**Collection of Marine Research Works, 2002, XII: 179-204**

# SHALLOW WATER HABITATS OF HON MUN MARINE PROTECTED AREA, NHA TRANG BAY, VIETNAM: DISTRIBUTION, EXTENT AND STATUS 2002

**Vo Si Tuan [1], Hua Thai Tuyen[1], Nguyen Xuan Hoa[1], Lyndon DeVantier[2]**
**[1] Institute of Oceanography (Nha Trang)**
**[2] IUCN Hon Mun MPA Pilot Project**

ABSTRACT The recently gazetted Hon Mun Marine Protected Area, Nha Trang Bay, Khanh Hoa Province, central-southern Vietnam supports a diverse array of coastal and marine habitats - coral reefs, seagrass beds, mangrove stands, sandy beaches, cobble-boulder beaches and rocky shores - in a relatively small area (160 $km^2$). Distribution and extent of habitats is related to the mainland - oceanic gradient, degree of physical exposure, influence of the Cai River, and the different geomorphological and topographic features of the nine continental islands in the MPA. Seagrass beds, composed by at least seven species, and with cover ranging from < 10 % to > 75 %, are well developed in sheltered sandy-muddy areas on W. and N. coasts of Hon Mieu and Hon Tre. Small mangrove stands (< 1 ha), composed of three species, also occur in sheltered inter-tidal areas of the deeply-incised bays of N. and S. Hon Tre. Coral communities, occasionally with high living cover (~ 50 %), are distributed around most islands, although of generally small areal extent and with little true reef development, as most communities occur directly on sub-littoral boulders and island bedrock. Highest average hard coral cover (> 50 %) was developed on Hon Mun, Hon Cau and Hon Vung, justifying their selection as 'Core Zones' in the Temporary Zoning Plan for Hon Mun MPA. Highest cover of recently dead corals (~ 10 % on average and approaching 100 % in patches) was on S. and N. Hon Tre and S. Hon Vung, mostly caused by predation by crown-of-thorns sea stars and destructive fishing methods (blasting and poisons). Other threats and impacts include anchor tourist & diver damage; bioerosion by sea-urchins; coral diseases; sediments, nutrients and other pollutants in flood run-off, shipping; and coral bleaching. Over-fishing poses the most urgent threat, both directly through destructive methods and indirectly through complex cascading effects on community ecology. Few locations with abundant demersal fishes remain in MPA coastal waters, the result of extensive and intensive over-exploitation, both legal and illegal. The N.E. coast of Hon Tre supports seagrass beds and mangroves, key habitats not included in MPA Core Zones at present. Providing that local village support can be engendered and adequate enforcement assured, conservation of representative examples of these key habitats should help in replenishment of brood stocks and restocking of commercially and artisanally exploited species, and facilitate ecologically sustainable use of these renewable natural resources.

# CAC HE SINH THAI BIEN CUA KHU BAO TON BIEN HON MUN: PHAN BO VA HIEN TRANG 2002

**Vo Só Tuan[1], Höa Thai Tuyen[1], Nguyen Xuan Hoa[1], Lyndon DeVantier[2]**
**[1]Vien Hai Döông Hoc (Nha Trang)**
**[2]Dö an Khu bao ton bien Hon Mun**

TOM TAT Vung bien cua khu bao ton bien Hon Mun thuoc vònh Nha Trang tænh Khanh Hoa la nôi thuan lôi cho sö ña dang ve he sinh thai bien vôi sö co mat cua ran san ho, tham co bien, röng ngap man va vung ñay mem hoac vach ña. Phan bo va qui mo cua cac he phu thuoc vao ñieu kien tö nhien, anh höông cua ñat lien, ñac ñiem ñòa hình cua 9 hon ñao. Cac tham co bien vôi ít nhat 7 loai ñöôc ghi nhan va ño phu tö 10 – 75% phat trien ô nhöng vung ñöôc che chan co nen ñay la bun cat ô phía tay va bac cua Hon Mieu va Hon Tre. Cac dai röng ngap man (<1ha) chæ phan bo ô vung trieu cua cac vònh kín ô bac va nam Hon Tre. Cac quan xa ran san ho phan bo ô hau het cac vung ven ñao vôi cau truc ran khong ñien hình chiem öu the. Tính trung bình ño phu cua san ho cöng vao khoang 13% (giao ñong tö <1-75%), cua san ho chet khoang 8% (<1-50%) va cua san ho mem khoang 5% (<1-50%). Ño phu trung bình cao nhat cua san ho cöng (>20%) thuoc ve cac khu vöc Hon Mun, Hon Cau va Hon Vung, nhöng nôi ña ñöôc löa chon lam vung loi trong phan vung tam thôi khu bao ton bien. San ho mem phong phu nhat ô Hon Cau, Hon Vung va Hon Tam. San ho chet nhieu nhat (trung bình 10% va co nôi len 100%) ô phía nam va bac Hon Tre, nam Hon Vung. Nguyen nhan gay chet co the la do sao bien gai va ñanh ca huy diet nhö dung chat no hoac Cyanua). Nhöng tac ñong khac can tính ñen bao gom tha neo böa bai, du lòch bat can, xoi mon sinh hoc do cau gai, benh san ho, lang ñong tram tích, nhiem ban höu cô va cac chat khac do chat thai tö song Cai, dau va chat gian tau cua tau thuyen, tay trang san ho do tang cao nhiet ño nöôc bien. Khai thac qua möc la ñe doa lôn nhat do tac ñong tröc tiep cua ñanh bat huy diet va gian tiep do lam mat can bang sinh thai. Viec chæ mot so ít ñiem con lai cac loai ca kinh te la dau hieu cua sö khai thac qua möc (hôp phap va phi phap). Mat ño ca con töông ñoi ô Hon Mun, Hon Cau va Hon Vung - nhöng nôi ñöôc löa chon la vung loi va ô ñong Hon Tre – nôi co ty le san ho song / san ho chet tot nhat (>6 : 1). Vung lan can thuoc ñong bac Hon Tre co phan bo cua tham co bien va röng ngap man chöa ñöôc khoanh vao vung loi tam thôi hien nay cua khu bao ton. Tren cô sô nhöng ket qua nay, hoat ñong bao ton can xac ñònh ro hôn cac khu vöc öu tien trong chien löôc lau dai nham phuc hoi nguon bo sung cho cac quan the thuy sinh vat va cac loai kinh te cung nhö duy trì tính ben vöng sinh thai cua vung bien thuoc khu bao ton.

## I. INTRODUCTION

Vietnam is developing an integrated network of Marine Protected Areas to conserve representative examples of its globally significant coastal and marine biodiversity and to provide for ecologically sustainable use of its renewable natural resources (e.g. fisheries). As an initial step in this process, the recently gazetted Hon Mun Marine Protected Area (MPA) was

established in Nha Trang bay, Khanh Hoa province, Southern Central Vietnam in 2002. According to survey on Scleratinia of Vietnam, this region is considered as the most species rich in coastal waters of Vietnam (Vo 1998). The MPA supports high levels of biodiversity in a diverse array of coastal and marine habitats in a relatively small area (160 $km^2$). The MPA is also subject to intense and increasing levels of human use, and to minimize future impact, a set of Temporary Regulations and Zoning Scheme was introduced by the Hon Mun MPA Authority (April 2002, Figure 1), the Vietnam Government agency responsible for managing the MPA.

The application of a zoning scheme for Hon Mun MPA - the allocation of different levels of protection and use to different places - is a key tool in the management of natural ecosystems (see e.g. Kenchington 1990), widely applied in MPAs globally. Although allocation of areas to different zones is based on a range of socio-economic and ecological considerations and priorities, 'conservation value' is one important consideration, embracing concepts of both representativeness and quality of habitats (e.g. Levy et al. 1996, DeVantier et al. 1998).

From the ecological standpoint in Hon Mun MPA, previous Rapid Ecological Assessments (REA) had identified the conservation value of some key locations (e.g. Hon Mun, Cheung and Vo 1993 - WWF, Institute of Oceanography, Nha Trang), although little ecological information was available for much of the MPA. From the socio-economic standpoint however, levels of use were already known to be high in most areas. Hon Mun MPA supports more than 5,000 local villagers (mostly fisher families), visiting fishermen from other areas of Khanh Hoa Province, and flourishing tourism centred on the adjacent coastal city of Nha Trang (popn. ca. 300,000).

MPA waters are a major supplier of fish and other seafood, through harvest of wild stocks and through increasing development of aquaculture (mostly reef lobsters Panulirus spp. and to a lesser extent groupers Serranidae). The MPA is also developing as a major area of dive tourism and other recreational boating activity, and is thus a prime candidate for a multiple-use zoning approach. Indeed, present and projected future levels of use preclude any other approach, and with rapid expansion of these various uses - both legal and illegal - levels of threat and impact are increasing rapidly. Focused effective management was thus urgently needed, and to this purpose, the preliminary zoning scheme and temporary regulations were implemented by the Hon Mun MPA Authority. The multiple-use scheme applies three zones with different levels of use and protection:

- Transition (minimal limits on access and activities),
- Buffer - intermediate levels of access and extraction, and
- Core - regulated tourism and prohibition of extractive activities (Hon Mun MPA Regulations Booklet 2002 and Figure 1).

