THE MARINE PROTECTED AREA OF NHA TRANG BAY, VIETNAM: INITIAL TRENDS IN RESOURCE STATUS AND UTILIZATION (2002-2005)

Master thesis in International Fisheries Management
(30 credits)
By

Le Doan Dung

Department of Aquatic Bioscience
Norwegian College of Fishery Science
University of Tromsø, Norway

May 2007

Large picture: Overall picture of the Nha Trang Bay MPA

Small picture: Coral reef at the Nha Trang Bay MPA

Source: http://www.nhatrangbaympa.vnn.vn

ACKNOWLEDGEMENTS

First of all, I would like to send deep appreciation to my supervisor Ass. Prof. Jorge Santos for his full support and teaching from beginning to ending my thesis. My study could not be finished without his assistances.

I would like to express that my work would not have been possible without the encouragement of Dr. Chu Tien Vinh, the National Director of Nha Trang Bay MPA, and his authorization to make use of the date repertory available from previous ecological surveys conducted in the MPA. I would like to thank him and his authorization for all precious supports.

My sincere gratitude goes to Norwegian Fisheries College (NFH), Tromsø University and NORAD that have given full knowledge, lectures and funding during studying in Tromsø, Norway. I also give thanks to SEMUT for your financial support to undertake my fieldwork. My two educational years could not be done without RIMF's support.

I also express thanks to Mr. Hector Andrade (Center for Marine Resource Management-MAREMA), Mr. Nguyen Van Quan, and Dr. Dam Duc Tien (HIO), Mr. Ho Van Trung Thu (Nha Trang Bay MPA Authority), Mr. Nguyen Van Long (NIO) and my friend, Toms William for their comments and English review of manuscript.

I would like to thank all my IFM (2005-2007) classmates and Vietnamese friends who have supported part of my life in Tromsø.

I would like to give dear words to my wife, my little twin daughters, my parents and members of my big families, their never-ending love and moral support to me.

Tromsø, 14 May 2007

Le Doan Dung

TABLE OF CONTENTS

ABBREVIATIONS

AIG	Alternative Income Generation
CA	Correspondence Analysis
CCA	Canonical Correspondences Analysis
CPUE	Catch per unit effort
DANIDA	Danish International Development Assistance
DCA	Detrended Correspondence Analysis
GBRMP	The Great Barrier Reef Marine Park
GDP	Gross Domestic Products
GEF	Global Environmental Facility
HIO	Hai Phong Institute of Oceanography
Hp	Horse power
IUCN	The World Conservation Union
MCS	Monitoring, Control and Surveillance
MoF	Ministry of Fisheries
MPA	Marine Protected Area
NIO	Nha Trang Institute of Oceanography
nm	Nautical mile
PCA	Principle Component Analysis
RDA	Redundancy Analysis
REA	Rapid Ecological Assessment
RIMF	Research Institute for Marine Fisheries
VNDs	Vietnamese Dongs (Currency, 16,045 VNDs is equivalent to 1$)
E Hon Tre	East Hon Tre
N Hon Mieu	North Hon Mieu
SW Hon Mot	Southwest Hon Mot
SW Hon Mun	Southwest Hon Mun

ABSTRACT

The marine protected area (MPA) of Nha Trang Bay, in eastern Vietnam, was created in 2002 as a pilot initiative to enable an adequate management of the fringing reef communities, while providing opportunities for alternative livelihoods to the local fisher populations. A re-assessment of the data obtained during the baseline survey performed in 2002 and of an inventory performed in 2005 indicates a reasonable decline in faunal diversity and density in the MPA. Multivariate analyses of a great number of species suggest a cascading effect: a general negative trend in the richness of hard-corals at different depths is associated with an increase in macro-algal cover, and this links with a marked decline in the density of herbivorous fish. The reef of Hon Mun, a core zone at the hearth of the MPA and an attraction for underwater tourists, showed some recovery of the coral cover and density of other macro-invertebrates. Despite the loss in fish density, the structure of the fish food web seemed to remain unaltered. Reefs in the buffer area of Hon Mieu and Hon Mot showed, on the contrary, great declines in the faunal component and a clear increase in algal cover. These reefs are those most affected by human derived impacts, including urban run-off, shipping, silting, mariculture, fishing and tourism. The most distant reef analysed, at Hon Tre, although formally a core zone, is allegedly under strong fishing pressure owing to lack of surveillance enforcement. The major impact, so far, seems to be a marked decline in diversity and density of fish. Whilst the present data were collected during the initial stages of marine protection and need further replication, it is becoming evident that urban development and, particularly, fisheries and mariculture, which depend on great amounts of wild seed and feed collected in the area, may become antagonistic activities to the recovery of the reef to earlier states. Managers devising future management plans have now a base for re-scaling the size and zonation regime of the protected area, as well as that of adjacent industrial activities.

