 in increments of 0.1 (from 0: no injury to any colony of that species in the site to 1: all colonies of the species were dead, see Methods above). Sites were compared for the amounts of injury to their coral communities, for the percentage of the total number of species present in each site that were injured, and the average injury to coral species in each site.

III. RESULTS & DISCUSSION

1. Environmental setting

1.1. Reef development:

There was little recent (Holocene) reef development around the Islands, with most sites having coral communities developed directly on non-reefal rock (42 %, mostly deeper sites) or as incipient reefs with some biogenic accretion (36 % of sites, Table 4). Two locations (4 sites, 11 % of sites) supported small reef flats, at Dam Tre (N. Hon Tre) and E. Hon Tre, and a further 2 locations (4 sites in Bai Bang Bay N.E. Hon Tre) supported large inter-tidal reef flats (> 50 m, reef development rank 4).

In general, the most extensive reef development in MPA waters occurs in the N. facing bays, notably on N. and N.E. Hon Tre and N. Hon Mun, although in most places these reefs have been extensively damaged by blast and poison fishing, river impacts and careless anchoring (Vo *et al.* 2002).

Table 4: **Levels of reef development, 36 survey sites in 18 locations, Hon Mun MPA**

Ave. reef development (s.e.)	Median	Mode	Percentage of 36 sites in each category			
			1	2	3	4
1.9 (0.2)	2	1	42	36	11	11

The overall lack of extensive reef-building may be attributable to the synergistic operation of some or all of the following factors: recurrent mass coral mortality from typhoons; localized upwelling of cool waters on lower reef slopes, recurrent coral predation, ENSO events, high rates of bioerosion, competition with macro-algae, failure of reef lithification processes (Behairy *et al.* 1992). Most recently, negative impacts have occurred through river flood run-off causing reduced salinity, high levels of nutrients, turbidity and sediments and / or hypoxia.

1.2. Other environmental variables:

The individual coral reef communities were usually developed as small patches in the island bays, often separated by intervening sandy or rocky areas devoid of corals or with very low coral cover. The communities were developed from low-tide level to ca. 30 m depth, on slopes ranging from 10° - 60° to the horizontal (Table 5), and were usually surrounded by sand or merged into sand-silt on their deeper extent.

Most communities occurred in semi-sheltered (41% of sites) or semi-exposed environments (33% of sites) although distributed over the full range of exposures (Table 5), from sheltered (8%) to highly exposed (17%). Most communities were exposed to negligible (36% of sites) or minor (42% of sites) levels of sedimentation, with deeper near-shore sites moderately (11%) or severely affected (11%). Water clarity ranged from 5 - 25 m (ave. 14 m) and was highest at Hon Mun, Hon Rom, Hon Noc, Hon Cau, Hon Vung and S.E., E. and N.E. Hon Tre (~ 15 m or more). By contrast, most near-shore sites had lower water clarity (< 10 m), notably Hon Mieu, Hon Tam and inside Dam Bay, Hon Tre. These sites also had highest silt loading, particularly the deeper slopes, contributing to the reduced water clarity.

Table 5: **Summary statistics for environmental and ecological variables, 36 survey sites in 18 locations, Hon Mun MPA**

Environmental variable	**Mean (s.e.)**	**Range**	**Median**	**Mode**
Slope angle (degrees)	24° (2 °)	10° - 60°	20°	10°
Exposure (rank 1 - 4)	2.6 (0.1)	1 - 4	2.5	2
Water clarity (Visibility m)	14 (1)	5 - 25	15	15
Hard substrate (rank %, 0 - 5, Table 2)	4.7 (0.1)	3 - 5	5	5
Sand (rank %, 0 - 5, Table 2)	0.9 (0.1)	0 - 2	1	1
Silt (rank %, 0 - 5, Table 2)	0.8 (0.1)	0 - 3	1	0

Despite the lack of recent reef accretion, some sites (Table 6) supported large corals or coral stands, formed predominantly at the different locations by massive *Porites*, *Pachyseris speciosa, Merulina ampliata, Acropora formosa*, *A. nobilis*, *A. microphthalma, A. copiosa, Montipora crassituberculata, M. aquituberculata, M. hispida, Hydnophora grandis* and *Echinopora hirsutissima*. Based on known growth rates, the largest of these corals were a century or more in age.

Table 6: **Sites with very large coral colonies, Hon Mun MPA. s - shallow, d – deep**

Site name (number)	**Coral species**
Bai Bang N.E. Hon Tre (5d)	*Porites massive* *Pachyseris speciosa*
E. Hon Tre (4d)	*Merulina ampliata*
S. Hon Tam (2s)	*Hydnophora grandis*
S.E. Hon Tre (11s)	*Echinopora hirsutissima* *Montipora hispida*

S. Hon Mot (6s), N.E. Hon Mieu (1s), S.W. Hon Mun (8s)	*Acropora formosa* *Acropora nobilis* *Acropora microphthalma* *Acropora copiosa*
S.W. Hon Mun (8s), S.E. Hon Tre (11s), E. Hon Tre (4s)	*Montipora aquituberculata* *Montipora crassituberculata* *Montipora hispida*

1.3. Coral cover:

There was considerable variability in coral cover, in response to site-specific characteristics and disturbance histories (mostly blast fishing, river impacts and crown-of-thorns seastar predation), and species-specific tolerances to exposure, levels of sedimentation, turbidity and illumination. Here we highlight key sites for conservation and present a broad-scale overview of the 18 locations in MPA waters, to facilitate comparison with other large reef areas (Wilkinson 2000).

Overall cover of stony corals (including the reef-building hydrozoan 'fire coral' *Millepora*) among 18 survey locations averaged ca. 27 % (Fig. 2). Highest cover (> 50 %) occurred at S.E. Hon Tam (Site 2s), E. Hon Tre (4d), S.W. Hon Mun ('Moray Beach' 8s), S.E. Hon Tre (11s), N.E. Hon Tre (Bai Bang 14s) and S. Bay, Hon Mun (16s). These sites represent the best remaining areas of high coral cover in Hon Mun MPA (also see Vo *et al.* 2002). High coral cover, although often characteristic of healthy coral communities, is becoming rare both within Hon Mun MPA and indeed throughout much of S.E. Asia, the result of human and natural impacts (see later), and these local sites are all worthy of high protection (Table 7). High stony coral cover was often associated with large mono-specific coral stands (Table 6), notably of:

- Submassive and encrusting merulinids *Hydnophora grandis* (S.E. Hon Tam, site 2s) and *Merulina ampliata* (S.E. Hon Tre, site 4d);

- Branching acroporids *Acropora formosa, A. nobilis* and *A. copiosa* (N.E. Hon Mieu, S.W. and S. Hon Mun, sites 1s, 8s and 16s);

- Foliose - encrusting - digitate species of the acroporids *Montipora* and fire corals *Millepora* spp. (N.E. Hon Mieu and S.W. Hon Mun, sites 1s, 8s);

- Foliose - encrusting agariciid *Pachyseris speciosa* (Bai Bang, N.E. Hon Tre, site 4d).

Overall average coral cover (27%) was higher (double) than that estimated during the habitat assessment (Vo *et al.* 2002) for several reasons, primarily because the present taxonomic assessment was much less extensive, being focused on many of the high diversity (and high coral cover) sites in MPA waters. During the manta-tow survey, coral cover was assessed around Hon Mun MPA overall. Further, each taxonomic survey location (2 sites) was smaller than one individual manta-tow site, and the taxonomic survey locations were divided into deep and shallow sites. During manta-tow, cover on the entire reef slope was assessed and integrated to produce a single value for each tow.

Dead coral cover averaged 11%, ranging among individual sites from < 5 - 50%. Highest levels of dead coral cover (31 - 50%) occurred at S. Hon Mot (site 6s), Dam Bay, S. Hon Tre (site 7s) and Dam Tre, N. Hon Tre (sites 15d, s). Coral death was caused by blast fishing and river influences (Dam Tre, N. Hon Tre), predation by crown-of-thorns seastars and *Drupella* snails (Dam Bay, S. Hon Tre) and also possibly coral bleaching in 1998 (S. Hon Mot). Overall cover of soft corals in the 36 sites averaged 9% (Fig. 2), with highest cover (11 - 30%) in the sites on Hon Mieu (site 1s), Dam Bay (7s), S.W. Hon Mun (8s, d), Hon Rom (9d), S.E. Hon Tre (11s), Hon Vung (12s) and Hon Cau (13s).

Cover of macro-algae averaged 8% (Fig. 2), with highest cover (31 - 50 %) at the offshore rock, N.W. Hon Tre (site 18s). The adjacent coast of Hon Tre also supports high macro-algal cover, notably of *Sargassum* and *Padina* spp. (Vo *et al.* 2002). Cover of turf algae averaged 18% (Fig. 2), with highest cover (31 - 50%) at Hon Vung (12d), Dam Tre, N. Hon Tre (15d, s) and the offshore rock, N.W. Hon Tre (18d, s). In the case of Dam Tre, the high cover of turf algae was developed on dead corals killed by blast fishing. Cover of encrusting coralline algae averaged 14% (Fig.2), with comparatively little range in cover among sites (ranks 1 and 2, to 30%).

High cover of living hard and soft corals were positively associated with areas of high exposure and maximum reef development, and negatively associated with the presence of silt and high sedimentation (Fig. 3). By contrast, high cover of dead corals, turf and macro-algae were positively associated with high levels of blast fishing, predation from crown-of-thorns seastars and *Drupella* snails and coral diseases.

Comparisons of the results for individual sites with those of previous survey in 1993 indicate that although some sites have remained in good condition, others have deteriorated (eg. for hard coral –Table 7). Because the precise locations of the 1993 WWF surveys were not identical to the 2002 taxonomic assessment, the assignment of direction of change in cover was conservative and provides a broad comparison only.

Table 7: **Comparison of live hard coral cover from 2002 with 1993 (WWF 1993), Hon Mun MPA. +ve indicates an increase in hard coral cover from 1993 - 2002; -ve indicates a decline in cover**

Site name	**WWF 1993**		**Hon Mun MPA 2002**		**Direction of change**
Method	Contour transects	Vertical transects	Habitat assessment	Taxonomic assessment	
Hon Mun NE coast (PADI beach)	1s: 32 %	38 %	1 - 10 %	No data	-ve
	1d: 23 %				
Hon Mun SW	2s: 40 %	38 %	51 - 75 %	51-75 %	+ve

(Moray beach)	2d: 50 %			31 - 50 %	
Hon Mun N coast	3s: 77 %	44 %	31 - 50 %	No data	no change
	3d: 52 %				
Hon Mun NW coast	4s: 31 %	20 %	1 - 10 %		-ve
	4d: 36 %				
Hon Mun NE coast (ii)	5s: 50 %	42 %	1 - 10 %		-ve
	5d: 28 %				
Hon Mun SE coast (South Bay)	6: No data	24 %	31 - 50 %	51 - 75 %	+ve
				1 - 10 %	
Hon Cau	Hs: 13 %	8 %	31 - 50 %	31 - 50 %	+ve
	Hd: 10 %			1 - 10 %	
Hon Mieu	M: No data	27 %	31 - 50 %	31 - 50 %	no change
				1 - 10 %	
Hon Tre (Bich Dam)	B: No data	14 %	11 - 30 %	No data	no change
Note: the 1993 WWF surveys used 2 different quantitative methods (contour and vertical transects) at different depths while the 2002 habitat and taxonomic surveys scored coral cover as ordinal ranked categories (Table 2).					