These zones and their accompanying regulations were developed from necessity, to minimize the increasing impacts and threats to some key areas of the MPA (e.g. Hon Mun, Figure 1), prior to thorough

ecological and socio-economic review of the zoning scheme, regulations and other management options. As part of this review process, the present paper - the first in a series on Biodiversity Assessment - provides base - line information on the distribution, extent and current status of the marine and coastal habitats of Hon Mun MPA in March - April 2002.

### Aim of the biodiversity assessment

The overall aim of the biodiversity assessment in the Hon Mun MPA is to provide a systematic framework to determine the status of the biodiversity, to identify priority areas for conservation and to develop a system for monitoring changes in ecosystem health and marine resources.

Biodiversity assessment will focus on two specific themes. These are:

- Review the status of knowledge of biodiversity of Nha Trang bay and Hon Mun MPA area, identify gaps and plan and conduct assessment activities to fill these gaps in the information base.
- Establish a bio - physical monitoring system to determine the impacts of the changes in the management regime within the MPA.

This paper documents one aspect of the first theme - habitat assessment surveys undertaken to provide baseline data on the key habitat types and their status around the islands within the MPA. These key habitats include coral reefs, seagrass beds, mangroves, sandy - muddy bottom areas and rocky shores. The surveys used standard field methods to document the extent, distribution and locations and status (types and levels of disturbance) of these habitats.

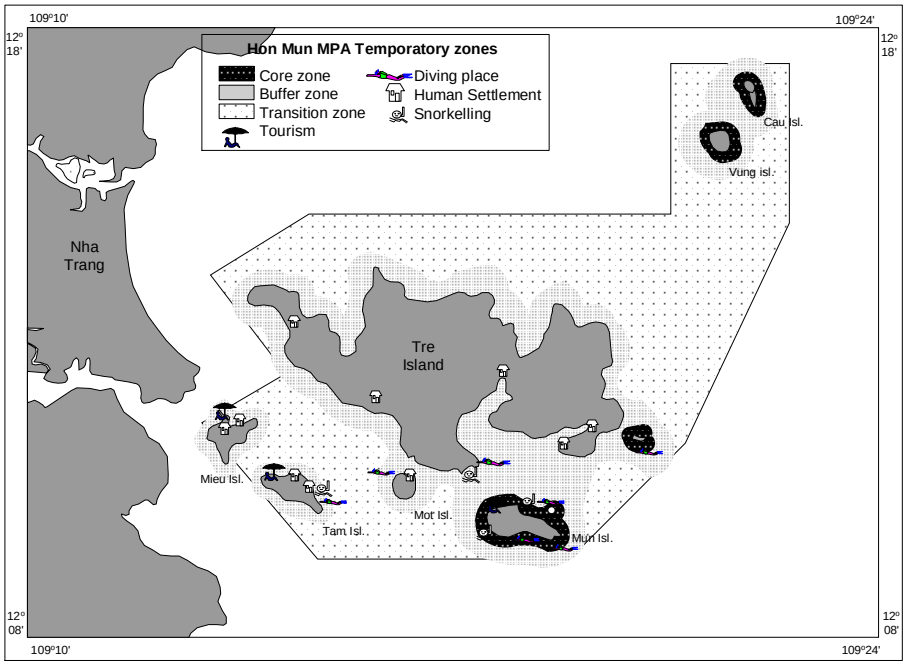


**Fig. 1:** Map of Hon Mun MPA showing the three different zones and some of the uses. Fisheries occur in most areas. Map provided by courtesy of Hon Mun MPA Pilot Project

## II. METHODS

### 1. Site description

The Hon Mun MPA is located in Nha Trang bay, Khanh Hoa province – Southern-Central Vietnam (Latitude: 12 deg. 09 min. - 12 deg. 15 min. N, Longitude: 109 deg. 13 min. - 109 deg. 22 min. E). The MPA encompasses some 160 $km^2$ of offshore waters and island coasts (Figure 1). There are nine islands included in the MPA, situated from ~ 1km to ~ 15 km offshore, providing a wide range of coastal and marine habitat types in relation to prevailing oceanographic conditions and gradients in mainland - oceanic influences. The diverse array of tropical habitats includes coral reefs, soft bottom communities, seagrass beds, small stands of mangroves, sandy beaches and rocky shores. The MPA is located immediately adjacent to the coastal city of Nha Trang and its port at Cau Da. Two rivers, the Cai river in the north and the Be river in the south, flow into Nha Trang bay, with the potential to influence water quality in the MPA. The river catchments and riparian vegetation have been extensively modified for agriculture and aquaculture in recent decades.

### 2. Field methods

The distribution, extent and status of the coastal and marine habitats were assessed using the manta-tow method. Manta-tow is a standard field method of REA, employed and recommended by the Global Coral Reef Monitoring Network (GCRMN, English et al. 1997). It requires little technical field support, making it useful for isolated locations, and has been employed in both REA and monitoring on the Great Barrier Reef, Australia, and other reef regions since the 1970s (e.g. Kenchington 1978, Oliver et al. 1995, Sweatman et al. 1998).

The present surveys were undertaken from small motor boats supplied by NIO and the IUCN Hon Mun MPA Pilot Project. Manta-boards, data-sheets and other field equipment were supplied by NIO. Highly trained observers were towed behind the small boat at a set speed around all the island perimeters in March-April 2002. Manta-towing requires good field conditions to be most effective, and fortunately water clarity was usually adequate (10 m or more, other than in small areas in the deeply incised bays on Hon Tre, Table 1) with clear skies and low cloud cover throughout. Surveys were conducted between 8.20 am and 3.20 pm to ensure adequate underwater illumination for accurate assessment. Each manta-tow was of 2 min. duration, at which time the boat stopped and a set of standard observational data (Table 1) was recorded onto waterproof data-sheets. The precise geographical position was also recorded using portable GPS (grid system WGS 84).

The boat drivers ably handled maintenance of appropriate survey position during manta-tow, particularly in areas of complex coastal geomorphology, by use of a standard signaling system between boat driver and observers. As far as practicable and depending on the particular sub-littoral terrain, the tow path was over areas of 4 - 8 m depth, allowing satisfactory observation of a ca. 5 - 10 m wide swathe of habitat - representing a 'haphazard' sample of the coastal sublittoral benthos. Some small areas with very deep water (e.g.

eastern sides of Hon Cau, Hon Vung and Hon Mun) were unsuitable for manta-tow. Here the sub-littoral habitats consist of steep - vertical island bedrock descending to > 20 m depth - beyond the underwater visibility range of the observers. Even with the tow boat moving as close to the cliff face as sea conditions and safe practice permitted, the observers were unable to view the sub-littoral communities. Additionally, areas of intensive aquaculture activities (e.g. western and northwestern parts of Hon Mieu) were unsuitable, because of the many floating and submerged lines, nets and other underwater obstacles and because of the often heavy boat traffic. These areas were assessed as far as practicable by spot-check dives where the same categories of information were recorded.

For coral and seagrasses, visual estimates of their percentage cover of the substratum were assigned to standard ranked ordinal categories (Table 2). These broad categories have been shown to be relatively insensitive to biases among different observers (Miller & De'ath 1995, Miller & Muller 1998) and capable of discriminating among contrasting benthic assemblages (Done 1982, DeVantier et al. 1998). Recent modifications to the first percent cover category (1- = 1-5 %, 1+ = 6-10 %), as made for manta-tow in the Long-term Monitoring Program of the Great Barrier Reef in Australia (AIMS LTM Program, Sweatman et al. 1998), were employed (Table 2).

**Table 1:** Manta-tow details for the nine islands in Hon Mun MPA, 2002

| Island | Date(s) of survey | Total tow number | Average cloud cover (low, medium, high) | Average underwater visibility (mean, median, mode) |
|---|---|---|---|---|
| Hon Tam | 22 March | 28 | low | 8m, 7m, 12m |
| Hon Mot | 23 March | 22 | low | 11m, 12m, 12m |
| Hon Rom | 25 March | 5 | low | 22m, 20m, 20m |
| Hon Mieu | 23 March, 7 April | 11 (5 tows, 7 spot-checks) | low | 5m, 4m, 6m |
| Hon Tre and Hon Noc | 25-28 March, 6 April | 206 | low | 9m, 10m, 10m |
| Hon Mun | 26 March | 22 | low | 17m, 20m, 20m |
| Hon Cau | 7 April | 6 | low | 11m, 10m, 10m |
| Hon Vung | 7 April | 6 | low | 10m, 10m, 10m |
| Total: 9 Islands | 8 days | 306 tows | low | 10m, 10m, 12m |

Rationale and methods for most of the survey parameters are explained in detail elsewhere (e.g. Oliver et al. 1995, English et al. 1997, Sweatman et al. 1998) and require no further explanation here. However, assessment of several parameters does require additional explanation, as detailed below:

**Massive corals:** Large, old massive or boulder corals are an important structural element of coral reefs world-wide, forming the medium-term (centuries) basis of complex reef

communities and providing major framework elements in long-term reef-building (millennia). These species grow slowly, at ~ 5 - 15 mm radial expansion each year, and some species (e.g. massive Porites spp.) contain in their skeletons proxy records of environmental conditions (e.g. river run-off, sea temperature) during their lifetimes and thus are important recorders of climate change (Isdale 1984). Their distribution within the MPA was thus of interest from geomorphological and environmental viewpoints, and the presence of large colonies (> 2 m diam.) was noted during the tows (Table 2).