Key words: MPA, Vietnam, Fisheries, Aquaculture, coral reef

1. INTRODUCTION

1.1. General information

1.1.1. Natural and community characteristics

The Nha Trang Bay Marine Protected Area (MPA) comprises nine islands and their surrounding waters (Tung, 2002). The biggest island, Hon Tre, occupies the center of the archipelago (Figure 1.1). The nine islands are located about 1-15 km from the mainland, the East coast of Central Vietnam. The MPA provides the basis for a diverse array and marine habitats, including coral reefs, soft bottom communities, seagrass beds, mangroves, sandy beaches and rocky shores, and associated high levels of biodiversity (Cheung & Tuan, 1993; Tuan, 2002a). The MPA water areas are also fishing grounds for many residents and a number of outsiders, and marine aquaculture has been developing rapidly in recent years with large increases in utilized area. The MPA has also been developing as a major destination for tourism in Vietnam. Moreover, due to a high abundance of larvae, this water area is being considered as a major nursery ground to supplement fish larvae to other coral reefs of Vietnam and maybe Cambodia (Wilkinson, 2000).

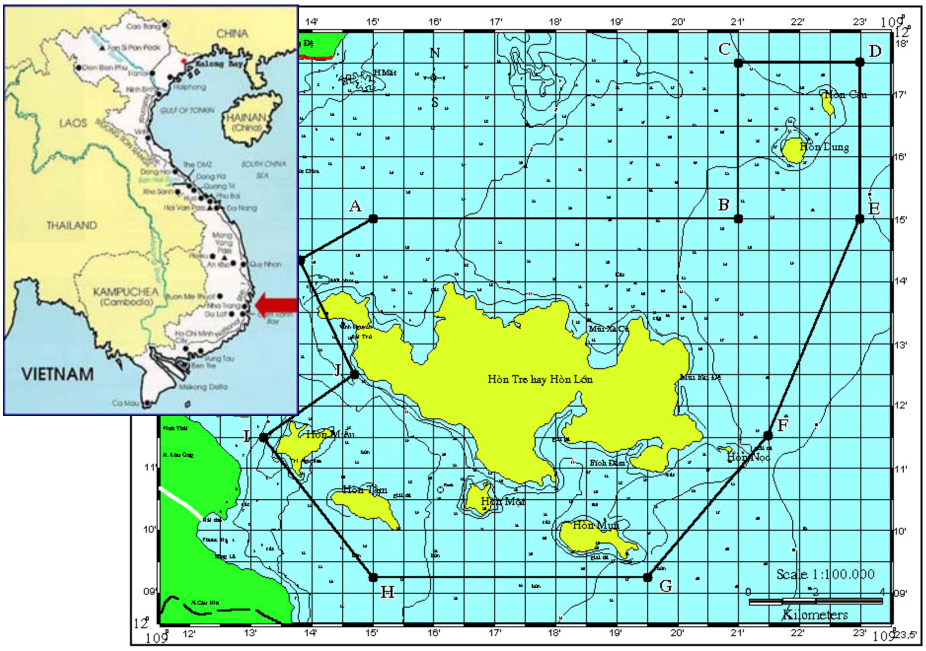


Figure 1.1: Map of Viet Nam showing the Nha Trang Bay MPA location and study areas [Source: Maps cited from (Vinh, 2001)]

1.1.2. Biodiversity and status of recent declines

Biodiversity assessments in May-June, 2002 revealed that the biodiversity of Nha Trang Bay was high, with 350 species of reef building corals, 220 species of demersal fish, 160 species of mollusks, 18 species of echinoderms, 62 species of algae and seagrass (Tuan et al., 2002e). This presented the highest marine biodiversity yet known from Vietnamese coastal waters, and indicates that MPA shares strong biogeographic affinities with neighboring nations and the Indo-West Pacific center of diversity (Tuan et al., 2005b).