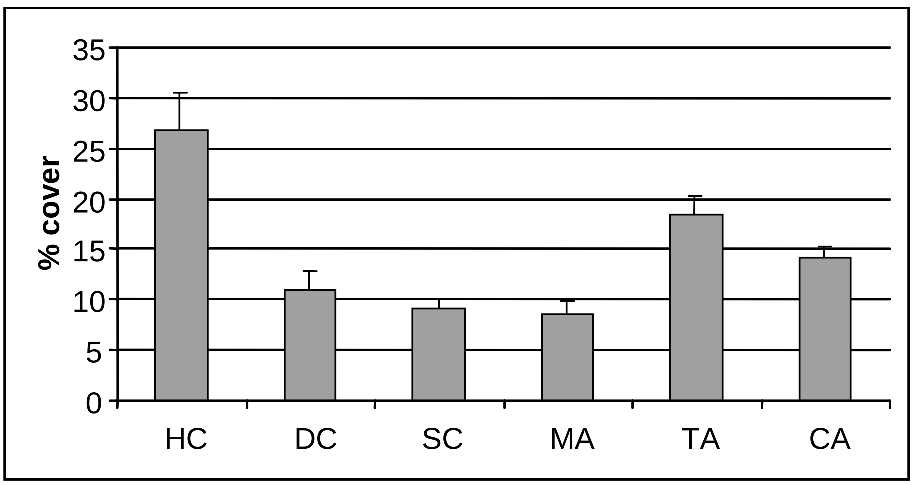

Figure 2: **Overall cover (and s.e.) of hard corals (HC), dead corals (DC), soft corals (SC), macro-algae (MA), turf algae (TA) and coralline algae (CA) in the 36 sites at 18 locations, Hon Mun MPA, 2002**

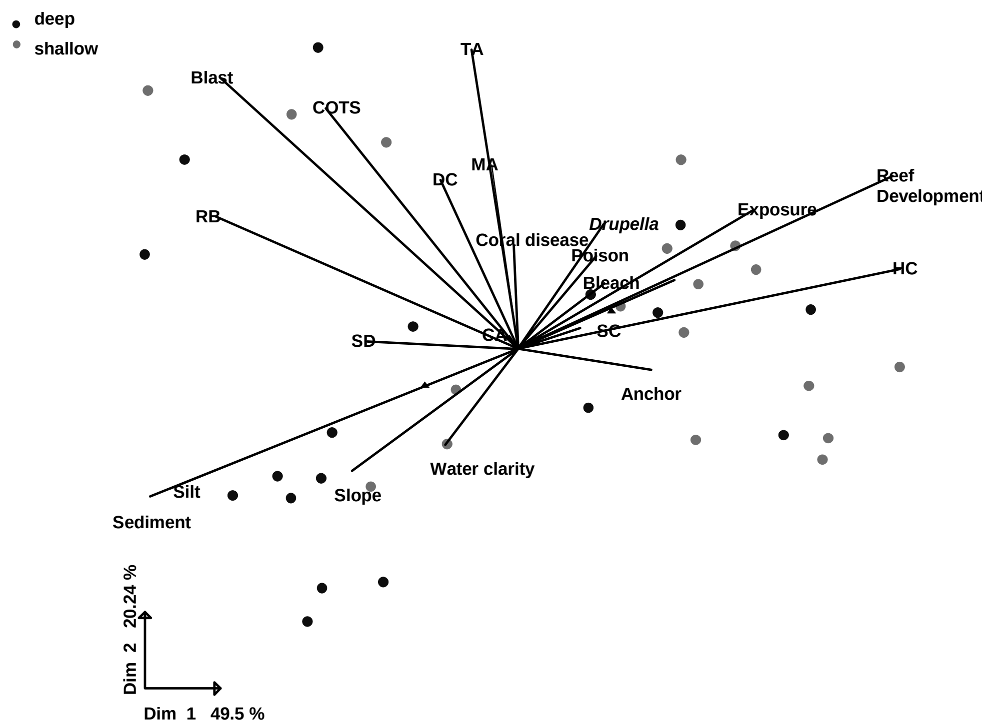

Figure 3: **Redundancy Analysis biplot of 18 locations in relation to ecological and environmental variables, where HC - Hard Coral cover, DC - Dead Coral cover, SC - Soft Coral cover, MA - Macro-Algae cover, TA - Turf Algae cover, CA - Coralline Algae cover, RB - Rubble cover, SD - Sand cover, Silt - Silt cover. Environmental variables as ranked scores (see Table 2 for details). Vectors point in direction of highest scores for the indicated variables. The first 2 dimensions account for ca. 70 % of total variance**

Of the sites remaining in good condition, the best examples are South Bay and Moray Beach (SW coast) on Hon Mun. These areas retain very high living coral cover (> 50%) on their shallow slopes (to 8 m depth), showing an increase in cover since 1993. By contrast, living coral cover on much of the N. coast of Hon Mun has deteriorated markedly since 1993, through a combination of careless anchoring, destructive fishing and coral predation by the crown-of-thorns seastar *Acanthaster planci*.

These trends in living stony coral cover were also reflected in the comparisons of dead coral cover. Notably, there were already high levels of dead coral cover on the N.E. coast of Hon Mun in 1993, although this has continued to increase and spread to 2002. Remedial actions by the MPA Authority, local villagers and dive clubs, including enforcement of regulations prohibiting fishing and anchoring, provision of boat moorings, and control programs for *A. planci*, should help to rehabilitate these areas in future. For soft corals, there was little overall change in cover among the different sites from 1993 to 2002, with Hon Cau (and neighbouring Hon Vung) continuing to support highest soft coral cover (31-50%) in MPA waters (also see Vo *et al*. 2002).

2. Species diversity and replenishment

Diversity overall and for each of the taxonomic groups (corals, fish, macro-benthos and algae) is considered for the individual sites (*alpha*, within-habitat), among sites (Hon Mun MPA – *beta*) and regionally (South China Sea – *gamma*) (after Whittaker 1972, also see Paulay 1997). Herein diversity is considered simply as the number of species present (richness). Levels of evenness - dominance (e.g. Shannon-Weiner Index H') was also calculated (see later).

The species-sample curves for each taxonomic group and for the groups combined demonstrated that diversity for most groups was still increasing after 13 locations had been surveyed (eg. for all taxa – Fig. 4), and that further survey is likely to reveal additional species. For the corals, with an addition 10 sites in 5 locations surveyed, the majority of species were recorded after 15 locations, although further species and indeed new distribution records for Vietnam were still being found after 18 locations had been assessed (Fig. 5).

2.1.Location/Site (alpha)Diversity:

+ ***Overall***

Diversity for the four major taxonomic groups (corals, fish, macro-benthos and algae together) at the different locations (deep and shallow sites combined) ranged between 198 species and 341 species, with a location average of 286 species (s.e. 12 spp., Fig. 6), and median of 298 species. Richest locations included Hon Cau (341 species), Hon Vung and E. Hon Tre (322 spp.), S.E. Hon Tre (319 spp.), S.W. Hon Mun (Moray Beach, 308 spp.), Hon Noc (302 spp.) and Bai Bang (N.E. Hon Tre, 297 spp.). These locations were all situated well offshore, away from river influences and also relatively little affected by local impacts (destructive fishing, crown-of-thorns seastar predation, Vo *et al*. 2002).

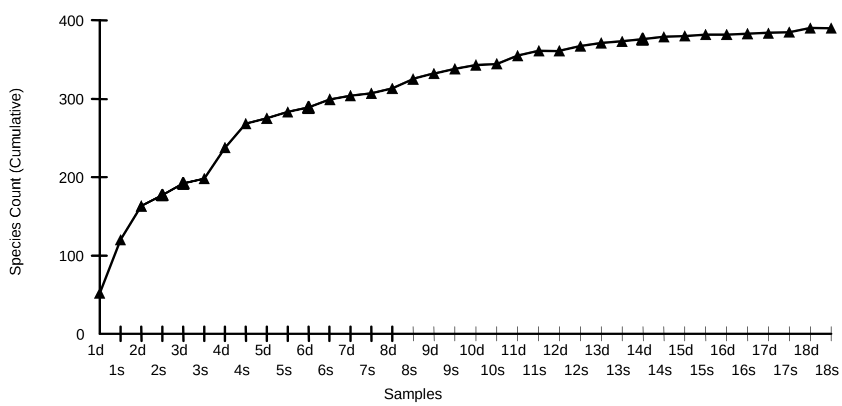

Figure 4: **Species - sample curve for all taxa, 13 locations (deep and shallow sites)**

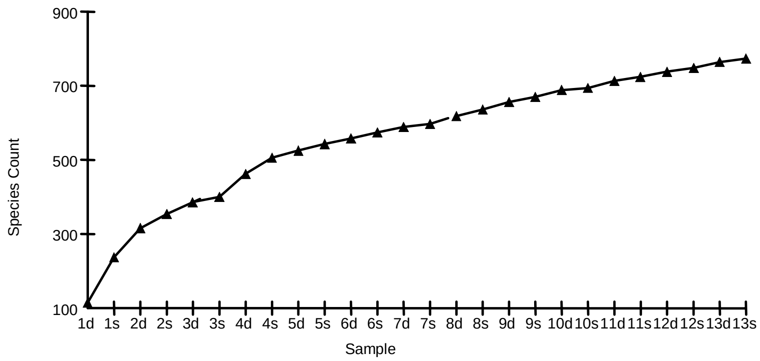

Figure 5: **Species - sample curve for all corals, 18 locations**

For overall diversity and for the different taxonomic groups, there was high congruence in the ratios of average site: location diversity, ranging between ~ 60 and 72% (Table 10), indicating strong proportional consistency in habitat (depth) partitioning among species in the different groups (i.e. both shallow and deep sites hosted *on average* 60 - 70% of the species present at each location, irrespective of taxonomic group). For the corals and for all taxa combined, this produced substantial overlap in community *composition* between deep and shallow sites, although major differences in relative abundance of individual species with depth produced substantial separation in community structure (Fig. 7).

At the individual sites (deep and shallow independently), total diversity averaged 196 species (Fig. 3, median 200 species and range of 115 - 249 species). As with the above locations, highest overall richness (> 200 spp., Table 8) occurred at E. Hon Tre (sites 4s, d), Hon Noc (10d), Hon Vung (12s, d), Hon Cau (13d, s), S.E. Hon Tre (11s, d), S.W. Hon Mun (8s, d) and Hon Rom (9s, d).