**Abundant fish:** Fish abundance is particularly difficult to quantify both because of the mobility of some species and differences in diurnal patterns of activity. The surveys therefore focused on the larger demersal 'site-attached' or 'home-ranging' species - mostly reef-associated (e.g. serranids, lutjanids, lethrinids, haemulids, ballistids, acanthurids, scarids, labrids), which tend to be present in their home ranges most of the time, rather than their pelagic counterparts (e.g. tuna, mackeral). The relative abundance of these demersal fishes in each manta-tow was assessed as the presence / absence of fish schools, a relative measure for comparison of locations within MPA waters. The measure does not indicate absolute abundance or provide a comparison with other areas outside the MPA (Table 2). Similarly for sea urchins, estimates of abundance were relative within MPA waters (Table 2).

**Blast fishing:** Blast fishing leaves a characteristic signature in reef areas - ranging from shattered corals to large holes (craters) in the reef matrix. Blast fishing was both widespread and intense in some parts of the MPA and, where observed, impacts were assigned to one of three ranked categories: Present / Common / Abundant (Table 2).

**Poison fishing:** Poison fishing impacts are comparitively difficult to identify because the evidence is not as characteristic as that of blast fishing, creating problems in the definitive subsequent assignment of cause of coral death. For example poison fishing, coral disease, predation by crown-of-thorns seastars or Drupella snails, and coral bleaching all have similar ecological effects - partial or total mortality of corals and can all leave similar evidence after the event. Notably, coral diseases and crown-of-thorns sea stars are present in Hon Mun MPA waters, although no recent coral reef bleaching has occurred in Hon Mun MPA during the winter - spring period of 2001-02, with water temperatures remaining close to average at time of survey. To separate the likely impact of poison fishing from the other impacts, effects of poison fishing were defined as pale coloured corals surrounded by otherwise healthy reef areas. This definition was based on prior personal observations of the Institute of Oceanography survey team, and provided for conservative estimates of the extent of poison fishing, as it only included recently affected corals, not those that had been dead for some time, and excluded predation by crown-of-thorns seastars and damage from coral diseases (see later). Corals deemed to be recently affected by poison fishing were counted on each tow (Table 2).

**Coral diseases:** Diseases such as ‘white band' and 'black band' have

characteristic etiologies of gradual progress across the affected coral colony surface, visible as a white or black band separating the remaining living coral from the adjacent dead coral surface. Corals affected in this manner were counted on each manta-tow (Table 2).

**Table 2:** Benthic attributes and % cover categories used during manta-tow survey, Hon Mun MPA, 2002

| Parameter | Measure (each manta-tow) | Unit of measure |
|---|---|---|
| Island name | | |
| Date | | |
| Time | | |
| Cloud cover | visual estimate | As proportion of sky covered by cloud |
| Direction | location on island | e.g. NW corner, S side |
| Latitude | degree, minute, decimal minute | Taken with portable GPS, WGS 84 |
| Longitude | degree, minute, decimal minute | Taken with portable GPS, WGS 84 |
| Manta-tow number | count | For each island (1 … n) |
| Underwater visibility | visual estimate | metres |
| Substratum type | category | Rock, Sand, Rubble, Mud, Reef, Mix |
| Live hard coral cover | category (1-5) - rank % cover | 0 = absent, 1- = 1-5 %, 1+ = 6-10 %, 2 = 11-30 %, 3 = 31-50 %, 4 = 51-75 %, 5 = 76-100 % |
| Dead hard coral cover | category (1-5) - rank % cover | 0 = absent, 1- = 1-5 %, 1+ = 6-10 %, 2 = 11-30 %, 3 = 31-50 %, 4 = 51-75 %, 5 = 76-100 % |
| Soft coral cover | category (1-5) rank % cover | 0 = absent, 1- = 1-5 %, 1+ = 6-10 %, 2 = 11-30 %, 3 = 31-50 %, 4 = 51-75 %, 5 = 76-100 % |
| Crown-of-thorns seastars | count - category | Number (1 … n) and Present / Common / Abundant |
| Coral scars | count | Recently dead white patches on corals |
| Diseased corals | count | Characteristic disease etiology - e.g. 'white-band', 'black-band' |
| Bleached corals | presence / absence | Partially blanched - totally white corals |
| Anchor damage | count | Smashed - fragmented corals |
| Blast fishing damage | category (1-3) | Blast 'craters' - Present / Common / Abundant |
| Poison fishing damage | count | Poisoned pale corals |
| Large massive corals | presence / absence | Massive corals > 2 m diameter |
| 'Abundant' Fish | yes / no | Presence of schools of fish - a comparative measure within Hon Mun MPA waters |
| Sea urchins | category (1-3) | Present / Common / Abundant |
| Seagrass | growth-form, category (1-5) - rank % cover | Very short, Short, Oval, Long / Ranks 1 - 5 as per coral cover |
| Recommended site for taxonomic survey | yes / no | Areas supporting representative or unique benthic assemblages - communities |
| Notes | | Any outstanding biological - ecological - geographic - human usage or other features |

**Crown-of-thorns seastars:** The coral-feeding Crown-of-thorns seastar Acanthaster planci is a natural feature of Indo-Pacific coral reefs, although marked episodic increases in abundance (population outbreaks) in some areas (e.g. Great Barrier Reef, Australia; Ryukyu Islands, Japan) have been related to relaxation of predation pressure (notably from fishes and snails removed by overfishing) and to increasing nutrient enrichment from river run-off (see Moran 1986, Birkeland and Lucas 1990, Sapp 1999 for reviews). During the surveys it became apparent that large numbers of crown-of-thorns seastars were present in some areas of the MPA. The seastars were counted and/or categorized as Present / Common / Abundant (Table 2). Individuals from the aggregated populations on Hon Tre and Hon Vung were sampled for:

- size - aboral diameter (cm)
- arm number and injury - regeneration
- gender
- reproductive status.

**Coral reef bleaching:** Bleaching, the whitening of corals and other reef species following expulsion of their endo-symbiotic micro-algae (zooxanthellae) and / or photosynthetic pigments following physiological stress, has increased dramatically in distribution, extent and intensity in recent years (Glynn 1991, 1993, Brown 1997, Wilkinson et al. 1999). Bleaching can be triggered by a wide variety of stresses, often working in synergy, including fluctuations in salinity, turbidity, and temperature. Levels of coral mortality from bleaching depend on the intensity and duration of the stress, ranging from negligible (complete coral recovery) to severe (near-total coral mortality) across a range of spatial scales from the individual coral colony to the reef-scape to the reef province. Large-scale 'mass' bleaching events are usually associated with periods of elevated sea temperatures, with the largest event on record occurring during the 1998 El Nino - Southern Oscillation. Future climate change scenarios suggest that bleaching events are likely to become both more common and more severe, with serious adverse effects for reef communities (Hoegh-Guldberg 1999, Wilkinson et al. 1999). In some reef areas of Hon Mun MPA, high sea temperatures during the 1998 event caused bleaching (Wilkinson 2000), although impact appeared to be mitigated by local upwelling of cooler waters, with relatively minor subsequent coral mortality (unpublished data). Evidence of coral bleaching - partially blanched to completely white corals - was noted during the surveys (presence / absence, Table 2).

### 2.1. Quality assurance

The manta-tow method assigns either binary (presence / absence) or broad, ordinal ranked categories to most parameters assessed. These categories have been shown to be relatively insensitive to biases introduced through observer variability or other sources (e.g. Fernandez et al. 1990, Miller & De'ath 1995). For the other parameters - recorded as counts - the results provide conservative estimates of their abundance and impact. The potential for bias in the field data from observer variability was further reduced by:

- use of the same highly trained staff (Mr. Tuyen, Mr. Hoa and Dr. DeVantier) throughout the surveys,

- conduct of a methods review workshop prior to the surveys,
- regular field checks and comparison of scores during the surveys,
- Data entry checking procedures to ensure accuracy of data.

### 2.2. Data storage and analysis

Field data-sheets were filed at NIO. Data were stored in EXCEL at the end of each day. Summary descriptive statistics (e.g. mean, median, mode) were generated from the field data for the overall assessment, for each island and for the relatively large island of Hon Tre: southeast coast (Tows 1-40), entire south coast (Tows 1-80), north coast (tows 81-162) and east coast (tows 163-206). For graphical presentation of the coral cover results, the mid-point of the ranked cover category from each tow was used (e.g. category 1- = 3 % cover, category 1+ = 8 %, 2 = 20 %, 3 = 40 %, 4 = 63 %, 5 = 88 %) to calculate means and standard errors.

## III. RESULTS

### 1. Distribution and extent of habitats

**Overview:** The nine islands in the MPA area, located from ~ 1km to ~ 15 km offshore, provide the topographic basis for a wide range of coastal and marine habitat types, developed in relation to prevailing oceanographic conditions and gradients in mainland - oceanic influences. The diverse array of tropical habitats includes coral reefs, soft bottom communities, seagrass beds, mangroves, sandy beaches and rocky shores. Coral reef communities occur in patches around most of the islands, their structure varying in relation to the degree of physical exposure, with coral species having strong wave-tolerant growth forms predominating in the more exposed areas (e.g. acroporids) and more sediment-tolerant species in the sheltered bays (e.g. poritids, fungiids). On the most exposed coasts and points, rocky shores and steep undersea cliffs are formed of island bedrock and spectacularly large boulders. The rocky shores support mostly sparse benthic cover - related to their highly exposed location directly in the face of seasonally intense wave action. In the most sheltered areas of the large bays on Hon Tre, the coral communities merge into sandy - silty areas, some of which support seagrass beds. Adjacent to the seagrass beds at the inner margins of the deeply incised bays on Hon Tre, small patches of mangroves are developed.