Throughout the World, and notably in southeast Asia, coral reefs and their biodiversity suffer threats from a range of direct human activities, increase in global temperature and unpredictable changes of weather (Bryant et al., 1998; J E N Veron., 2000; Spalding, 2001). Coral reefs in Vietnam are no exception (Talaue., 2000). Although they have remained in good condition in a few areas, with coral cover reaching 100%, in many other areas the once-flourishing coral reefs and associated biota have been badly damaged by over-exploitation, illegal fishing and other impacts (Tuan, 2002c; Tuan et al., 2002e). Destructive fishing and over-exploitation for meeting the people's demand for seafood, as well as the aquaculture and tourism industry for outsiders, depleted a large part of coral reefs in Nha Trang Bay, including the northern coast of Hon Tre. Until 2002, many species of reef fish, sharks, mollusks, crustaceans, and particularly targeted species were becoming decreasingly common, or locally extinct, in Nha Trang Bay. Commercially targeted groups such as ornamental angel fishes (Pomacanthidae), groupers (Serranidae), snappers (Lutjanidae) had been in poor condition for more than one decade (Cheung & Tuan, 1993). Overall, coral reefs of the study area were facing threats from a range of local, regional and global impacts (Tuan, 2002a).

1.2. Objectives and zoning of Nha Trang Bay MPA

1.2.1. Objectives

Recognizing its important biodiversity values and the intense and increasing pressures placed upon the marine area by human use, the Government established the first comprehensive MPA of Vietnam in the Hon Mun region in 2002. This was performed with the assistance of the World Conservation Union (IUCN Vietnam program., 2001), and funding of the GEF/World Bank and DANIDA- through the Hon Mun MPA Pilot Project. The objectives of the Hon Mun MPA were *"to enable local island communities to improve their livelihoods and, in partnership with other stakeholders, effectively protect and sustainably manage the* *marine biodiversity at Hon Mun as a model for collaborative MPA management in Viet Nam"* (IUCN Vietnam program., 2001; Wilkinson, 2000). Since then, the MPA was first named Hon Mun, and at the end of 2005 pilot project the MPA was handed over to the local government and re-named Nha Trang Bay MPA. The protected area has two key roles: first, *addressing socio-economic issues of local island communities,* and second, *the sustainable management of marine biodiversity* (Tung, 2002). By working in partnership to improve the livelihoods of local island communities, the project aimed to reduce or eliminate the socio-economic factors driving the gradual degradation of marine habitats and loss of biodiversity within the MPA.

1.2.2. Functional regimes and zoning

On 11 March 2002, the People's Committee of Khanh Hoa Province issued a "*Temporary Regulation and Zoning Scheme"* for the MPA establishment. The scheme sought to promote a management regime for the protection of marine biodiversity, while providing for the regeneration of fisheries stocks and balancing the various uses of the areas.

"The temporary regulation" is a very comprehensive document and it includes: information on specific legislation; regulation of activities within the MPA with regard to boat landing, fishing, aquaculture, tourism, research and education; description of activities related to Monitoring, Control and Surveillance (MCS); and organizational issues including, sustainable finance, the responsibility of the different stakeholders, users operating within the MPA, implementation organizations and managers.

The regulatory instrument considers three functional regimes within the MPA as a basis for zoning:

* Core zones: high level conservation zones (J L Baker B Sc M Env St., 2000) that aims to strictly protect habitat, biodiversity, marine resources and environment, and provide good conditions for scientific research, education and training (Vinh, 2003a). All fishing activities, except for a traditional '*dam dang'* fixed net, are banned in core areas (Tung, 2002).