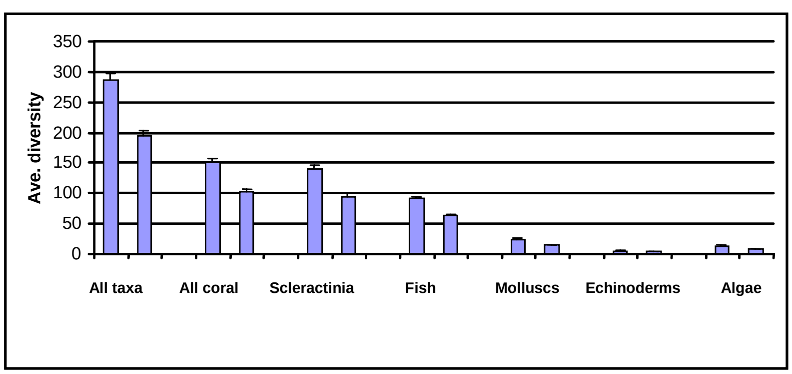

Figure 6: **Average diversity (+ 1 s.e.) for all taxa, all corals, Scleractinian reef-building corals, fish, molluscs, echinoderms and algae, Hon Mun MPA. Left bars are the location values, right bars are the individual site (deep and shallow) values**

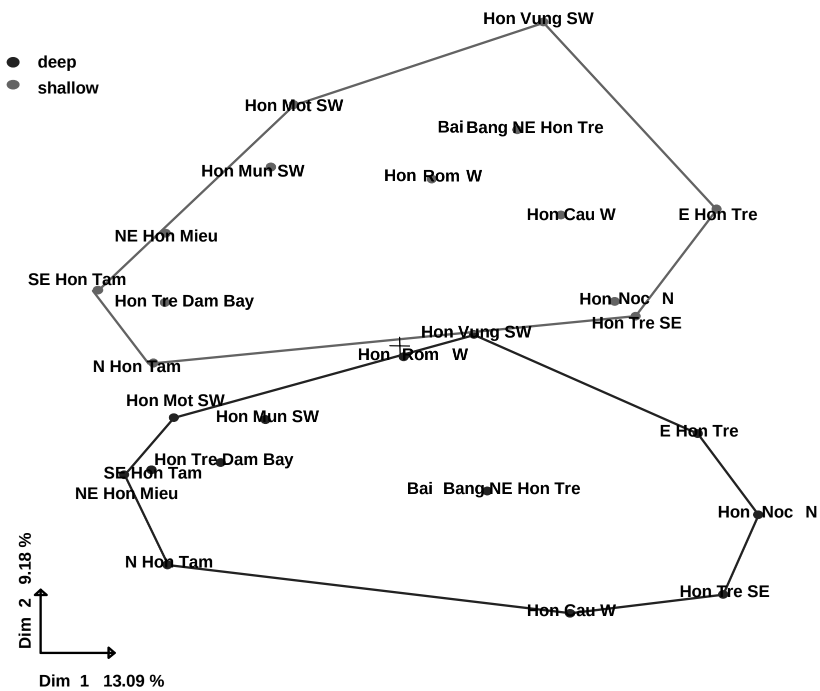

Figure 7: **Depth effects on coral reef community structure, all taxa combined, 13 locations, derived from hierarchical clustering (Euclidean distance metric, complete linkage fusion strategy) of the species - abundance data. The first 2 dimensions account for 22% of the total variance**

Table 8: **Proportion of average location diversity represented in average site diversity overall and for the different taxonomic groups**

Taxonomic group	Proportion Site / Location
Overall	0.684941
All corals	0.685318
Scleractinia	0.683149
Fish	0.702361
Molluscs	0.614063
Echinoderms	0.723881
Algae	0.656627

+ *Corals*

For all corals, including the alcyonarian soft corals and related sessile Anthozoa (e.g. zoanthids, corallimorpharians, hydrozoans), average location diversity was 150 species (s.e. 8 spp., median 156 species). Of this, the reef-building Scleractinia accounted for > 90 % (Fig. 10), with average location diversity of 139 species (s.e. 8 spp., median 147 spp.). This level of alpha diversity compares favourably with other diverse Indo-west Pacific reef areas (e.g.

Australia's Great Barrier Reef, and parts of Indonesia). Richest locations at E. and S.E.Hon Tre (Locations 4 and 11) supported > 190 coral species.

At the individual sites, diversity of all corals averaged ~ 100 species overall (site range 45 - 150 spp.), being marginally higher in the 13 locations (26 sites) surveyed for all taxa (Fig. 10) than the 18 locations (36 sites) surveyed for corals. The slight decline in average site diversity of corals with the increase in sites was attributable to the depauperate nature of the coral communities fringing the offshore rock at N.W. Hon Tre (sites 18s, d, Fig. 1), likely attributable to negative impacts from Cai River flooding. Scleractinian diversity followed similar trends, with average richness of > 90 spp. overall (range: 39 - 143 spp.). Highest diversity sites were similar to those listed above, including E. Hon Tre (both shallow and deep 4s, d), Hon Noc (10d), S.E. Hon Tre (11s, d), Hon Vung (12s), Bai Bang (14s, d) and S.W. Hon Mun (8s) and Hon Cau (13d, s).

Thus high coral diversity in Hon Mun MPA was not depth specific, occurring at depths from 3 m (e.g. Bai Bang and Moray Beach, Hon Mun shallow) to > 20 m (e.g. E. Hon Tre and Hon Noc). High diversity also occurred in sites with exposures ranging from semi-sheltered to exposed, and with coral cover ranging from < 10% (e.g. Hon Noc) to > 50% (e.g. Moray Beach, Hon Mun). Highest coral diversity was however largely restricted to the offshore areas, away from river influences and in places least affected by local human impacts (blast and poison fishing) or predation. Notably lowest coral diversity occurred at sites closest to the Cai River (offshore rock, N.W. Hon Tre, site 18) or affected by crown-of-thorns seastar predation (W. Dam Bay, Hon Tre, site 7). Corals in the former location also exhibited high incidence of disease and fouling by other organisms (e.g. barnacles).

+ Fish

For home-ranging demersal fish in the families censused, location diversity averaged 91 spp. (se. 3 spp., median 94 spp., range 72 - 104 spp.). Highest diversity locations (> 100 spp.) included Hon Vung, Hon Cau, Hon Mun (Moray Beach), Bai Bang (N.E. Hon Tre) and Hon Rom, and as with the corals, were offshore locations less affected than inshore areas by river impacts and destructive fishing. For individual sites, diversity ranged from 44 - 77 species (average: 64 spp., s.e. 2 spp. median: 65 spp.), being richest on the deep slope of Hon Vung.

+Macro-benthos

For molluscs, species richness among locations averaged 25 species (s.e. 2 spp., median 23 spp., range 15 - 41 spp.), with richest locations and sites again predominantly the offshore areas: Hon Vung, Hon Cau, S.E. Hon Tre and Hon Noc. For echinoderms, the MPA supports a highly depauperate fauna of low average species richness (5 spp., s.e. 2 sp., median 5 spp., range 0 - 11 spp.). Richest locations included the offshore Hon Vung (location 12), which also supported several species previously unrecorded during the surveys (Fig. 8). Contrary to the other taxonomic groups, inshore locations S.

Hon Tam, Hon Mieu and Hon Mot (locations 2, 1 and 6 respectively) were among the most diverse. For individual sites, the richest areas were the deep slopes at Hon Vung and Hon Mot.

+ *Algae*

For macro-algae, species richness among locations averaged 13 species (s.e. 2 spp., median 14 spp., range 0 - 28 spp.), with richest locations and sites being widespread from inshore to offshore in MPA waters (e.g. S. Hon Tam and Hon Cau). For individual sites, high algal diversity occurred at S. Hon Tam (both deep and shallow sites), Hon Cau (both deep and shallow sites), Bai Bang (shallow), E. Hon Tre (deep) and S.E. Hon Tre (shallow).

2.2. Hon Mun MPA (Beta) diversity:

Beta diversity for Hon Mun MPA is here expressed as the tally for the various taxonomic groups from all survey locations.

+ *Overall*

For the various taxonomic groups combined, beta diversity in Hon Mun MPA waters was 790 species, comprised of 390 species of corals (ca. 357 spp. Scleractinia), 222 species of fish, 106 species of molluscs, 18 species of echinoderms and 55 species of macro-algae (Table 9). At least 7 species of sea-grasses are also present (Vo et al. 2002), such that overall reef-associated diversity among these groups approaches 800 species in total. Note that for all corals and Scleractinia, total is from 18 locations (36 sites). For Scleractinian corals the species tally includes species for which further taxonomic study is required and for which final specific identifications remain unconfirmed (and confirmed species). It thus presents the maximum values for each group. For algae, the number of phyla is listed, rather than families.

Table 9: **Overall (beta) diversity, Hon Mun MPA, 2002**

Taxonomic group	All corals	Reef-building corals	Fish	Molluscs	Echinoderms	Algae	Overall
Family	26	15	38	33	10	4	126
Genera	87	64	102	52	13	35	353
Species	379	351 (325)	222	106	18	55	790

+ *Corals*

MPA waters support some 380 species of corals and associated sessile benthic Anthozoa, of which most (ca. 351 species) are reef-building scleractinian corals (Table 9). For the reef-building taxa, specific identities of some 30 species remain unconfirmed, and are the subject of continuing taxonomic revision. Diversity for soft corals and other associated groups is significantly underestimated, because of difficulties in assigning species level identifications in the field and also because of a lack of expertise in these groups among the present survey team. Richest individual locations (E. and S.E. Hon Tre) supported almost half of total beta diversity (190 of the 380 coral spp.).

Comparison with previous species tallies indicate that the present survey has recorded > 90% of all reef-building coral species known from Hon Mun MPA (152 species), and increased the total by 11 genera and ca. 200 species. Many of these were already known from Vietnamese waters, although for 1 genus (*Micromussa*) and some 40 species, their occurrence in Hon Mun MPA represents distribution range extensions to Vietnam (see Gamma Diversity later).

+ Fish

MPA waters support some 220 species of reef-associated fishes, in 104 genera from 38 families (Table 9), representing ca. two-thirds of the 200 fish species recorded during previous surveys of Nha Trang Bay (WWF 1993), and with new records for the area. The speciose families Pomacentridae and Labridae were both well represented, as was the Chaetodontidae, with 22 species of butterfly fishes and allies. By contrast, the Pomacanthidae (Angel fishes) were rare, with 2 species previously common in Nha Trang waters (*Pomacanthus imperator* and *P. sexstriatus*) being extremely rare (*P. imperator*) or not recorded during the present study. Their current rarity is clearly attributable to high demand from the ornamental fish aquarium trade, with fish pairs fetching more than 100 US dollars.

Similarly, the commercially valuable groups of large food fishes Serranidae (e.g. *Plectropomus, Epinephelus, Cephalopholis* spp.), Lethrinidae (*Lethrinus* spp.) and Lutjanidae (*Lutjanus* spp.) were both highly depauperate and of low relative abundance and sizes, reflecting the intense fishing pressure. Notably, these groups have been depauperate in MPA waters during all previous surveys, although species diversity continues to decline, indicating both long-term (decade) and continuing depletion (Table 12). Other notable absentees from the present list included the labrid Hump head maori wrasse *Chelinus undulatus* and serranid barramundi cod *Cromileptes altivelis*, once common components of many Indo-west Pacific reef fish assemblages. These species are among the most favoured of all target fishes for the Asian live fish food trade, and are now locally extinct in many areas of East Asia, almost certainly including Hon Mun MPA.