**Coral reefs:** Coral reefs and coral communities fringe parts of all islands, although there is little true reef accretion in most areas. Rather, most coral communities are developed directly on sub-littoral basalt boulders or bedrock, with only minor biogenic in-filling around the boulders. Greatest amount of reef building (long-term accumulation of biogenic reef material) has occurred in patches on the north coast of Hon Tre and to a lesser extent on N. Hon Mun (Figure 2). On N. Hon Tre, reef slopes and narrow sub-tidal 'reef-flats' have developed - notably on the eastern side of the more-eastern of the two large north-facing bays, although blast fishing and other impacts have killed most corals there at present (see later). In total, previous surveys have reported some 200 species of reef-building and soft corals, representing all major growth forms - encrusting - plate, branching,

table, foliose, digitate-club-shaped, massive and mushroom - growing from low tide level to more than 20 m depth in offshore areas with high water clarity.

**Seagrass beds:** At least seven species of seagrass (Halophila ovalis, H. decipiens, H. minor, Thalassia hemprichii, Enhalus acoroides, Cymodocea rotundata, Halodule uninervis form mono-specific - mixed beds in all of the large bays on Hon Tre (both S. and N. facing), on the W. and N.W. sides of Hon Mieu (mostly T. hemprichii and H. ovalis) and to a lesser extent elsewhere (Fig. 2). The area around Vung Me village supports a bed composed predominantly by Halophila minor with some Halophila ovalis. Further east on the north coast of Hon Tre, a large bed of Enhalus acoroides - Halophila ovalis is established in the more-western of the large N.-facing bays (Dam Gaa), while the more-eastern bay (Dam Tre) supports a small bed composed Halophila minor and to a lesser extent Halophila ovalis. Small and / or sparse patches of seagrass are also developed on sandy areas of most islands, including Hon Mot (eastern sand patch) and Hon Mun. The larger seagrass beds provide important nursery grounds for fishes, crustaceans and other species, some of commercial importance. A small artisanal fishery for blue swimmer crabs Portunus spp. exists in the Enhalus seagrass bed at Dam Gaa, N. Hon Tre.

At present, no Dugong occur in the MPA or adjacent coast. It is not known whether the seagrass areas ever supported Dugong populations, although the relatively small extent of seagrasses around the islands would have precluded establishment of large offshore Dugong populations. Larger seagrass beds are reported to occur along the mainland coast, in the vicinity of Cau Da, and on large mainland bays further N. were likly to have these supported Dugong in the past.

**Mangroves:** Three species of mangrove (Rhizophora mucronata, Avicennia officinalis and Lumnitzera racemosa) are present in the MPA, growing in small stands (< 1 ha in area) in the sheltered parts of the large S.-facing bay (Dam Bay) and more-western of the N. facing bays (Dam Gaa) on Hon Tre.

**Muddy - sandy bottoms:** Large amounts of terriginous sediment are transported into MPA waters with the annual flooding of the Cai River (usually from October - December, pers. obs.), causing a seasonally marked increase in turbidity and reduction in water clarity (to < 5 m) as far offshore as Hon Mun, with at present unknown effects on the sessile benthos. Levels of water movement around much of the island coastlines preclude long-term settlement of the very fine silts and mud in shallow coastal waters (< 6m). Muds are deposited in deeper waters and / or transported out of the MPA. Thus most shallow non-reefal or non-rocky areas support sandy patches rather than muds, although shallow areas of fine silts - muds do occur in the inner margins of the deep bays on Hon Tre (Bich Dam, Dam Bay, Dam Gaa) and areas of Hon Mieu and Hon Tam.

Shallow sandy areas are developed as small beaches (< 1 km in length) on Hon Tre (N. and S. coasts), Hon Mieu, Hon Tam, Hon Mot and Hon Mun (e.g. 'Moray Beach'), the sand patches extending offshore to > 10 m

depth in most of these areas. Some of the sub-littoral sandy areas support seagrasses (see above) and / or macro-algae, others are generally clear of macro-benthos. Anecdotal reports indicate that some of these beaches were used as nesting sites by sea turtles in the past. Sea turtles are rarely reported in Nha Trang bay today, and it seems likely that the breeding populations are either highly depleted or locally extinct.

**Rocky shores:** Rocky shores are prominent features around much of the coastlines of all islands. On the exposed headlands and eastern facing coasts, the island bedrock and large boulders form spectacular coastal cliffs continuing steeply underwater as the major sublittoral substrate to depths in excess of 20 m. These exposed rocky shores support encrusting benthic communities composed of sparse corals, algae, molluscs, barnacles and other wave-tolerant species. Some of the small bays on most islands (e.g. Hon Tre, Hon Mot, Hon Tam) are formed of cobbles-boulders rather than sand, many of which border sub-littoral areas of rich coral communities.

## 2. Status of habitats

**Coral reefs:** Coral cover was patchily distributed around the MPA, ranging from < 1 % (sandy - rocky areas) to > 50 % and approaching 100 % in small coral-rich areas (e.g. S.W. Hon Mun, E. Hon Tre, S.W. Hon Mot, S. Hon Tam, Figure 2). There were significant inter-island and within-island (Hon Tre) differences in coral cover in the MPA (Figure 3). Overall, live hard corals covered approximately 13 % of the coastal sublittoral substrate, dead corals covered ~ 8 % and soft corals covered ~ 5 % of the sublittoral (Figure 3). Highest average hard coral cover was developed on Hon Mun (27 %), Hon Vung (23 %) and Hon Cau (22 %), justifying their a priori selection as 'Core Zones' in the Temporary Zoning Plan for Hon Mun MPA (Figure 1). Highest average soft coral cover was also distributed on Hon Cau (22 %), with Hon Vung and Hon Tam also supporting substantial cover of soft corals (> 10 % on average).

Cover of dead corals ranged from < 1 % to ~ 50 % in patches. Worst-affected were reef areas on Hon Tre. Most reefs of the N. coast had been badly damaged by blast and poison fishing and river influences, while some reefs of the S. coast had been damaged by predation by crown-of-thorns seastars. Highest average dead coral cover was at S. Hon Tre and Hon Vung (12 - 13 %, Figure 3), mostly attributable to predation by crown-of-thorns seastars and to destructive fishing methods (see later). The lower average dead coral cover on N. Hon Tre, at 7 %, did not reflect less intense impact there, but rather that reef areas are less widespread along the coast - being interspersed among the steep coastal areas and sandy beaches.

Overall, there remained more live hard coral cover than dead coral cover in the MPA in March-April 2002, the ratio being weakly positive (1.7) for the MPA overall (Figure 4). The strongest positive ratios occurred at E. Hon Tre (> 6), Hon Cau (> 4) and Hon Mun (~ 3). The only area with a ratio of < 1 (higher average cover of dead corals than live corals) was N. Hon Tre (0.7, as described above).

**Large massive corals:** Large massive corals are rare in most areas of the MPA - an observation consistent with the general lack of major reef

building (biogenic accretion) in MPA waters. Most of the sites which did support individual colonies or populations of large massive corals were located on Hon Tre (Table 3), particularly the western sides of the deeply incised bays of Bich Dam and Dam Bay (mostly Porites spp.), and the small bay at the extreme N.E. corner of Hon Tre (Bai Bang). This bay supports the largest colonies of Porites spp. (to ~ 4 m diameter) recorded in MPA waters, some of which could provide valuable environmental data if cored (e.g. Isdale 1984). Other large Porites colonies occur on the eastern-facing reef of Hon Mieu, on S.W. Hon Tre, and S.E. Hon Mot. Two very large colonies of Pavona sp. are developed on the N. coast of Hon Tre, in the small bay forming the western side of the more eastern of the two large bays (Dam Tre).