* Buffer zones: zones where some limited access activities are permitted (J L Baker B Sc M Env St., 2000). Buffer zones are open to traditional fishing gears; however, management activities are focused on 'no anchoring', 'no trawling' zones and planned aquaculture (Tung, 2002).

* Transition zones: or 'general use' zones in which various managed uses and activities are permitted, if those activities do not adversely affect the core protected areas (J L Baker B Sc

M Env St., 2000). Their aims are to protect habitats and maintain ecosystem, to make a good condition for Alternative Income Generation (AIG) and for other activities, such as scientific research, education, training, tourism and entertainment (Vinh, 2003a). The transition zone is open to traditional fishing gears, and management focus on limiting trawling activities (Tung, 2002).

Table 1.1: Nha Trang Bay MPA regulations

Activities	**Zones**		
	Core	**Buffer**	**Transition**
Diving and Snorkeling	Yes	Yes	Yes
Education	Yes	Yes	Yes
Research and Training	Yes	Yes	Yes
Mooring on buoys	Yes	Yes	Yes
Tourism boats	Limited	Yes	Yes
Jetski and Parasailing	No	Yes	Yes
Fishing	No	Yes	Yes
Anchoring	No	Limited	Yes
Aquaculture	No	Limited	Yes
Spear and Dive fishing	No	Limited	Limited
Trawling and Destructive fishing	No	No	No
Polluting activities	No	No	No

Source: (Hon Mun Authority., 2002)

Zoning of Nha Trang Bay MPA

Initially, core zones were defined as water areas that surrounded four islands with the high biodiversity value, including Hon Mun, Hon Noc, Hon Vung and Hon Cau (upper Figure 1.2, red colour areas) (Tung, 2002). Since the end of 2005, there have been changes in the zoning scheme. The most significant changes were that Hon Noc was removed from a core zone, and the north-facing bays of northeastern Hon Tre and southern corner of Hon Tre, known for high cover of seagrass, were added into a core zone (sanctuary). Thence, core zones are found surrounding five islands: Hon Mun, Hon Vung, Hon Cau, northeast Hon Tre and a part of Dam Tre. SE Hon Mieu, SW Hon Tam, S Hon Mot and northern corner of Hon Tre were categorized as a habitat rehabilitation zone. In four islands, Hon Tre, Hon Mieu, Hon Tam, and Hon Mot, buffer zones were defined as a 300m belt surrounding core zone. Transition zones were the last to be added to the MPA, and are shown in light colour in Figure 1.2 (Hon Mun Authority., 2002; Vinh, 2003a).