+ Macro-benthos

-Molluscs

MPA waters support some 106 species of reef-associated molluscs, in 52 genera from 33 families (Table 9), representing ca. one-third of the 111 mollusc species recorded during previous surveys of Hon Mun MPA (WWF 1993) and adjacent waters. This may indicate a substantial shift in species composition within MPA waters, but may also be attributable, at least in part, to differences in sampled habitat, the present surveys being focused on coral reefs. The Conidae (cone shell genus *Conus*), Muricidae and Cypraeidae (cowrie genus *Cypraea*) were relatively well represented, although with substantial differences in species composition from prior surveys. For the cowries, a significant decline in species diversity was apparent (from 13 to 7 species). Three species of pearl shell *Pinctada* and 3 species of giant clam *Tridacna* were also present.

The coral-feeding snail *Drupella cornus* was common, preying mostly on branching species of *Acropora*. By contrast, just 1 species of reef abalone *Haliotis* was recorded (*H. varia*), with the commercially important *H. assanina* absent. This species had been heavily exploited in local waters, to the point of local extinction (Table 10). Similarly, the Giant Triton *Charonia tritonis* was absent from the surveys, and was not seen in any of the prior assessments undertaken for this project, despite the presence of outbreak populations of its prey, the coral-feeding crown-of-thorns seastar. This spectacular shell has been extensively collected from most of its Indo-west Pacific distribution range over the past century, and is still for sale in local marine curio shops of Nha Trang, and a feature of many home ornament collections. Sources of the commercial shells are unknown but may include the Spratly Islands and other remote reef areas.

Table 10: **Commercially important species of fish, mollusc and echinoderm not recorded during the present surveys that were previously recorded (PR) from Hon Mun MPA or adjacent waters or were likely to occur there, based on known distribution ranges (DR)**

Family	**Species**	**Previously recorded (PR) or within known distribution range (DR)**
Pomacanthidae	*Pomacanthus imperator*	PR
	Pomacanthus sexstriatus	PR
Lethrinidae	*Lethrinus nebulosus*	PR
	Lethrinus miniatus	PR
	Lethrinus xanthochilus	DR
Lutjanidae	*Lutjanus kasmira*	PR
	Lutjanus monostigma	PR
	Macolor niger	PR
Serranidae	*Anyperodon leucogrammicus*	PR
	Cephalopholis cyanostigma	PR
	Cephalopholis miniata	DR
	Epinephelus tauvina	DR
	Epinephelus fasciatus	PR
	Plectropomus oligacanthus	PR

	Plectropomus leopardus	DR
	Plectropomus maculatus	DR
	Cromileptes altivelis	DR
Labridae	*Chelinus undulatus*	DR
Haliotidae	*Haliotis assanina*	PR
	Charonia tritonis	DR
Holothuridae	*Holothuria scabra*	PR

+ Echinoderms

MPA waters support a relatively depauperate reef-associated echinoderm fauna (ca.18 species in 13 genera from 10 families, Table 9), representing about one-third of the 27 species recorded during previous surveys of Nha Trang Bay (WWF, 1993). Notable absentees were the commercially important sea cucumber species, including *Holothuria scabra*, a previously common species in MPA waters and the focus of a commercial fishery prior to the collapse of its local population (Table 12).

+ Algae

MPA waters support some 55 species of reef-associated macro-algae, in 35 genera from 4 phyla (Table 9), and 7 species of seagrass in 5 genera (Vo *et al.* 2002), representing ca. 25 % of the 252 reef-associated seaweed species recorded during previous surveys of Nha Trang Bay. As the present surveys were focused on coral reefs, it is likely that many additional species occur in other habitats. Major seasonal shifts in composition (and abundance - biomass) also affect the overall diversity, and thus the complete species tally for macro-algae will be higher than the ca. 250 species reported to date. Notable areas of high algal richness, the inshore areas and N. Hon Tre, are likely to receive substantial nutrient enrichment in seasonal run-off from the Cai and Be Rivers, and in re-suspension of silts during rough weather. The proliferation of macro-algae on N. Hon Tre has also been fostered through the provision of habitat via destruction of the once-flourishing coral communities through destructive fishing and river run-off (Vo *et al.* 2002 and see Fig. 3 for positive association between cover of dead corals and macro-algae).

2.3. Regional (Gamma) diversity:

+ Reef-building corals

Some 357 species of reef-building corals in 64 genera, representing ca. 50 % and 80 % of the entire Indo-Pacific species and generic 'pools' were recorded. Of these, some 40 species (Table 11) and 1 genus (the mussid *Micromussa*) are new records for Vietnam. For most of these species, their prior distributions were restricted to the Indo-west Pacific centre of diversity of the Philippines - Indonesia - New Guinea (Veron 2000). Their occurrence in Hon Mun MPA indicates that this area (and Vietnam more generally) is more diverse than previously known, and closer to the diversity centre in species composition and overall scleractinian diversity. Of the other new distribution records in the present list, some were previously known from E. Asia and Taiwan and / or Japan (e.g. *Alveopora minuta, Fungia taiwanensis*), suggesting dispersal and gene flow along the E. Asian coast.

Other species were known from the central Indian Ocean extending into Indonesia and 1 species, provisionally identified as *Favites spinosa* appears to be a new distribution record for the Pacific Ocean, its previous known range being restricted to the W. Indian Ocean. Additionally, 1 species of *Fungia* shows substantial variation from all described species, being closest to *Fungia spinifer* and perhaps representing a geographic variant (Plate 2). Alternatively, this species may be undescribed, although further taxonomic work is required to verify this. Indeed, further taxonomic study is required to verify the provisional identities of some 30 coral species, including 7 of the new distribution records. Specimens of these species will be forwarded to Dr. J.E.N. Veron (Australian Institute of Marine Science) for confirmation.

Despite recent major advances in field identification (e.g. Veron 1986, Wallace 1999, Veron 2000) and stabilizing of the taxonomy, substantial taxonomic uncertainty and disagreement among different authors still remains, particularly in the families Acroporidae and Fungiidae. For example Wells (1954, 1956), Hoeksema (1989), Wallace (1999) and Veron (2000) each provide different taxonomic classifications for several corals. Veron (1986, 1995), provide interesting discourses on the problem of synonymy. Contributing to these disagreements among workers are several factors, in part related to the 'reticulate' nature of evolutionary processes in the Scleractinia (Veron 1995):

- Morphological 'plasticity' – the tendency of the same species to grow in different ways in different biotopes (phenotypes), or to have different genotypic morphotypes, both of which can vary with geographic location;

- Lack of reliable and consistent morphological characters in certain taxa; and

- Hybridization - some previously well-defined 'separate' species interbreed successfully, whereas certain 'single' species have morphotypes that appear reproductively isolated, at least in some locations (see e.g. Harrison & Wallace 1990, Willis *et al.* 1997). Recent advances in coral reproductive studies, combined with chemical and molecular taxonomy, should improve taxonomic understanding substantially over the next several decades.

Table 11: **New reef-building coral distribution records for Vietnam, their known locations of occurrence and average relative abundance. Species identifications and distribution ranges follow Veron (2000). For some species, further taxonomic work is required to confirm specific identity (signified by cf.), * indicates prior record for Vietnam at NIO**

Family	Species	Locations	Ave. relative abundance
Acroporidae	*Acropora proximalis*	Hon Tam	uncommon
	Acropora vermiculata	many locations	uncommon
	Acropora cf. irregularis	Bai Bang	rare
	Acropora pectinatus	Bai Bang, Hon Vung, Hon Mun	uncommon
	Acropora kirstyae	S. Hon Tre	rare
	Acropora azurea	Hon Vung	rare
	Acropora wallaceae	Bai Bang	rare
	Acropora aspera *	Bai Bang, Hon Mot, Hon Mun	uncommon
	Astreopora randalli	Bai Bang	rare
	Montipora hirsuta	Hon Mieu	uncommon
	Montipora incrassata	Hon Cau	uncommon
Pocilloporidae	*Seriatopora stellata*	Hon Vung	rare
Fungiidae	*Fungia taiwanensis*	Hon Mun	rare
	Fungia cf. spinifer	many sites	uncommon
Siderastreidae	*Psammocora cf. obtusangula*	Bai Bang, Hon Rom	uncommon
Agariciidae	*Psammocora cf. gemmae*	Bai Bang, E. Hon Tre	uncommon
	Coscinaraea crassa	Hon Tam, Hon Cau	rare
Merulinidae	*Hydnophora grandis*	Hon Tam	uncommon
Pectiniidae	*Echinomorpha nishiharai* *	Hon Tam, Hon Mun	uncommon
	Mycedium robokaki	E. Hon Tre, Hon Noc	uncommon
Mussidae	*Acanthastrea subechinata*	Hon Noc, E. Hon Tre	rare
	Acanthastrea brevis	Hon Noc	rare
	Micromussa amakusensis	Hon Cau	rare
	Lobophyllia flabelliformis	many sites	uncommon
Faviidae	*Favites spinosa*	Hon Mieu	rare
	Favites vasta	Hon Tam, Hon Mot	rare
	Platygyra contorta	E. Hon Tre, Bai Bang,	uncommon
	Platygyra carnosus	Hon Mieu, Bai Bang	rare
	Platygyra acuta	Hon Vung, Hon Mun, Hon Mot	uncommon
	Leptoria irregularis	S.E. Hon Tre, Bai Bang	rare
	Montastrea salebrosa	Bich Dam, Dam Tre	rare
	Caulastrea curvata	Hon Noc	rare
	Barabattoia laddi	Hon Cau	rare
	Echinopora pacificus	many sites	common
Poritidae	*Alveopora minuta*	Bai Bang	rare
	Goniopora burgosi	E. Hon Tre	uncommon
	Porites cf. attenuata	Bai Bang, Hon Vung	uncommon
	Porites cf. negrosensis	Hon Tam, Hon Mun, Bai Bang	uncommon
	Porites cf. horizontalata	Hon Tam	rare

Despite the taxonomic uncertainty, it is clear that Hon Mun MPA supports highly diverse coral communities formed of a unique 'composite' fauna from several different biogeographic areas (e.g. South China Sea, Indo-west Pacific centre of diversity, E. Asia and Indian Ocean). In terms of generic diversity however, the 64 genera recorded during the present study corresponds closely with those recorded previously from Vietnam (with the addition of *Micromussa*), and remains well below the 80 genera recorded from the diversity centre (Veron 2000), consistent with some attenuation from the centre. Despite the high coral diversity in Hon Mun MPA, some species and species groups previously reported from Nha Trang Bay were not found, including the acroporid genus *Anacropora*, the 'bottlebrush' *Acropora* group (e.g. *A. echinata, A. carduus, A. subglabra*) and the oculinid *Galaxea longisepta*. Thus, in total (and with additional survey), it is likely that the full diversity for the area approaches 400 scleractinian species. This represents remarkable richness given the relatively small reef area available for recruitment and levels of impact to many other sites (Vo *et al*. 2002). This south-central area of Vietnam is recognized as the most diverse for coral reef species (Vo and Hodgson 1997), attributable to widespread dispersal, suitable environmental conditions and broad habitat heterogeneity, and lends strong support to the selection of Nha Trang Bay as the first dedicated MPA in Vietnam.