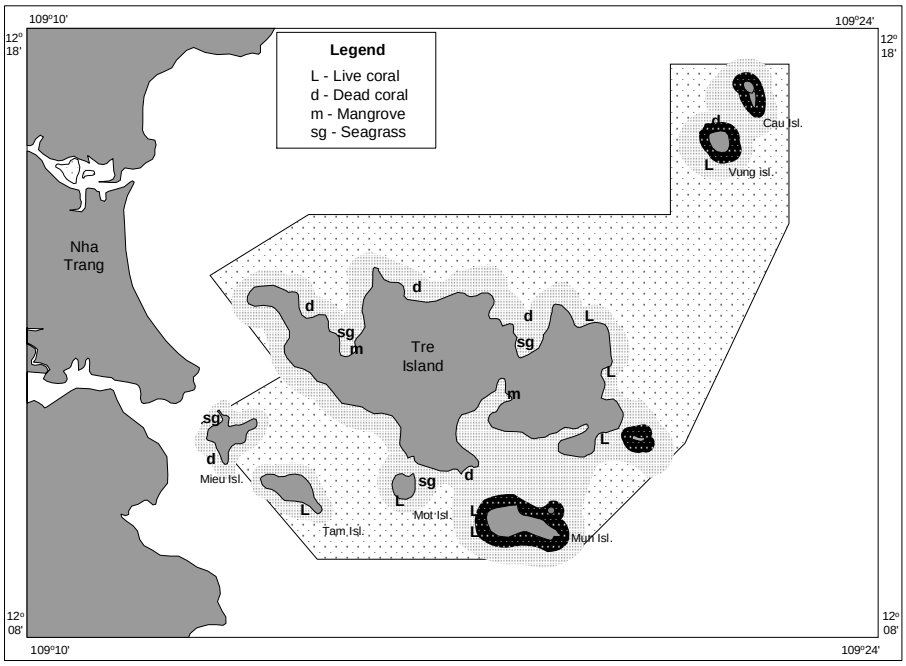


**Fig. 2:** Map showing the distribution of different habitat types within Hon Mun MPA. CR - Coral Reef or community, SG - seagrass bed, MG - Mangrove stand, RS - Rocky shore; SB - Sandy Beach; MS - Muddy-sandy area

**Seagrass beds:** Seagrass beds ranged in benthic cover from < 1 % to > 75 %, with average cover of ~ 20 % overall. As noted above the most extensive beds were developed in the sheltered bays of Hon Tre and Hon Mieu - growing in sandy-muddy areas and occasionally interspersed among seaweeds and corals (e.g. Thalassia hemprichii - Halophila ovalis bed, W. Hon Mieu - seagrass cover < 10 %). The largest single intact bed occurred at Dam Gaa, N. coast Hon Tre - a mono-specific bed of Enhalus acoroides. merging into Halophila ovalis and the very small species on its seaward extent. Cover in this bed ranged from > 75 % in the centre of the Enhalus patch to ~ 10 % on it seaward extent, with an average of ~30 %. Another

large bed in S.W. Hon Tre, composed mostly of Halophila minor and to a lesser extent Halophila ovalis, has average cover of ~ 20 %. The seagrass bed in the more eastern of the two large north-facing bays on Hon Tre, composed mostly of H. ovalis and Halophila minor, has average cover of ~ 40 %. The seagrass beds appeared in relatively good condition, with little apparent local human impact from anchoring or land - river run-off. Seasonal effects of the Cai River flooding in October - December - a likely major influence - are unknown at present.

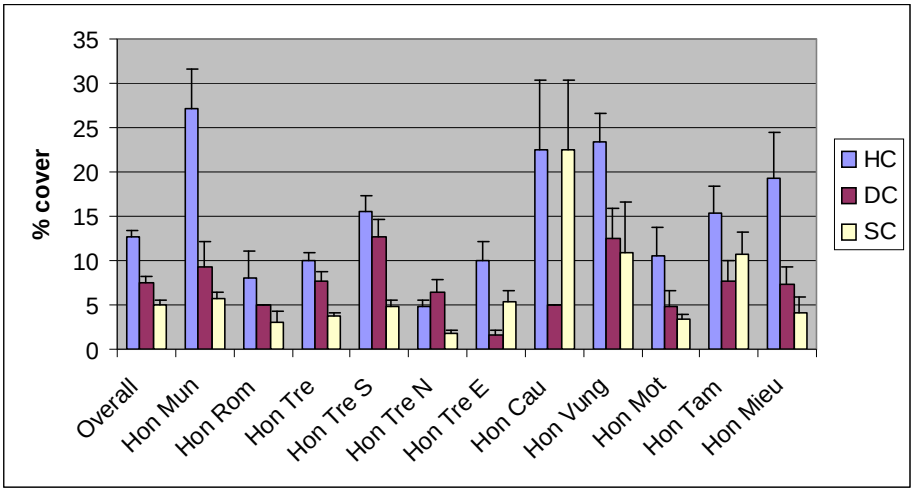


**Fig. 3:** Average percent cover of hard corals, dead corals and soft corals in MPA waters overall and for each island, March-April 2002. Average cover values were determined by assigning the mid-point coral cover value for each category for each individual manta-tow. Error bars represent 1 standard error of the mean

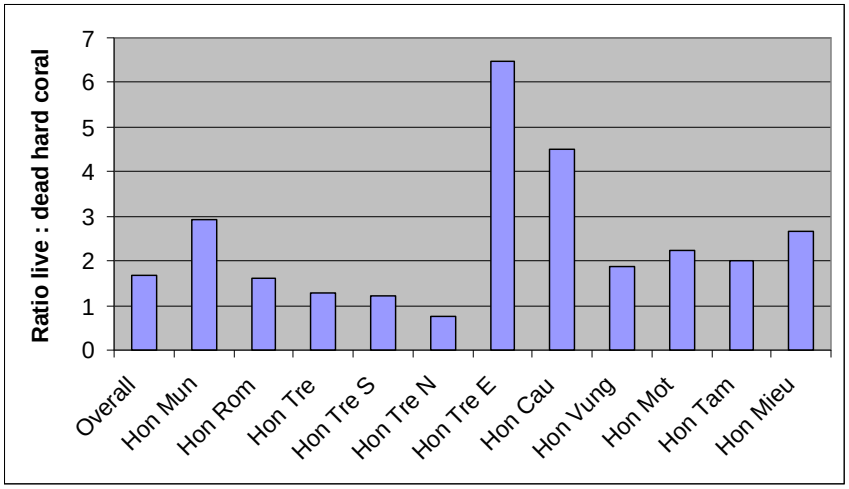


**Fig. 4:** The ratio of average cover of live : dead hard corals in Hon Mun MPA overall and for each island, 2002

**Mangroves:** The physico - chemical conditions and topographic evironment of much of the MPA is not suitable for mangroves, other than in the sheltered bays of Hon Tre where small stands are developed. Anecdotal reports suggest that substantial clearing of these mangrove stands had occurred in the past, notably in Dam Bay. However, more recently the clearing has apparently been reduced and mangroves may now be recolonizing some areas. Although of small areal extent, the mangroves are likely to serve an important role as nursery grounds for fishes, crustaceans and other fauna and their long-term conservation is a matter of priority.

**Table 3.** Distribution and occurrence (% of manta-tows) of large massive corals, 'abundant' fish, blast fishing damage, poison fishing damage, anchor damage, diseased corals, crown-of-thorns seastars and sea urchins in Hon Mun MPA, March - April 2002

| Island | Percentage of manta-tows | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Large massive corals | Abundant fish | Blast fishing damage | Poison fishing damage | Anchor damage | Diseased corals | Crown-of-thorns | Abundant sea urchins |
| Overall | 15 | 20 | 10 | 5 | 8 | 7 | 18 | 15 |
| Hon Mun | 5 | 77 | 5 | 5 | 45 | 18 | 14 | 9 |
| Hon Rom | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| Hon Mot | < 5 | 0 | 0 | 18 | 14 | 9 | 23 | 27 |
| Hon Tam | 0 | 29 | 0 | 0 | 18 | 0 | 25 | 18 |
| Hon Mieu | 27 | 9 | 0 | 9 | 9 | 17 | 18 | 0 |
| Hon Tre & Hon Noc | 20 | 15 | 13 | 2 | 2 | 6 | 16 | 10 |
| Hon Tre sector | 50 (S.E.) | 42 (E.) | 32 (N.) | 6 (N.) | 13 (S.E.) | 10 (S.) | 27 (S.) | |
| Hon Vung | 0 | 50 | 33 | 50 | 0 | 33 | 67 | 17 |
| Hon Cau | 0 | 50 | 17 | 0 | 0 | 0 | 0 | 0 |

**'Abundant' fishes**: As noted above, the survey assessment protocol for abundant fishes provides a relative measure of demersal fish stock sizes within MPA waters, rather than a larger scale comparison with other geographic areas. In this context, 'abundant' indicates the presence of even small schools of any fish - rather than providing any indication of high abundance per se. With this important caveat, in MPA waters overall ca. 20 % of sites supported fish schools. The best areas included Hon Mun (77 % of tows, Table 3), Hon Vung and Hon Cau (50 % of tows), providing additional justification (with coral cover, see above) for their inclusion in MPA 'Core Zones'. The largest schools of fish and highest species diversity were at

E. Hon Tre (42 % of tows), possibly reflecting its relative inaccessibility and isolation (low local human population) and high physical exposure to wind and waves. The area is fished by surface-supplied 'hookah' diving and other methods (with several boats operating during the period of these surveys), but at present retains better stock sizes than elsewhere in MPA waters.

Conversely ca. 80 % of survey sites no longer support any noticable demersal fish schools or large demersal fish (e.g. > 20 cm diameter), attributable to extensive and intensive over-exploitation using both legal and illegal fishing methods. Species composition is seriously depleted across a wide range of different taxonomic groups. Most important groups of food fish, including the snappers (Lutjanidae), groupers (Serranidae) and emperor breams (Lethrinidae) are highly depauperate in species composition, of extremely low local abundance, and when present, individuals are generally of small size. For at least some species, populations are either at the point of local extinction or already locally extinct. Some obvious examples from different taxonomic groups include the highly distinctive and greatly prized table fish 'Napoleon' or 'Maori' wrasse Chelinus undulatus - a major target of the live food fish trade, the sea cucumber 'Sand fish' Holothuria scabra and abalone 'Ass ear' snail Haliotis assanina. Anecdotal reports indicate that commercial fisheries for the sand fish and abalone existed in MPA waters until they became uneconomic through over-exploitation.