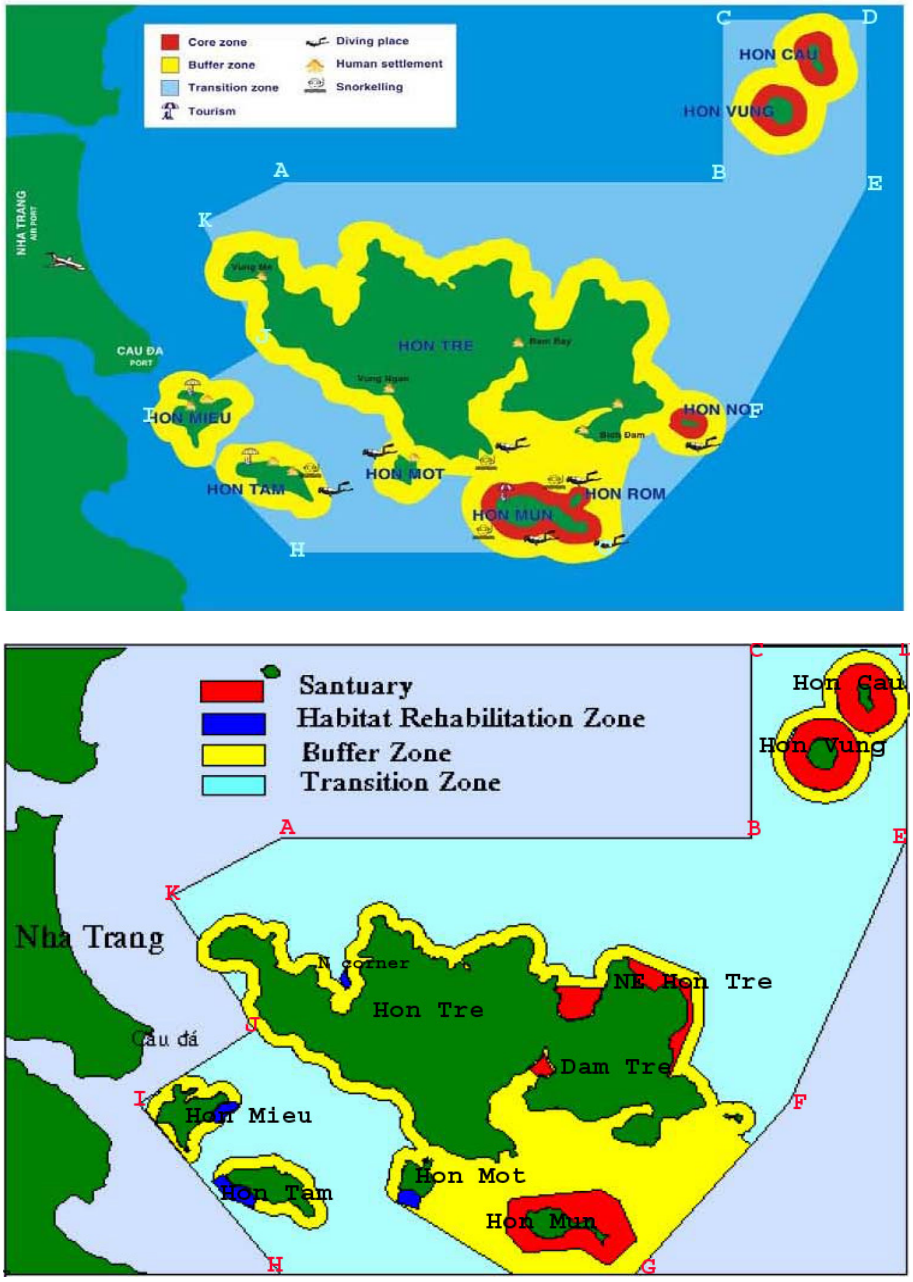


Figure 1.2: Nha Trang Bay MPA's zoning from 2002 to 2005 and rezoning scheme (below)
Figure courtesy of Nha Trang Bay MPA Authority

1.3. Size and zonation of coral reef MPAs

A principle applies in selecting and delineating coral reef protected areas was stated by Salm (2000) is that fewer large protected areas are to be favored over a greater number of smaller ones. Also according to him 'aggregation' (establishing fewer larger areas) seems the best approach coupled with an effective use zoning scheme. The optimal size of a protected reef area is designed around a strictly controlled sanctuary zone or core zone, the optimal area encompasses sufficient reef to be self-replenishing for all species. Charles (2003) gives the example for the case of the protected area of the Chagos Archipelago, Indian Ocean, a too low percentage (3%) of total area of shallow reefs is protected, thus, this protected area seems to collect some failure in protection. The spatial design of a protected area, with strong consideration of its optimal size, is particularly important for MPAs if their main management objective is to protect biological diversity. This design is less important for other management objectives (Salm, 2000).

MPAs for coral reefs essentially comprise three functional zones. These are a core zone (sanctuary zone), a buffer zone (recreational zone) and a transition zone (a general use zone). However, in IUCN's (1995) policy document for MPAs in Australia it is suggested that the concept of buffer zones is usually possible only in large MPAs, in which areas that are large enough to 'buffer' or 'dilute' impacts can be designated. Salm (2000) suggests two concepts of the critical minimum core size for protected coral reefs and possible ways to measure them. The first critical minimum core size is the smallest reef size in which most of the species in the vicinity are virtually certain to be found. For example, a 300 hectare coral reef of the Chagos Archipelago in the Indian Ocean contained 95% of all the coral genera found in the Archipelago, and is now zoned as a core (Salm, 1980; Salm, 1984). The second critical minimum core area can be empirically defined as the equivalent to one and half times the area of the first critical minimum core zone. In the example above, the second critical minimum core zone would be 450 hectares (1.5 x 300 ha). In practice, the second critical minimum core zone should be initially implemented as a precautionary measure if urgency, or lack of funds and suitable personnel, prevent immediate conduction of research. For coral reef where high biodiversity is not a major issue the critical minimum core area might be reduced (Salm, 2000). Another rule of the thumb is that the core zone should be selected to encompass reef habitats as diverse as possible. Excluding a core zone, the remainder of the MPA functions as the buffer, and this includes the transition zones that aim to minimize contact and conflict between different uses. Moreover, if preserving biodiversity is the main objective of the MPA for a coral reef, it is essential that the MPA is designed to encompass as much habitat and species diversity as possible (Salm, 2000).