2.4. Replenishment:

Sites and locations with high coral cover, and with high coral, fish, macro-benthic and algal diversity and abundance (CI, see Methods) were considered crucial for the maintenance and replenishment of reef populations (Table 12). For the reef-building corals alone, the 5 highest scoring sites were at Bai Bang (N.E. Hon Tre), S.E. Hon Tre, E. Hon Tre, S.W Hon Mun (Moray Beach) and S. Hon Mun (S. Bay).

For all corals and allied sessile Anthozoa, there was high congruence with the ranking for reef-building corals, expected given the strong contribution to overall coral cover, diversity and abundance of the reef-building species. Of note here, however, is the higher rank for S. Hon Vung, attributable to the higher cover and richness of soft corals. For all taxa combined, there was also reasonable congruence with the coral rankings, with S.W. Hon Mun, S.E. Hon Tre, and E. Hon Tre scoring highly for all groups, but with the improved ranks of Hon Vung and Hon Cau, signifying their importance for the other groups, particularly fishes.

Table 12: **Rankings of sites in terms of replenishment potential CI. Separate rankings are provided for the reef-building corals, all corals (for 36 sites in 18 locations) and all taxa combined (for 26 sites in 13 locations). The highest scoring site at each location is listed first, as shallow (sh.) or deep**

Location	Replenishment Index CI		
	Reef-building corals	All corals	All taxa
1 N.E. Hon Mieu	13 (sh.), 36	11 (sh.), 36	9 (sh.), 26
2 S.E. Hon Tam	16 (sh.), 19	19 (deep), 20	12 (sh.), 18
3 N.E. Hon Tam	33 (sh.), 34	33 (sh.), 34	24 (deep), 25
4 E. Hon Tre	3 (deep), 6	5 (deep), 6	4 (deep), 7
5 Bai Bang, N.E. Hon Tre	10 (deep), 11	12 (deep), 14	10 (sh.), 13
6 S.W. Hon Mot	12 (sh.), 26	15 (sh.), 25	11 (sh.), 21
7 Bich Dam, S. Hon Tre	21 (sh.), 31	21 (sh.), 31	17 (sh.), 23
8 S.W. Hon Mun, Moray Beach	4 (sh.), 15	2 (sh.), 10	1 (sh.), 6
9 Hon Rom	14 (sh.), 20	13 (sh.), 18	14 (sh.), 15
10 Hon Noc	17 (deep), 29	16 (deep), 29	16 (deep), 22
11 S.E. Hon Tre	2 (sh.), 7	1 (sh.), 7	2 (sh.), 8
12 S. Hon Vung	8 (sh.), 25	4 (sh.), 26	3 (sh.), 20
13 W. Hon Cau	9 (sh.), 23	9 (sh.), 23	5 (sh.), 19
14 N. Bai Bang, N.E. Hon Tre	1 (sh.), 18	3 (sh.), 17	
15 Dam Tre, N. Hon Tre	24 (sh.), 27	24 (sh.), 28	
16 S. Bay, S. Hon Mun	5 (sh.), 22	8 (sh.), 22	
17 N.E. Hon Mun	28 (sh.), 32	27 (sh.), 32	
18 Rock, N.W. Hon Tre	30 (deep), 35	30 (deep), 35	

2.5. Coral Reef Communities:

a) Coral communities

The corals provide the structural basis for the development of reef communities, and thus their community structure were considered separately from the other groups. In Hon Mun MPA, the corals formed four major community 'types' (A - D, Fig. 8), broadly distributed in relation to incident environmental conditions, particularly the near-shore - offshore physico-chemical gradient (turbidity - light attenuation - sedimentation, salinity, depth and levels of physical exposure). These communities were composed of characteristic indicator species and relatively ubiquitous species showing varying levels of fidelity (Figs. 9 - 13).

Community A: *Stylocoeniella - Australomussa* community

Key indicator species included the astrocoeniids *Stylocieniella guentheri* and *S. armata*, soft corals *Dendronephthea* and corallimorpharians, the mussid *Australomussa rowleyensis*, the trachyphylliid *Trachyphyllia geoffroyi*, the pocilloporid *Pocillopora kelleheri*, various agariciids, pectiniids and faviids (Fig. 9).

This community had low average cover of hard corals and soft corals, moderately high cover of dead corals and high cover algae (Fig. 14), moderate levels of total abundance, richness, evenness - dominance and rarity (Fig. 15). This community occurred mostly in deeper areas of moderate exposure, with moderate - good water clarity, and with moderate - high levels of reef development. This community type is well represented in MPA Core Zones, being present at Hon Noc, Hon Mun and Hon Cau (Figs. 8, 1).

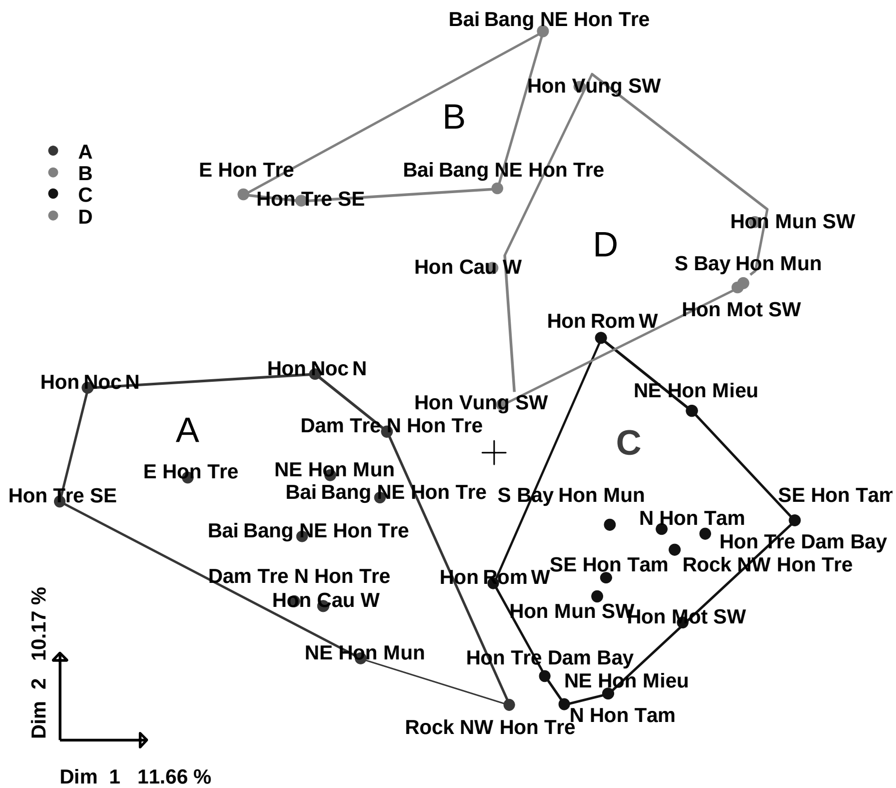

Figure 8: **Biplot of coral community types defined by hierarchical clustering (Euclidian distance metric, complete linkage fusion strategy) of species-abundance in the bio-inventories of 36 sites, 18 locations. Convex hulls delimit the distribution of sites in four community types A - D. Dimensions 1 and 2 account for ~ 22 % of the observed variance**