## 3. Threats and impacts

The MPA faces a wide range of threats and impacts, ranging from the local through the regional to the global. A by-no-means exhaustive list includes:

a. Local

- Over-fishing, including destructive fishing with blasting and poisons
- Coral predation by population outbreaks of crown - of - thorns seastars
- Anchor damage
- Tourist & diver damage
- Abnormal rates of bio-erosion by large populations of sea-urchins
- Coral diseases
- Ballast water discharge - oil spills

b. Regional

- River flooding & other mainland influences
- Over-fishing by 'outside' fishermen

c. Regional - global

- Coral reef bleaching.

The present extent and impact of some of these threats are discussed briefly below.

## 4. Local - regional threats

**Overfishing:** MPA waters are heavily over-exploited by local villagers and by 'outside' fishermen, mostly from nearby mainland villages in Khanh Hoa Province. Fishing pressure at present is far greater than is ecologically sustainable and anecdotal reports from local village fishermen indicate that catch per unit effort has declined steadily in recent years (Ms. Yen, IUCN Hon Mun MPA Project pers. comm.). Substantial details of the various fishing methods employed in MPA waters are beyond the scope of the present report, but in summary include:

- trawling (mostly in offshore waters away from coral reefs but potentially

affecting juveniles of demersal fish species
- light fishing with lift / push nets - often close to reefs
- gill netting
- purse seine with / without lights
- hookah air diving with / without poisons
- blast fishing
- hook and line
- trolling
- 'Dam dang' fixed net
- other methods

Several of these methods are illegal in Vietnam and / or in MPA waters, including blast fishing, poison fishing, fishing with strong lights (> 10,000 watts) and trawling. In the MPA Core Zones, the recently gazetted Temporary Regulations and associated Zoning Scheme (Fig. 1) prohibit all forms of fishing (with the one exception of the 'Dam Dang' fixed nets, although there is no enforcement of the new regulations as yet (May 2002).

**Blast fishing:** Overall, ca. 10 % of manta-tows had evidence of blast fishing in the form of 'craters' and / or other obvious physical damage to reef areas - a significant figure when it is remembered that extensive sandy areas and rocky shores also formed a substantial part of the survey and in the latter areas blast evidence is not well preserved. The most extensive and intensive blast damage occurred on the N. coast of Hon Tre, where almost one-third of all sites have been affected, mostly to moderate or severe degree (Table 3). Most reef areas on this N. coast had been heavily blasted, with large 'craters' - holes in the reef matrix ~ 1 m deep and 4 - 6 m diameter and / or shattered corals - rubble and large toppled chunks of old reef matrix (~1 m diam.) clearly visible.

Other areas with notable blast damage include the offshore islands of Hon Vung and Hon Cau - although damage here is relatively minor in comparison with N. Hon Tre. Anecdotal information suggests that much of this damage occurred some five - 10 years ago, as the scarcity of fishes has made this practice less economically attractive than previously. Nonetheless blast fishing continues in MPA waters, being clearly audible underwater, with charges detonated regularly in the vicinity of Hon Mun, presenting an on-going threat to ecological integrity.

**Poison fishing:** Definitive assignment of reef damage to poison fishing is fraught with uncertainty because several causes of coral mortality have similar long-term effects and evidence to those of poison fishing - i.e. dead corals and surrounding patches of reef (c.f. characteristic damage following blast fishing). In the present study, as described above, poison fishing impacts were defined as pale coloured corals surrounded by otherwise healthy reef areas. The definition, by only including recently affected corals, not those that had been dead for some time, provided a conservative estimate of impact, particularly as no indication of recent coral bleaching was found in MPA waters (see later).

This important caveat notwithstanding, evidence of poison fishing was found at Hon Mun, Hon Mot, Hon Mieu, Hon Tre and Hon Vung, being most intensive at the latter site (Table 3). Abandoned poison fishing 'squirt bottles' were also observed on the reef at Hon Mot. Overall ca. 5 % of manta-tow sites were affected, with at least some of the surface-supply 'hookah' divers using

poisons to capture fish, both for food and to supply the aquarium trade. The amount and species composition of ornamental fish taken to supply the aquarium trade from MPA waters is unknown. However, the local dive clubs report marked recent declines in ornamental fishes at some sites, suggesting that the practice is continuing. Anecdotal reports suggest that poison fishing is increasing, and with blast fishing, poses an on-going threat to ecological integrity. At least one company exports ornamental aquarium fishes from Nha Trang, and it is recommended that research be conducted into the impact of the aquarium trade on ornamental reef fish stocks in MPA waters.

**Anchor damage:** Overall anchor damage was apparent in < 10 % of survey sites (Table 3), being concentrated around Hon Mun Island (Table 4), where almost half the sites were affected to greater or lesser degree, and focused in areas with the most intensive tourism activities (e.g. 'Moray Beach', South Bay, 'PADI Beach' - N. coast). Most intense damage occurred at Moray Beach (> 3 broken corals per manta-tow). Other sites with noticable damage were in the vicinity of the villages and where fishing boats anchor (e.g. S.E. coast of Hon Tre, Hon Mot, both with < 1 broken coral per tow on average) and near the tourist resort, N. Hon Tam. Given the intensive tourism activity at the sites around Hon Mun (up to 30 boats daily), impacts from anchor damage, although unsightly and of concern, are less than may have been expected (i.e. Hon Mun has some of the highest coral cover and best ratios of living : dead coral in MPA waters, Figs 3, 4).

**Tourist and diver damage:** Physical impacts from tourists and divers (other than caused by boat anchoring) are mostly resrticted to Hon Mun, Hon Mot, Hon Tam and Hon Mieu. In Hon Mun, impacts include breakage of corals through careless diving and littering. The recreational dive companies in Nha Trang encourage their divers and snorkellers to exercise care to avoid damaging corals, and most divers do try to avoid breaking corals. However the large numbers of novice and trainee divers make complete avoidance difficult to achieve. Further, visitors on the tourist 'party' boats receive little to no information or instruction about the need to protect the marine environment and considerable amounts of litter are thrown overboard. Local villagers and outside fishermen also contribute to this litter load. The Hon Mun MPA Project Education and Awareness Unit's recently produced brochures and other targeted education materials and activities should help to address these impacts in future.

**Diseased corals:** Coral diseases - 'white-band' and 'black-band' - were uncommon, occurring at low frequency and restricted to only one or a few coral colonies in ca. 7 % of manta-tow sites overall (Table 3). Highest frequency of occurrence was on tabular Acropora spp. at Hon Vung (33 % of sites), Hon Mun (18 %) and Hon Mieu (17 %), related to the relative prevalence of table corals there. At present, coral diseases pose a relatively minor threat to MPA coral communities in comparison with other forms of disturbance (e.g. destructive fishing, crown-of-thorns seastars).

**Crown - of - thorns seastars Acanthaster planci:** The seastar was

present in low numbers in most coral areas (Table 3), occurring in ca. 18 % of manta-tows overall, around most islands. The seastars were aggregated in 'outbreak' densities (> 100 individuals $ha^{-1}$) at several sites, notably along the south coast of Hon Tre near the western entrance to Dam Bay (Bai Lan Beach) and westwards to opposite Hon Mot. Other large aggregated populations were present on the south coast of Hon Vung and south coast of Hon Mieu, while moderate populations (< 50 $ha^{-1}$) were present on the north coast of Hon Mun (near 'PADI Beach').

**Table 4:** Anchor damage in Hon Mun MPA, March-April 2002

| Island | Site name | No. broken corals | Average incidence/ tow |
|---|---|---|---|
| Hon Mun | overall | 28 | 1.3 |
| Hon Mun | Moray Beach | 16 | 3.2 |
| Hon Mun | North reefs (including PADI Beach) | 5 | 1 |
| Hon Mun | South Bay | 7 | 1.4 |
| Hon Rom | overall | 0 | 0 |
| Hon Mot | overall | 6 | 0.3 |
| Hon Tam | overall | 11 | 0.4 |
| Hon Tam | N. coast | 8 | 1 |
| Hon Mieu | overall | 2 | 0.2 |
| Hon Tre | overall | 13 | < 0.1 |
| Hon Tre | SE coast (E. of Bich Dam-Dam Bay) | 12 | 0.7 |
| Hon Noc | overall | 0 | 0 |
| Hon Cau | overall | 0 | 0 |
| Hon Vung | overall | 0 | 0 |

Samples from the outbreak seastar populations on S. Hon Tre (Bai Lan) and S. Hon Vung indicated a size range of from ca. 28 cm - 57 cm aboral diameter (Table 5), suggestive of ages of three years or more (Moran 1986). All individuals were gravid, both samples being predominantly composed by females, with likely spawning period to follow the full moons of May - August. Level of predation on the seastars, as determined from the proportion of missing / regenerating arms, was minor (17 %) on Hon Tre but much higher on Hon Vung (63 %), suggesting the activity of more predators there (probably including various fishes - triggers, puffers, emporers and possibly the large gastropod mollusc Charonia tritonis). The higher predation rate on Hon Vung is consistent with the fish assessment, which reported larger populations of fishes on Hon Vung than on S. Hon Tre (see Table 3 above).

**Sea urchins:** Like crown-of-thorns seastars, marked recent increases in the abundance of sea urchins in some coral reef areas (e.g. W. Indian Ocean, Caribbean Sea) have been related to relaxation of predation pressure from overfishing. In Hon Mun MPA sea urchins - mostly the long-spined Diadema spp. - were present in most areas, and were abundant (rank category score of 3) in ca. 15 % of sites, notably on Hon Mot (27 % of sites), Hon Tam (18 %) and Hon Vung (17 %, Table 3).