Table 1.2: Examples of the size of core zone, buffer zone and entire MPA

MPA names	Country	Core zone area or %	Buffer zone area	MPA's area	Reference
Lord Howe Island Marine Park	Australia	90,153 ha (30%)		300,510 ha	(Commonwealth Australia., 2003)
The Australian northern prawn fishery	Australia	15,830 km^2 (2%)		771,121 km^2	(Commonwealth Australia., 2003)
The great barrier reef marine park (GBRMP) (after the 2000s)	Australia	16,000 km^2 (4.6%)		345,000 km^2	(Commonwealth Australia., 2003)
GBRMP (before the 2000s)	Australia	5,000 km^2 (2%)		250,000 km^2	(J L Baker B Sc M Env St., 2000)
Macquarie Island Marine Park	Australia	5.71 million ha (12%)	10.4 million ha	47.6 million ha	(J L Baker B Sc M Env St., 2000) and http://www.environment.gov.au/coasts/mpa/macquarie/
Chagos Archipelago	Indian Ocean (UK)	3 km^2 (0.8%)		377 km^2	(Salm, 1980; Salm, 1984)
Glacier Bay National Park and Preserve	United State	53,000 acres (9%)		600,000 acres	(Commission on Geosciences-Environment and Resources (CGER). & Ocean Studies Board (OSB).), 2001)
Hoi Chan Marine Reserve	Belize	2.6 km^2 (14.4%)		18 km^2	(Roberts, 2000) and http://effectivempa.noaa.gov/sites/holchan.html
Dry Tortugas Ecological reserve	USA	2,800 nm^2 (10%)		28,000 nm^2	(Roberts, 2000)
The Galapagos Marine Reserve	Ecuador	120.6 km^2 (1.8%)		6,700 km^2	(Roberts, 2000; Servicio Parque Nacional Galapogos., 1998)

Note: Data calculated and cited from references

1.4. Rational of the study

Nha Trang Bay Marine Protected Area was established in 2002 with very wide purposes, including improving the livelihoods for island communities, and, in partnership with other stakeholders, effectively protecting and sustainably managing marine biodiversity. To achieve unambiguous goals, however, specific and measurable objectives must be defined in terms of what outputs and outcomes are being sought by Nha Trang Bay Authority. This in turn requires that well-defined management plans be developed, measures of MPA success identified, impacts of management actions be monitored and evaluated, and that the results of these activities be fed back into the planning process, to revise objectives, plans and outcomes (Pomeroy, 2004). In other words, MPAs need to be *adaptively managed*.

As a part of a dynamic management system the MPA authority must rely on a timely scientific assessment of the habitat and ecosystem of the Nha Trang Bay. Although annual monitoring and programs have gathered information on Hon Mun's reef communities (Tuan, 2002e; Tuan, 2005a,c), these time-series of data have not been treated in a comprehensive way to assess the development of the MPA since its inception. One of the challenges of the present analysis of the time series data is how to collate information gathered by different sources with regard to fisheries, aquaculture, and tourism activities, as well as transect surveys of a wide range of organisms, including macro-algae, invertebrates and corals, and fish.

The present work includes one survey of available information in the literature on trends in the fishery, aquaculture and tourism industries in the Nha Trang Bay area. Where information was lacking or needed updating some rapid appraisal of the situation of these industries was performed by means of interviews to different stakeholders. The main body of the present work consists of analyses of series of biological data collected in routine surveys, their interpretation by means of statistical techniques, an assessment of the ecological status of the reef, as well as some recommendations to future management plans and objectives.