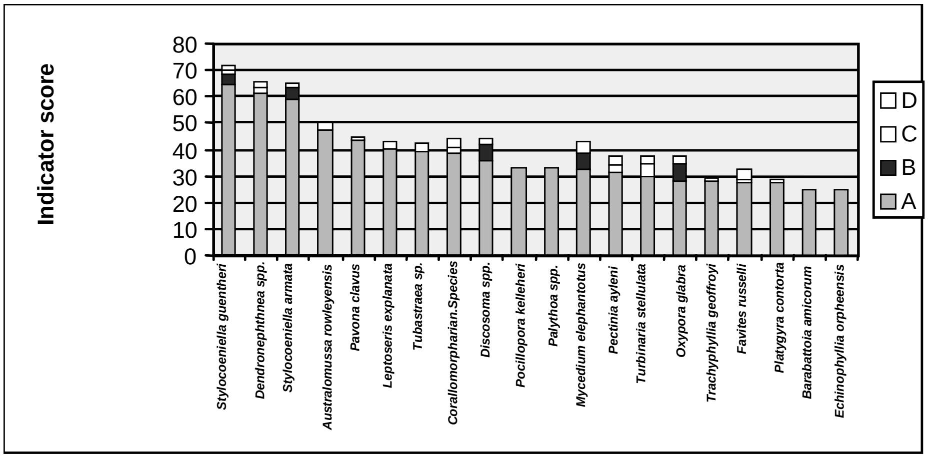

Figure 9: **Key indicator species for coral community A**

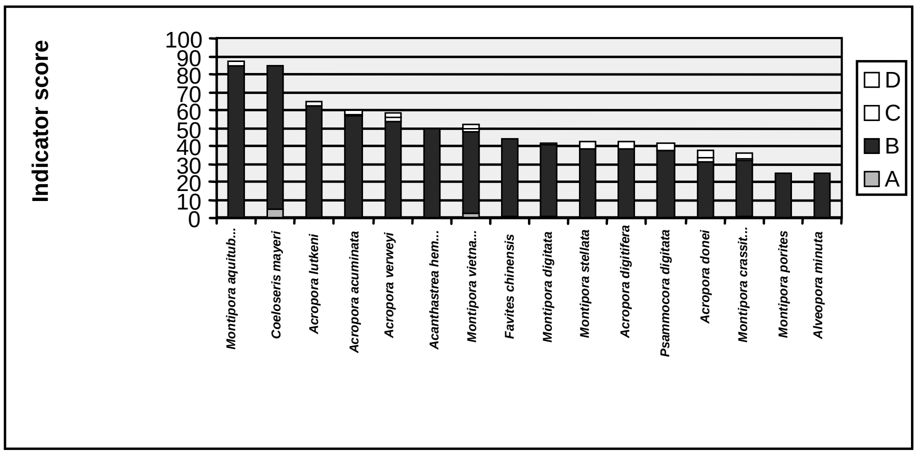

Figure 10: **Key indicator species for coral community B**

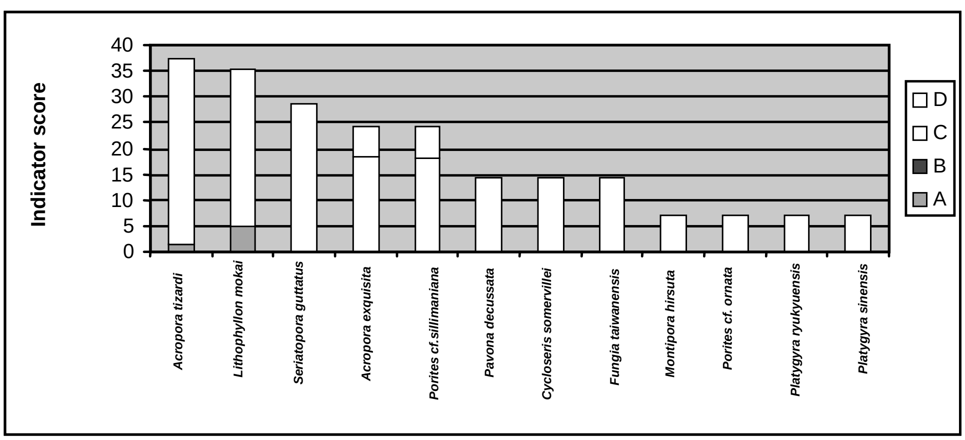

Figure 11: **Key indicator species for coral community C**

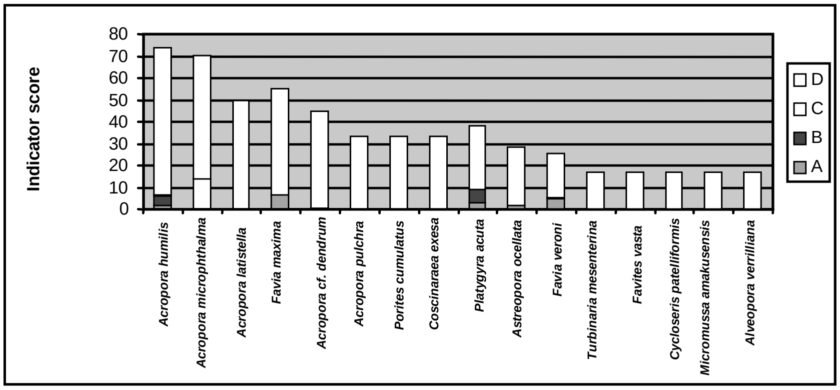

Figure 12: **Key indicator species for coral community D**

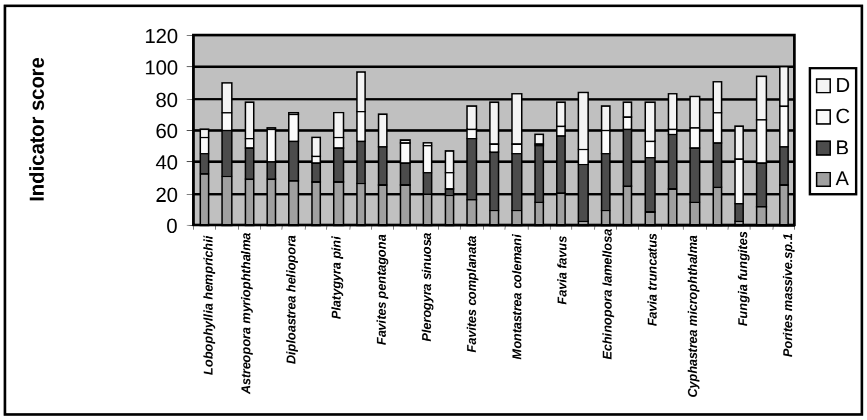

Figure 13: **Ubiquitous species showing low fidelity to particular community types**

Community B: *Montipora* - Coeloseris community.

Key indicator species included various acroporids - *Montipora* (*M. aquituberculata, M. crassituberculata, M. vietnamensis, M. digitata, M. stellata, M. porites*) and *Acropora* (*A. lutkeni, A. accuminata, A. verweyi, A. digitifera, A. donei*) and the agariciid *Coeloseris mayeri*. This community had highest average cover of hard corals (> 50 %), moderate cover of soft corals and low cover of dead corals and algae (Fig. 14), highest total abundance, diversity and rarity (Fig. 15). This community occurred in mostly shallow areas of moderate - high exposure, good water clarity, and with high levels of reef development. This community was restricted to the S.E. - N.E. coasts of Hon Tre (Fig. 8) and at present is not represented in MPA Core Zones (Fig. 1).

Given the importance of Community B in terms of most ecological attributes, including cover, diversity and hosting species otherwise rare in MPA waters (Figs. 14, 15), its conservation through inclusion as Core Zone or through other management measures is recommended as a priority.

Community C: Fungiid - mixed community

This community was composed of species with comparatively low levels of abundance and fidelity, including the acroporids *Acropora tizardi* and *A. exquisita* and *Montipora hirsuta*, the pocilloporid *Seriatopora* guttatus, the fungiids *Lithophyllon mokai, Cycloseris sommervillei* and *Fungia taiwanensis*, the poritids *Porites cf. sillimaniana* and *P. cf. ornata*, and faviids *Playgyra ryukyuensis* and *P. sinensis*. This community had low average cover of hard corals and moderate cover of dead corals, soft corals and algae (Fig. 14) and also scored lowest among the 4 community types for total abundance, diversity and rarity (Fig. 15). Although scoring lowest among the communities for rarity, this community supports a relatively high proportion of the new distribution records, including *Montipora hirsuta*, *Fungia taiwanensis* and the *Porites* spp. (Table 13). This community occurred mostly in near-shore areas of low - moderate water clarity, exposure and reef development (e.g. Hon Mieu, Hon Tam, Hon Mot, Rock, N.W. Hon Tre, Fig. 8) and is poorly represented in MPA Core Zones at present (deeper sites at Hon Mun).

Community D: *Acropora* community

Key indicator taxa included the acroporids *Acropora humilis*, *A. microphthalma*, *A. latistella*, *A. pulchra* and *Astreopora ocellata*, the faviids *Favia maxima*, *F. veroni*, *Favites vasta* and *Platygyra acuta*, the poritids *Porites cumulatus* and *Alveopora verriliana* and mussid *Micromussa amakusensis*. This community had moderate to high average cover of hard corals, highest average cover dead corals and soft corals and moderate cover of algae (Fig. 14) and scored moderately for total abundance, diversity and rarity (Fig. 15). This community occurred in mostly shallow areas of moderate exposure, water clarity and reef development. This community is represented in MPA Core Zones at Hon Mun, Hon Cau and Hon Vung (Figs. 8, 1).

+ Ubiquitous corals

In contrast to the key indicator species described above, a large suite of coral species was relatively ubiquitous, showing little fidelity to a particular community type, but rather occurring commonly in several (Fig. 13). These taxa were composed predominantly by massive and encrusting faviids (e.g. *Diploastrea heliopora, Platygyra pini, Favia, Favites, Montastrea, Cyphastrea* spp.). Other ubiquitous taxa included the mussid *Lobophyllia hemprichii*, acroporid *Astreopora myriophthalma* and fungiid *Fungia fungites* (Fig. 13). These species were all widely distributed and common (rank abundance > 2) in at least some of their sites of occurrence and almost certainly have locally viable populations.

There were highly significant differences among the 4 community types in key ecological variables, notably for total abundance, diversity and rarity and cover of hard corals and dead corals (Table 13, Figs. 14, 15, 16). Rarity (RI) was best represented in Community B, although locally rare species occurred in all community types (Fig. 16).

Table 13: **1-way ANOVA of differences among the 4 coral community types in terms of total abundance, diversity, Shannon-Weiner index and Rarity Index**

Attribute	Total abundance	Diversity	Shannon-Weiner index	Rarity Index
% SS	45.341	39.733	38.848	35.858
F-Ratio	8.848	7.032	6.776	5.963
P	< 0.0001	0.001	0.001	0.002

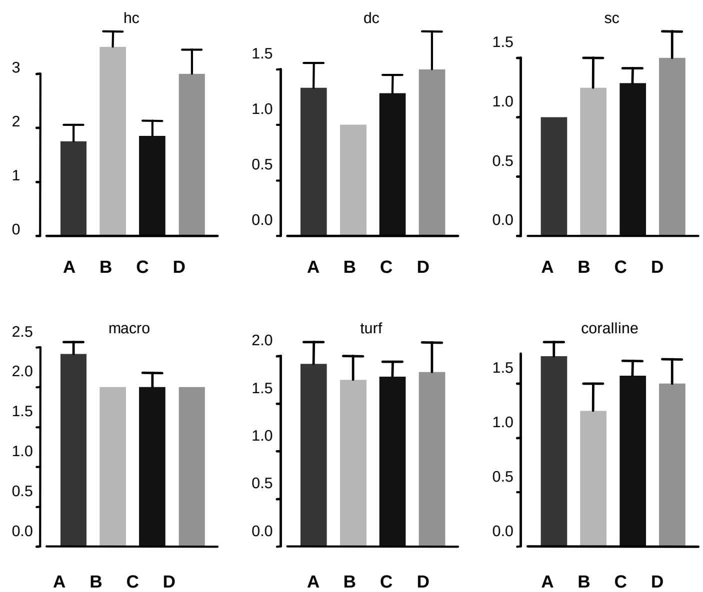

Figure 14: **Differences among the four coral community types in terms of benthic cover, where hc - hard coral, dc - dead coral, sc - soft coral, macro - macro-algae, turf - turf algae, coralline - coralline algae. Y axis: average cover expressed as the rank scores (see Table 1)**

b) Reef communities

A similar set of analyses was conducted for all taxa combined (corals, fish, macro-benthos and algae) for the 13 locations. These analyses identified 3 major reef community types (CL1 - CL3, Fig. 17), broadly distributed in terms of prevailing oceanography and environmental conditions. Communities CL1 and CL3 occur predominantly in the shallow and deep sites of offshore locations respectively, and are represented in MPA Core Zones at Hon Vung, Hon Cau and Hon Noc (Figs. 17, 1). The diverse sites at S.E., E and N.E. Hon Tre (Bai Bang) as represented in Coral Community B, also cluster with the communities CL1 and CL3 when all taxa were analyzed together (compare Figs. 8 and 17). The third reef community type (CL2, Fig. 17) is distributed mostly in near-shore locations, and is represented in MPA Core Areas at Hon Mun and Hon Rom.

The offshore communities CL1 and CL3 scored higher than the near-shore CL2 for total abundance, diversity, Shannon-Weiner index and Rarity index (Fig. 18), primarily because of the depauperate nature of some near-shore sites badly affected by predation, river run-off, destructive fishing and other impacts (see later and Vo *et al.* 2002). Notably, some sites supporting CL2 were similar in the ecological attributes as CL1 and CL3 (Fig. 19).