**Table 5.** Summary statistics of the crown-of-thorns seastar population samples at Bai Lan (S. Hon Tre) and Hon Vung, Hon Mun MPA, March-April 2002

| Site | No. seastars sampled | Size range (diam. cm) | Mean, median, mode diam. | % female: male | % seastars with injury |
|---|---|---|---|---|---|
| Hon Tre | 35 | 29 - 57 | 45, 44, 44 | 77 : 23 | 17 |
| Hon Vung | 54 | 28 - 52 | 39, 39, 37 | 63 : 37 | 63 |

**River and mainland influences:** Two rivers flow into Nha Trang Bay - the Cai River in the north, and smaller Be River in the south. Both have the potential to influence water quality and habitat integrity in Hon Mun MPA. The Cai River, flowing into Nha Trang Bay to the north of Hon Mun MPA, has historically exerted a positive influence on the MPA's marine habitats, as evidenced by the flourishing coral reefs that previously existed in suitable areas (e.g. away from steep cliffs) along the N. coast of Hon Tre as recently as the 1970s. The N. coast had the most significant levels of past reef accretion in Hon Mun MPA, indicating that river conditions were historically suitable for coral recruitment, growth and reef-building over the past several millennia.

Today these N. coast reefs have been largely reduced to expanses of dead coral and rubble, in many areas overgrown by macro-algae (mostly Sargassum and Padina spp.). This recent change in condition (an ecological 'phase-shift') can be attributed to the combination of destructive fishing, other disturbances, and recent negative impacts from the Cai River over the past several decades. The precise nature of these negative river impacts is unknown at present, but may include:

- increased nutrient enrichment from agricultural fertilizers and / or aquaculture activities,
- increased turbidity from clearing of riparian vegetation,
- increased pollution from pesticides from agriculture or other land-uses,
- toxic chemical spills.

The dominance of macro-algae and overgrowth of dead corals is a symptom of both nutrient enrichment - a likely result of river inputs - and lack of herbivorous grazing fishes (e.g. scarids, acanthurids) - resulting from overfishing.

**5. Regional - global threats**

**Coral reef bleaching:** During the present surveys, no evidence of recent bleaching was found, water temperatures during the spring period remaining close to normal. Anecdotal reports suggest the presence of coastal upwelling, although the distribution and seasonal patterns of local upwelling areas in Hon Mun MPA are not well documented at present. Such upwelling zones may provide a natural mitigation against the worst effects of future bleaching events. If so, this would provide greater intrinsic value to this MPA through its potential role in replenishment of reef species, and thereby confer greater regional importance for its effective conservation (DeVantier et al. 2000).

## IV. DISCUSSION

### 1. Management recommendations

**Conservation of representative habitats:** High quality coral reefs and

communities are well represented in the temporary Core Zones of Hon Mun (and Hon Rom), Hon Vung and Hon Cau. These sites were well selected in terms of their ecological attributes of coral cover and relatively high abundances of demersal reef-associated fishes. With adequate enforcement, these sites should provide for maintenance of representative examples of some of the different coral communities present in MPA waters (more exposed community types) and also for development of brood stocks and restocking of exploited species in the medium-term (~ 5 - 10 years).

Additional to the present Core Zones in Hon Mun MPA, the best ratio of live : dead coral cover and highest abundance and diversity of fish occurred along the east coast of Hon Tre, presently not included in the Core Zones. This area also has large expanses of steep rocky shore, and smaller areas of cobble-boulder beaches. From the ecological stand-point, the MPA would be well served by providing additional levels of protection to E. Hon Tre during future management planning, providing consensus can be reached with the local communities. Further small areas of high quality reef habitats include S. Hon Tam, S.W. Hon Mot, and S. Hon Tre (Table 6).

Representative examples of several of the key habitat types are not included in Core Zones at present (e.g. seagrass beds, mangroves). Sites with high quality examples of these habitats are listed in Table 6. The conservation of several of these areas should be considered a priority, through zoning or other management measures.

**Fisheries:** At present demersal fish stocks are in low numbers and most remaining fish are of small sizes in coastal areas of the MPA. Indeed for many commercially-important species, effective population sizes are very small to non-existent. Few natural brood stock remain and thus recruitment of new cohorts will rely largely on immigration through dispersal from other areas. The likely success of such recruitment is unknown, but it is likely that recruitment and rebuilding of stocks may be a prolonged process as demersal fish and other commercially-exploited species are in low abundance in many parts of Vietnam and indeed the South China Sea generally (DeVantier and Wilkinson 2002). In this respect, the establishment and enforcement of 'no take' zones, as exemplified by the Core Zones in Hon Mun MPA, remains a priority for other key locations in Vietnam, and the planned development of more MPAs is a matter of urgency if the present rapid depletion of coastal fisheries is to be redressed.

'No take' zones have proven effective in restoring fish stocks and contributing to ecologically sustainable local fisheries in other parts of South East Asia (e.g. Philippines), provided that they are not illegally exploited (Russ 1985, Russ and Alcala 1996a,b). This requires both a strong commitment by local and 'outside' fishermen, best developed through co-management, and effective enforcement, best achieved through strong surveillance and policing. Each of these aspects has not been implemented to date anywhere in Vietnam, and their effective pilot application in Hon Mun MPA will require significant effort by the MPA Authority and locals alike.

**Crown - of - thorns seastars:** In Hon Mun MPA, similarity in seastar population size structures between the two samples from Hon Tre and Hon Vung suggest recruitment of a single cohort three to fours ago (i.e. 1998-99). These seastars were developing gametes in April 2002 (e.g. white egg masses in the females) prior to spawning, probably following the full moons from May - August. Following spawning, the seastar larvae drift in the plankton for ~10 days to 2 weeks, and depending on sea surface currents, may remain close to their natal reef or may be carried to distant reefs. Thus some of the seastar larvae from Hon Mun MPA may remain there, may disperse to other parts of Khanh Hoa Province, other areas of Vietnam or even further afield. And similarly, some of the seastars present in Hon Mun MPA in 2002 may have drifted there as plankton from other parts of Vietnam.

**Table 6:** High quality representative habitats in Hon Mun MPA, for consideration as conservation priority

| Habitat type | Island | Latitude | | | Longitude | | |
|---|---|---|---|---|---|---|---|
| Seagrass bed & mangroves | Hon Tre N. coast (Dam Gia) | 12 | 12 | 965 | 109 | 15 | 420 |
| Seagrass bed | Hon Tre N. coast - 2nd NE bay | 12 | 12 | 860 | 109 | 18 | 565 |
| Mangroves | Hon Tre S. coast (Dam Bay) | 12 | 11 | 600 | 109 | 17 | 820 |
| Coral reef | Hon Tre N.E. bay | 12 | 13 | 207 | 109 | 19 | 502 |
| Coral reef | Hon Tre E. cobble bay - N. of Hon Noc | 12 | 12 | 597 | 109 | 19 | 765 |
| Coral reef | Hon Tre E. cobble bay - S. of Hon Noc | 12 | 11 | 362 | 109 | 19 | 553 |
| Coral reef | Hon Mot S.W. cobble bay | 12 | 10 | 463 | 109 | 16 | 370 |
| Coral reef | Hon Tam S.E. cobble bay | 12 | 10 | 14 | 109 | 15 | 52 |

The aggregated seastar populations (outbreaks) at S. Hon Tre, S. Hon Vung and S. Hon Mieu and smaller populations on Hon Mun pose a serious threat to coral communities in Hon Mun MPA, as coral areas are of small extent and of great importance to tourism and fisheries. As noted above, seastar outbreaks have occurred in many Indo-Pacific reef areas over the past 40 years. Although cause(s) of the outbreaks remain controversial (see Moran 1986, Birkeland and Lucas 1990, Sapp 1999 for reviews), the outbreaks have been linked with overfishing of keystone predators (e.g. Giant Triton shellfish Charonia Tritonis and various fishes - ballistids, lethrinids, lutjanids) and changes in water quality in river run-off, both of which may be implicated in Hon Mun MPA. Here extensive over-fishing has reduced predatory fish numbers and Cai River influences are also apparent in seasonal changes in water quality and the proliferation of macro-algae, notably on N. Hon Tre. Importantly, there were much higher rates of predation on the seastars at Hon Vung, where fish stocks remain at higher levels (Tables 3 and 5).

Replenishment of fishes in MPA waters over the next decade through 'no take' zones and other measures may contribute to reducing seastar numbers in the medium - long term. In the short term, because of the importance of conserving the remaining high quality coral areas for fisheries and tourism, 'control programs' to limit the present impact and future reproductive potential of the seastars were conducted in April - May 2002. Individual female seastars can produce millions of eggs each year, and with high fertilization success likely when aggregated in outbreak densities, the seastars have the potential to overwhelm coral communities. Thus the large aggregation of seastars on S. Hon Tre and seastars in the key tourism areas of Hon Mun were targetted, with excellent support provided by the local village divers and the recreational dive clubs of Nha Trang.