1.5. Objectives of the study

Nha Trang Bay is a comprehensive MPA in Vietnam and its organization is being used as a template for the implementation of other MPAs to be established in the near future in Viet Nam (Vinh, 2005). In the period of 2002-2005 a considerable amount of information was collected in the area using biodiversity measurements and surveys on the status of human activities were conducted yearly. The major reports include Tuan *et al*., 2005a; Dinh, 2005a,b; Nam, 2005 and Nga, 2002a-c. Unfortunately, the biological information collected has not been thoroughly analyzed, nor have any attempts been made to associate ecological trends with management strategies or the development of the fishery, aquaculture and tourism industries.

The aim of this study is to answer some pertinent practical questions: Can we measure changes in species abundance and community composition from 2002 to 2005, i.e. in the short period of three years posterior to the implementation of the MPA? Can we use some species or groups of organisms as simple indicators of reef change? Can specific human activities be linked to specific developments in reef communities? Can we relate changes in tourism, aquaculture and/or harvesting intensity to changes in diversity in MPA? Were these changes predicted and accounted for by the initial management plan for MPA? And finally, if changes occurred (in an undesirable direction) how can we adjust MPA management practice? The present work focuses essentially on ecological development within the MPA, but the link to the socio-economic development in the Nha Trang Bay area is an attempt to give an integrated assessment of the success of the MPA to management.

2. MATERIAL AND METHODS

2.1. The area and field methods

2.1.1. Description of the Nha Trang Bay MPA

The Marine Protected Area is situated in Nha Trang Bay with approximate coordinates $12^0$09'-$12^0$17'N and $109^0$13'-$109^0$23'E, and lies offshore from Nha Trang City, Khanh Hoa province, on the coast of central south Viet Nam (Hon Mun Authority., 2002). Total area of MPA is 160 km^2, corresponding to nine islands (38 km^2) and surrounding sea (122 km^2) with an average depth of 10-20m (Hoi, 1998). Coral reefs within the MPA are distributed in shallow waters around nine islands, to a maximum depth of 15m. All coral reefs have a fringing structure. Average water temperature within the MPA is about 27^0C, water transparency ranges from 3 to 11m, salinity (S) =34%o, and pH about 8.0. These and other chemical factors (NO_3^-, NH_4^+, PO_4^{-2}…) were considered excellent for mari-culture purposes with reference to the water quality standards set by Ministry of Fisheries of Viet Nam (MoF) (Aquaculture Faculty., 2005).

2.1.2. Rapid Ecological Assessment (REA)

The investigation of the occurrence of different organisms (bio-diversity) in the coral reef was performed using Rapid Ecological Assessment (REA) methodology. The investigations were part of the annual biodiversity monitoring programme carried out by the Nha Trang Institute of Oceanography (NIO) from 2002 to 2005. The data for the present study were made available by the Nha Trang Bay Authority, which has the responsibility for the management of the programme.

Biodiversity inventories were performed regularly in August 2002, as part of the implementation phase of the MPA pilot project, and reassessed in March-April 2005. Four key locations, with broad geographic spread across the MPA and representative of the different coral communities and zoning scheme, were chosen: southwest Hon Mun within the core zone, and southwest Hon Mot, north Hon Mieu and east Hon Tre within the buffer zone (Figure 2.1). Rapid Ecological Assessment (REA) methodology (DeVantier et al., 1998; James E. Magaros, 2004) was used to evaluate the reefs in term of detailed taxonomic inventory of living taxa, and is here described in some detail. The value of REAs is well recognized by coral reef researchers and managers, and wide variety of REAs have been developed since the 1970s (Endean & Stablum, 1975).