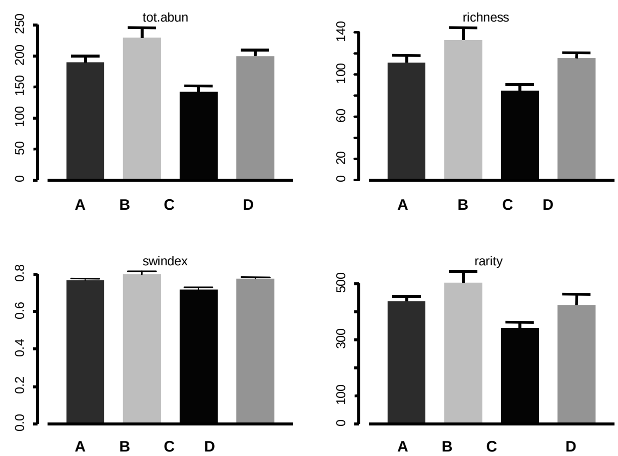

Figure 15: **Differences among the four coral community types in terms of total abundance (tot.abun), diversity (richness), Shannon-Weiner index of evenness-dominance (swindex) and local rarity index (rarity)**

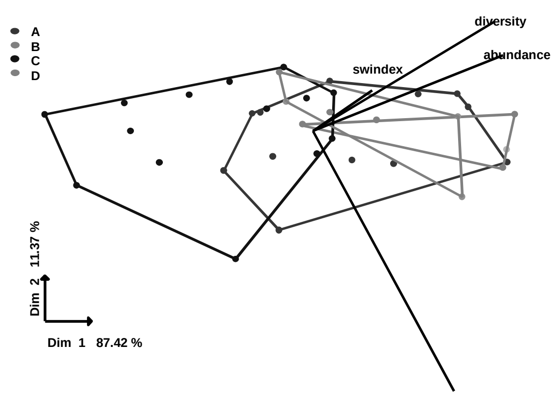

Figure 16: **Relations among the 4 coral community types and the different ecological indices (abundance, diversity - richness, Shannon-Weiner index and Rarity). Convex hulls delimit sites in each community. Vectors point in the direction of the highest scores for each index. The first two dimensions explain 99 % of the total variance**

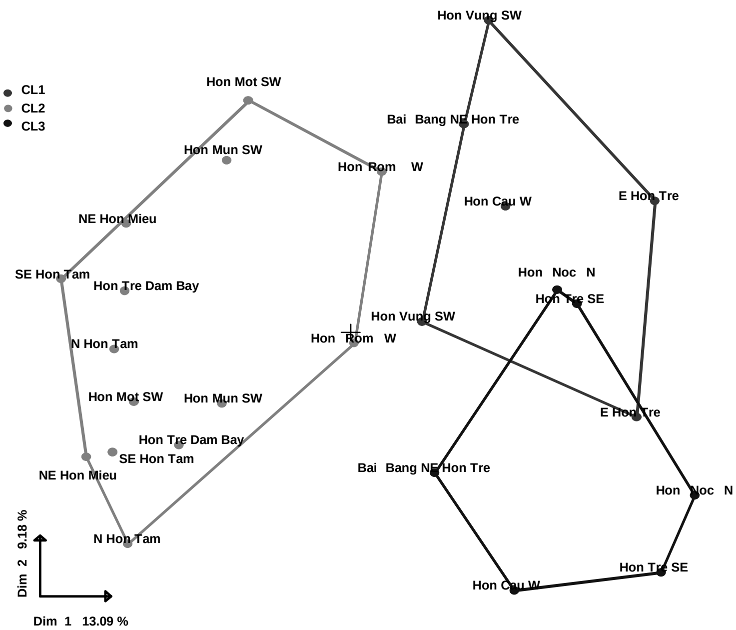

Figure 17: **Biplot of reef community types (all taxa combined) defined by hierarchical clustering (Euclidian distance metric, complete linkage fusion strategy) of species-abundance in the bio-inventories of 26 sites, 13 locations. Convex hulls delimit the distribution of sites in three broad community types CL1 - CL3. Dimensions 1 and 2 account for ~ 22 % of the observed variance**

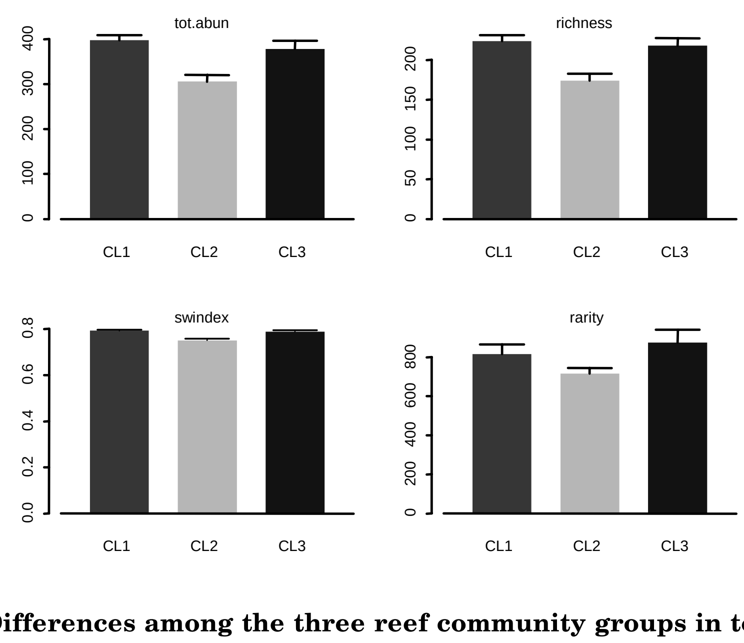

Figure 18: **Differences among the three reef community groups in terms of total abundance (tot.abun), diversity (richness), Shannon-Weiner index of evenness-dominance (swindex) and local rarity index (rarity)**

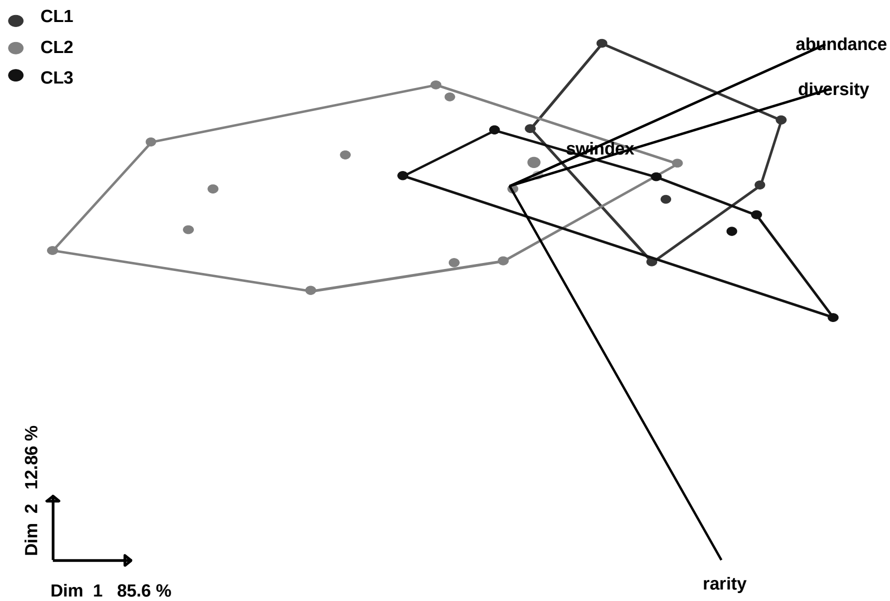

Figure 19: **Relations among the 3 reef community types and the different ecological indices (abundance, diversity - richness, Shannon-Weiner index and Rarity). Convex hulls delimit sites in each community. Vectors point in the direction of the highest scores for each index. The first two dimensions explain 98 % of the total variance**

c) Rarity and population viability

A large suite of species had locally restricted distributions (occurring in < 10% of sites overall), many of which were also locally rare in their sites of occurrence (rank abundance of 1, Table 1). At least some of these are unlikely to form locally viable populations. For example, the euphylliid coral *Catalophyllia jardineri* was recorded from a single individual. This beautiful species is highly desired, both for the aquarium trade and for its ornamental skeleton, and its local rarity in MPA waters is almost certainly attributable to over-collecting. Among the fishes, most of the few remaining target species in the commercially-important groups Serranidae, Lutjanidae and Lethrinidae were locally rare, and also of small sizes, and it will require some years before local populations can recover, provided effective management of the fisheries occurs.

2.6. Present status – disturbances:

Hon Mun MPA coral reefs ranged in condition from good, exhibiting high living coral cover, low dead coral cover, moderately - highly diverse coral, fish and macro-benthos assemblages to bad, exhibiting very high levels of dead coral cover and depauperate assemblages of corals, fish and macro-benthos. On average across the 18 locations surveyed, impacts from sediments, blast and poison fishing, anchoring, coral bleaching, predation and coral diseases were minor, although at some individual sites most of these impacts reached severe levels (Table 14). In this respect it should be noted that these locations were selected in terms of assessing biodiversity, rather than as a random sample of reef condition, and thus represent a biased sample of overall level of impact to reefs in MPA waters (e.g. compare with Vo *et al*. 2002). With this important caveat, worst affected sites were on the N. and S. coasts of Hon Tre, attributable respectively to destructive fishing and river run-off (N. coast) and crown-of-thorns seastar predation (S. coast). These impacts were reflected in the levels of injury sustained by the corals present (Fig. 20).

Table 14: **Summary statistics for environmental and ecological impacts, 36 survey sites in 18 locations, Hon Mun MPA**

Environmental - ecological variable	Mean (s.e.)	Range	Median	Mode
Sediment (rank 0 - 3)	1 (0.2)	0 - 3	1	1
Blast damage (rank 0 - 3)	0.6 (0.1)	0 - 3	0	0
Anchor damage (rank 0 - 3)	0.4 (0.1)	0 - 3	0	0
Poison damage (rank 0 -3)	0.1 (0.1)	0 - 1	0	0
Crown-of-thorns seastars (count)	1.0 (0.4)	0 - 10	0	0
Drupella snails (rank 0 - 3)	0.9 (0.1)	0 - 2	1	1
Bleaching (rank 0 - 3)	0	0 - 1	0	0
Coral diseases (rank 0 - 3)	0.3 (0.1)	0 - 3	0	0

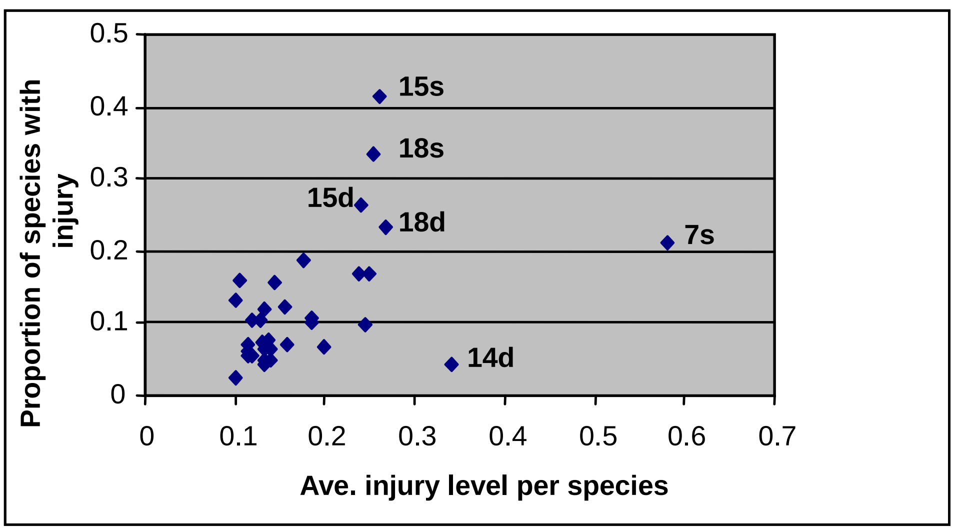

Figure 20: **Scatterplot of sites in terms of the proportion of coral species with injury and average levels of injury per species**

a) Levels of injury

Both the percentage of species that were injured and the average levels of injury per species ranged widely among sites (0 to ca. 40 % of species injured, with average injury levels per species from 0 to > 50 %, Fig. 20). As noted above, sites with highest injury occurred on Hon Tre (Sites 7s - Dam Bay, S. Hon Tre; sites15s, 15d - Dam Tre, N. Hon Tre; sites 18s, 18d - rock, N.W. Hon Tre). Most other sites were in better condition, with average injury levels and proportion of species injured of less than 20 %.