More than 600 seastars have been removed from MPA waters at time of writing, and follow-up control exercises are continuing among the dive clubs. Removal of the seastars, with major reduction in the aggregated population sizes, has interrupted the reproductive cycle prior to complete ripening of gametes, and thereby has reduced the potential reproductive output and numbers of seastars in the next generation. However, large numbers of the seastars are also present on mainland and island reefs to the north of Hon Mun MPA, posing a continuing threat to reefs of the MPA through future larval dispersal. Early warning of further recruitment of seastars may be gained through involvement of local divers in monitoring, as is presently being coordinated by the Hon Mun MPA Project.

**Anchor damage**: Sites with major anchor damage were restricted to Hon Mun, notably around 'Moray Beach' and South Bay. Future anchor damage is being minimized by installation of permanent fixed moorings by the Hon Mun MPA Project in suitable locations and implementation of regulations banning anchoring in key areas (Core Zones, see Hon Mun MPA Temporary Regulations 2002).

**River and mainland influences:** Flood run-off from the Cai River and possibly also the Be River has had an adverse effect on some habitats of Hon Mun MPA, notably on N. Hon Tre, through seasonal changes in turbidity, salinity, nutrients and possibly other pollutants. Addressing these impacts is beyond the direct responsibility or capacity of Hon Mun MPA Authority and will require an integrated coastal and hinterland management approach, best fostered through inter-agency cooperation in policy development and implementation (e.g. among Hon Mun MPA Authority, Department of Science and Technology, Provincial People's Committee, relevant communes, villages, non-government organizations and other agencies).

## 2. Conclusions

Hon Mun MPA supports a diverse array of sublittoral habitats, including coral reefs, seagrass beds, mangrove stands, sandy beaches and rocky shores. Some of these habitats remain in good condition, supporting high levels of biodiversity and providing valuable sustenance to local people and revenue through tourism. However, these habitats are under increasing pressure and subject to increasing

damage from a wide range of human and natural impacts, notably destructive fishing, predation by crown-of-thorns seastars, careless anchoring, river run-off and other sources of pollution. The MPA supports some 5,000 local villagers relying to a large extent on fisheries and / or aquaculture for their livelihoods, with major adverse effects on fish stocks from over-exploitation, and habitats from blast and poison fishing. Increasing tourism, mostly from small boats but with major island resort developments underway or in planning, poses both threats through habitat destruction and pollution, and opportunities - including additional income generation for locals and tourism 'user fees' for funding the much needed management initiatives. At present, coastal and marine habitats of Hon Mun MPA are at a critical point, as continued over-exploitation will cause the loss of the remaining high quality areas in a short period. Anecdotal information indicates that some areas have degraded significantly since 1994 when the initial assessment and recommendation for establishment of a MPA were made (Cheung and Vo 1993).

Threats and impacts range from the local through the regional to the global, and their amelioration will require dedicated management aimed at restoring the ecological integrity of the MPA. This should be focused initially on the 'manageable' local impacts, to develop resistance and resilience to the larger regional - global impacts beyond local management control (e.g. coral bleaching - climate change). The Hon Mun MPA Project has already taken important steps towards this goal, through designation of 'no take' Core Zones and associated regulations, and through activities such as the installation of permanent moorings for boats and crown-of-thorns seastar control program. The present assessment supports the initial selection of Core Zones, while also highlighting other key habitats that may be considered for higher levels of future protection, either as Core Zones or through other management measures.

Implementation of the multiple-use zoning approach can greatly mitigate future impacts and facilitate ecologically sustainable development, provided that a high degree of cooperation and compliance with regulations is contributed by both locals and visitors alike, fostered through education and awareness programs and enforced through effective surveillance and policing (Alder 1996, MacClanahan 1999). A higher level of cooperation will be required among government agencies and non-government organizations in the development of integrated coastal and hinterland management of the Cai River, identified as a major impact on the MPA. Integrated coastal management projects are presently being developed in the region, and a similar approach may be considered for Nha Trang Bay when opportunities, funding and logistics permit.

## ACKNOWLEDGEMENTS

This study, which forms part of a continuing series on Biodiversity Assessment in Hon Mun Marine Protected Area, was conducted under contract for the Hon Mun MPA Pilot Project. The authors sincerely thank the Hon Mun MPA Project (supported by the Government of Vietnam, Global

Environment Facility - World Bank, DANIDA and IUCN) and Hon Mun MPA Authority, for support in the conduct of this study.

## REFERENCES


1. Alder, J. 1996. Have tropical marine protected areas worked? An initial analysis of their success. Coastal Management 24: 97-114.
2. Birkeland, C. and Lucas, J. S. 1990. Acanthaster planci: Major Management Problem of Coral Reefs. CRC press, USA.
3. Brown B.E. 1997. Coral bleaching, a review. Coral Reefs 16S.
4. Cheung, C. P. S., and Vo, S. T. 1993. Survey Report on the Biodiversity, Resources Utilization and Conservation Potential of Hon Mun, Nha Trang, S. Vietnam. Vietnam Marine Conservation Southern Survey Team. WWF, Gland, Switzerland.
5. DeVantier, L. M., De'ath, G., Done, T.J., Turak, E. 1998. Ecological assessment of a complex natural system: a case study from the Great Barrier Reef. Ecological Applications 8**:** 480-496.
6. DeVantier, L. M., Turak, E., Al-Shaikh, K. A., Cheung, C.P.S., Abdul-Aziz, M., De'ath, G., Done, T.J. 2000. Ecological indicators of status of coral communities for Marine Protected Areas planning Case studies from Arabia. In: Lloyd, D., Done, T.J., Diop, S. (Eds.). Information Management and Decision Support for Marine Biodiversity Protection and Human Welfare: Coral Reefs. Australian Institute of Marine Science - United Nations Environment Programme Publ.
7. DeVantier, L.M. and Wilkinson, C.R. 2002. Global International Waters Assessment of the South China Sea. Technical Report to Kalmar University, Sweden, Implementing Agency for the Global International Waters Assessment.
8. Done, T. J. 1982. Patterns in the distribution of coral communities across the central Great Barrier Reef. Coral Reefs 1: 95-107.
9. English, S., Wilkinson, C. & Baker, V. 1997. Survey Manual for Tropical Marine Resources 2nd Edition. Australian Institute of Marine Science. 390 pp.
10. Fernandes, L., H. Marsh, P. J. Moran, and D. Sinclair. 1990. Bias in manta tow surveys of Acanthaster planci. Coral Reefs 9: 155-160.
11. Glynn, P. W. 1991. Coral bleaching in the 1980s and possible connections with global warming trends. Trends in Ecology and Evolution 6: 175-179.
12. Glynn, P. W. 1993. Coral reef bleaching ecological perspectives. Coral Reefs 12: 1-17.
13. Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50: 839-866.
14. Isdale, P. J. 1984. Fluorescent bands in massive corals record centuries of coastal rainfall. Nature 310: 578-579.
15. Kenchington, R. A. 1978. Visual surveys of large areas of coral reefs. In: Stoddart, D.R., and R.F. Johannes (Eds.) Coral Reefs: Research Methods. UNESCO: Paris, p. 149-161.
16. Kenchington, R. 1990. Managing Marine Environments. New York, Taylor & Francis.
17. Levy, K., T. F. Young, R. M. Fujita and W. Alevison. 1996. Restoration of the San Francisco Bay-Delta-River system: Choosing indicators of ecological integrity. Report to Calfed Bay-Delta Program and the US Environmental Protection Agency.
18. MacClanahan, T. R. 1999. Is there a future for coral reef parks in poor tropical countries? Coral Reefs 18: 321-325.

19. Miller, I.R., and De'ath, G. 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.
20. Moran, P. J. 1986. The Acanthaster phenomenon. Oceanography and Marine Biology Annual Review 24: 379-480.
21. Oliver, J., De'ath, G., Done, T. J., Williams, D. McB., Furnas, M., and Moran, P. 1995. Long-term Monitoring of the Great Barrier Reef, Status Report no. 1, Townsville: Australian Institute of Marine Science.
22. Russ, G. 1985. Effects of protective management on coral reef fishes in the central Philippines. Proceedings 5th International Coral Reef Congress 4: 219-224.
23. Russ, G. & Alcala, A. 1996 a. Marine reserves rates and patterns of recovery and decline in abundance of large predatory fish. Ecological Applications 6: 947-961.
24. Russ, G. & Alcala, A. 1996 b. Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines. Marine Ecology Progress Series 132: 1-9.
25. Sapp, J. 1999. What is Natural? Coral Reef Crisis, New York: Oxford University Press.
26. Sweatman, H., Bass, D., Cheal, A., Coleman, G., Miller, I., Ninio, R., Osborne, K., Oxley, W., Ryan, D., Thompson, A., and Tomkins, P. 1998. Long-term Monitoring of the Great Barrier Reef. Status Report number 3 1998, Townsville: Australian Institute of Marine Science.
27. Vo S. T. 1998. Hermatypic Scleractinia of South Vietnam. Proc. of Third Int. Conf. on Marine Biology of Hong Kong and South China Sea. Hong Kong, 28 Oct.- 3 Nov. 199. Hong Kong University Press: 11-20
28. Wilkinson, C., Linden, O., Cesar, H., Hodgson, G., Rubens, J., & Strong, A. E. 1999. Ecological and socio-economic impacts of 1998 coral mortality in the Indian Ocean: An ENSO impact and a warning of future change? Ambio 28: 188-196.
29. Wilkinson, C. R. 2000. Status of Coral Reefs of the World: 2000. Australian Institute of Marine Science.