Highest injury and mortality were sustained by acroporids, fungiids and poritids (Table 17). Some of these species had sustained high levels of injury in half or more of the sites in which they occur. For some species, recovery may be fostered through local recruitment, as healthy populations occur at other sites in MPA waters. For some species however, with apparently very restricted distributions and low abundance (low effective population sizes, Maruyama & Kimura 1980) within the MPA, recovery may be a prolonged process. For these species, recruitment may be mostly reliant on dispersal of larvae from further afield (Scheltema 1986, Harrison & Wallace 1990).

Table 17: **Coral species exhibiting high levels of injury, Hon Mun MPA. Species that are locally rare and thus highly prone to local extinction are bolded**

Species	**Proportion of 36 sites in which the species occurred**	**Proportion of those sites with injured colonies**	**Average injury per site**
Acroporidae			
Acropora cytherea	0.47	0.47	0.28
Acropora hyacinthus	0.33	0.33	0.33
Acropora insignis	0.42	0.2	0.33
Acropora lutkeni	0.11	0.25	0.3
Acropora microphthalma	0.31	0.36	0.35
Acropora nasuta	0.5	0.06	1
Acropora nobilis	0.44	0.56	0.21
Acropora plana	0.44	0.13	0.25
Acropora wallaceae	0.06	0.5	0.4
Euphylliidae			
Catalophyllia jardineri	0.03	1	0.5
Mussudae			
Acanthastrea hillae	0.08	0.33	0.4
Fungiidae			

Fungia concinna	0.75	0.11	0.33
Fungia fungites	0.56	0.1	0.25
Fungia horrida	0.06	0.5	0.3
Fungia repanda	0.72	0.04	0.3
Pocilloporidae			
Seriatopora hystrix	0.69	0.12	0.27
Poritidae			
Porites cylindrica	0.39	0.14	0.65
Porites massive sp. 1	1	0.86	0.21
Porites massive sp. 4	0.06	1	0.25
Porites nigrescens	0.67	0.21	0.32
Siderastreidae			
Psammocora profundacella	0.14	0.2	0.5
Dendrophylliidae			
Turbinaria peltata	0.78	0.21	0.23

2.7. Management Recommendations

- Sites of special conservation significance:

From the perspective of conservation of the coral reef communities, several aspects were considered to be of particular importance in making recommendations for amendment of the zoning scheme (also see Margules *et al.* 1988, Done 1995, DeVantier *et al.* 2000a,b):

- Achieving representativeness across the different community types in relation to their geographic distributions around the MPA;

-Conserving viable populations, particularly of species with restricted distributions and low abundance;

- Conserving sites of outstanding diversity, coral cover, and replenishment potential;

- Minimizing risk of future biodiversity loss in terms of the small extent of the individual communities, and their particular susceptibility to both localized and regional disturbances;

- Providing for future research opportunities. These coral communities provide unique opportunities for ecological, biogeographic, evolutionary and environmental - climatological studies.

From the perspectives of resistance and resilience in the face of future disturbance, and of maintenance and replenishment of populations, it is considered particularly important to protect sites that:

- Have been unaffected or little affected by disturbance;

- Host species with restricted distributions, considered to be uncommon or rare throughout their distribution ranges (e.g. for corals see Veron 2000).

As noted above, at present the Core Zones do not provide suitable representation of the broad communities (notably coral community B, Appendix 2), its outstanding biodiversity, rare species, and high replenishment potential. Thus S.E. - N.E. Hon Tre, supporting Coral Community B, is recommended for highest conservation status (Core Zone) buffered inside larger areas (Buffer Zone) incorporating a greater range of environmental conditions than the individual sites themselves. The near-shore communities, with outstanding examples at N.E. Hon Mieu, S.E. Hon Tam and S. Hon Mot, are also only poorly represented in Core Zones (e.g. Hon Mun) at present, and additional management measures may be deemed appropriate to conserve these sites.

ACKNOWLEDGEMENTS

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REFERENCES

1. Alder J., 1996. Have tropical marine protected areas worked? An initial analysis of their success. *Coastal Management* 24: 97-114.
2. Allen G. R., and R. Steene, 1994. Indo-Pacific Coral Reef Field Guide. Tropical Reef Research 378pp.
3. Barkman J. J., H. Doing, and S. Segal, 1964. Kritische bemerkungen und vorschlage zur quantitativen vegetationsanalyse. Acta Botanica Neerlandica 13: 394-419.
4. Behairy A. K. A., Sheppard C. R. C. and M. K. El Sayed, 1992. A review of the geology of coral reefs in the Red Sea. *UNEP Regional Seas Reports and Studies* No. 152, 36p.
5. Colin P. and C. Arneson, 1995. Tropical Pacific Invertebrates. Coral Reef Press, California, USA, 296pp.
6. DeVantier L. M., G. De'Ath, T. J. Done, and E. Turak, 1998. Ecological Assessment of a complex natural system: A case study from the Great Barrier Reef. *Ecological Applications* 8: 480-496.
7. DeVantier L. M., Turak E., Al-Shaikh K. A. and G. De'Ath, 2000a. Coral communities of the central-northern Saudi Arabian Red Sea. *Fauna of Arabia* 18: 23-66.
8. DeVantier L. M., Turak E., Al-Shaikh K. A., Cheung C. P. S., Abdul-Aziz M., De'ath G., Done T. J., 2000b. Ecological indicators of status of coral communities for Marine Protected Areas Planning: Case studies from Arabia. In: *Information Management and Decision Support for Marine Biodiversity Protection and Human Welfare: Coral Reefs*. Lloyd, D., Done, T.J. & Diop, S. (Eds),

Australian Institute of Marine Science – United Nations Environment Programme Publ.

9. Done T. J., 1982. Patterns in the distribution of coral communities across the central Great Barrier Reef. *Coral Reefs* 1: 95-107.
10. Done T. J., 1995. Ecological criteria for evaluating coral reefs and their implications for managers and researchers. *Coral Reefs* 14: 183-192.
11. Dufrene M. and P. Legendre, 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs* 67: 345-366.
12. Fabricius K. and P. Alderslade, 2000. Soft Corals and Sea Fans A comprehensive guide to the tropical shallow-water genera of the Central-West Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Townsville, Australia, 264pp.
13. Goslinger T. M., Behrens D. W. and G. C. Williams, 1996. Coral Reef Animals of the Indo-Pacific. Sea Challengers publ., Monteray, California, 314pp.
14. Gubby S., 1995. Marine Protected Areas Principles and techniques for management. Conservation Biology Series. Chapman & Hall, London, 232pp.
15. Harrison P. L. and C. C. Wallace, 1990. Reproduction, dispersal and recruitment of scleractinian corals. In: Dubinsky, Z. (ed.) *Coral Reefs (Ecosystems of the World 25),* Elsevier Science, Amsterdam, pp. 133-207.
16. Hoeksema B. W., 1989. Taxonomy, phylogeny and biogeography of mushroom corals (Scleractinia: Fungiidae). Zoologische *Verhandelingen* 254, 295pp.
17. Jongman R. H. G., C. J. F. ter Braak, and O. F. R. van Tongereren, 1995. Data Analysis in Community and Landscape Ecology. Cambridge University Press, 299pp.
18. Kenchington R., 1990. Managing Marine Environments. New York, Taylor & Francis.
19. Margules C. R., A. O. Nicholls, and R. L. Pressey, 1988. Selecting networks of reserves to maximize biological diversity. Biological *Conservation* 24: 115-128.
20. Maruyama T., Kimura M., 1980. Genetic variability and effective population size when local extinction and recolonization of subpopulations are frequent. Proceedings National Academy of Sciences USA 77: 6710-6714.
21. Miller I. R., and G. De'ath, 1995. Effects of training on observer performance in assessing benthic cover by means of the manta tow technique. *Marine and Freshwater Research* 47: 19-26.
22. Palumbi S., 1997. Molecular biology of the Pacific. *Coral Reefs* 16: S47 - S52.
23. Van der Maarel E., 1979. Transformation of cover-abundance values in phytosociology and its

effects on community similarity. *Vegetatio* 39: 97-114.

24. Veron J. E. N., 1986. Corals of Australia and the Indo-Pacific. Sydney and London: Angus and Robertson, Australia, 644pp.
25. Veron J. E. N., 1995. Corals in Space and Time The Biogeography and Evolution of the Scleractinia. University of New South Wales Press, 321pp.
26. Veron J. E. N., 2000. Corals of the World. 3 Vols. Australian Institute of Marine Science.
27. Veron J. E. N. and C. C. Wallace, 1984. Scleractinia of Eastern Australia. Part V: Family Acroporidae. *Australian Institute of Marine Science Monograph Series* VI, 483pp.
28. Veron J. E. N. and M. Pichon, 1976. Scleractinia of Eastern Australia. Part I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae. *Australian Institute of Marine Science Monograph Series 1*, 86pp.
29. Veron J. E. N. and M. Pichon, 1980. Scleractinia of Eastern Australia. Part III. Families Agaraciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae, Dendrophylliidae.. *Australian Institute of Marine Science Monograph Series* IV, 471pp.
30. Veron J. E. N. and M. Pichon, 1982. Scleractinia of Eastern Australia. Part IV. Family Poritidae. *Australian Institute of Marine Science Monograph Series* V, 210pp.
31. Veron J. E. N., Pichon M., and M. Wijsman-Best, 1977. Scleractinia of Eastern Australia. Part II. Families Faviidae, Trachyphyllidae. *Australian Institute of Marine Science Monograph Series* III, 233.
32. Vo S. T., Hodgson G., 1997. Coral Reef Of Vietnam: Recruitment limitation and physical forcing. Proceeding of 8th Coral Reef Symposium. Panama. 1997. I: 477-482.
33. Vo Si Tuan, Hua Thai Tuyen, Nguyen Xuan Hoa, Lyndon Devantier, 2002. Shallow water habitats of Hon Mun Marine Protected Area, Nha Trang bay, Vietnam: Distribution, extend and status 2002. Collection of Marine Research Works, 2002, XII: 179-204
34. Wallace C. C. & Wolstenholme J., 1998. Revision of the coral genus *Acropora* (Scleractinia: Astrocoeniina: Acroporidae) in Indonesia. *Zoological Journal of the Linnean Society* 123: 199-384.
35. Wallace C. C., 1999. Staghorn Corals of the World. CSIRO publ., Australia, 421pp.
36. Well J. W., 1954. Recent corals of the Marshall Islands. Prof. Pap. US. Geol. Surv., 260-I: 385-486.
37. Whittaker R. H., 1972. Evolution and measurement of species diversity. *Taxon* 21: 213-253.
38. Wilkinson C. R., 2000. Status of Coral Reefs of the World 2000.

Australian Institute of Marine Science.

39. WWF Vietnam Marine Conservation Southern Survey Team. 1993. *Survey Report on the Biodiversity, Resources Utilization and Conservation Potential of Hon Mun, Nha Trang, S. Vietnam*. WWF, Gland, Switzerland.