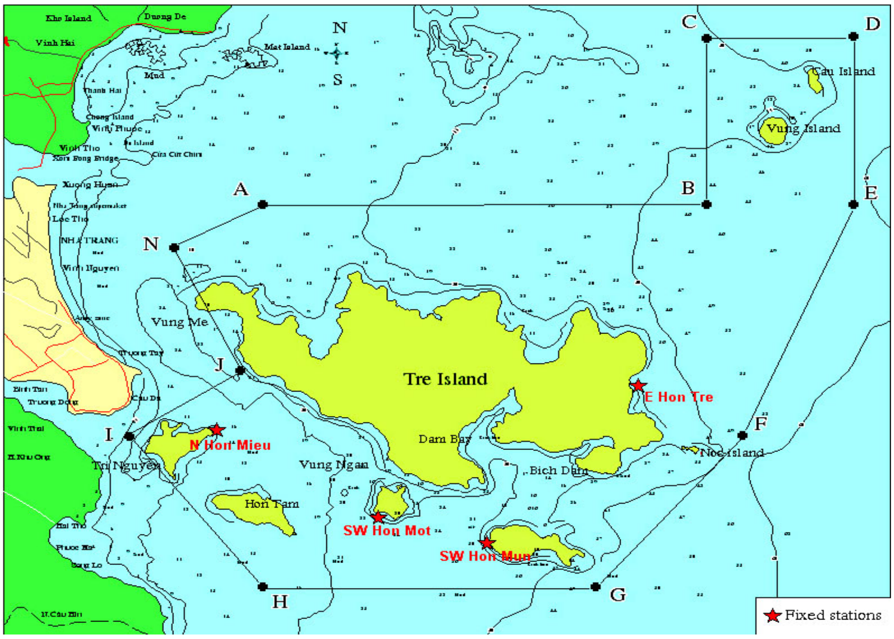


Figure 2.1: Map showing the location of four survey stations by REA method, 2002 and 2005 [Sources: Map cited from (Tuan, 2005a)]

In the field, two depth contours were surveyed independently at each site, including a deep slope (20m-8m) and shallow slope (7m-2m). Approximately 250m^2 per location and depth interval were surveyed: the total area corresponded to a transect 5m (2x2.5m) wide across the reef slope and 50m long along the slope. The selected living groups were corals, fish, macro-benthos and algae. Data were recorded by observers experienced in the field identification of the four groups, using SCUBA diving equipment. Each specialist diver swam slowly and recorded all species and their abundance categories within 250m^2, on waterproof paper on a clipboard. Although each specialist focuses on his/her biotic category, all of the surveys were conducted along a set of sites that were laid out by the first team to enter the water, and eventually retrieved the 50m tapes used as transect lines. Normally the fish observer entered the water first. To avoid disturbing the fishes, the benthic observers (corals, invertebrates, algae) entered the water 15 to 20 minutes later and went to the start of the first 50m transect. In this way, all of the biotic observations are referenced with regard to the same spatial coordinates, producing a more integrated biological description of a reef community than would any single, specialized survey. The complete duration of the dive in each depth stratum averaged 45 minutes. The total length and width of the site area surveyed during the census was recorded, allowing survey area to be determined if there was insufficient time to complete whole area during the dive. At the end of each dive the taxonomy inventory was reviewed, and each species was ranked in terms of its relative abundance in the community (Table 2.1). These broad categories rank taxa in terms of the relative abundance of individuals, rather than the contribution to benthic cover. For several living organisms the ranks are subjective assessments of abundance rather than quantitative counts (DeVantier et al., 1998). The ranks were also not identical among the different taxonomic groups. This is a consequence of differences among the specialists in their standard ranking systems, and attempts were made to harmonize the sampling methodology to the methods used in similar surveys elsewhere. Although the method is 'semi-quantitative' or qualitative in nature it has proven far superior to more traditional quantitative methods, like transects, quadrats in terms of biodiversity assessment. Not only is data collection normally faster, but also more comprehensive as this method allows the specialist to actively search for new species occurrences, rather than being restricted to a defined quadrat area or transect line (DeVantier et al., 1998). Rare species or uncommon species that could not be identified *in situ* were sampled and photographed using a digital camera. In the laboratory the different taxa were classified to the lowest possible taxonomic levels by experts of Nha Trang Institute of Oceanography (NIO). It was, thus, possible to identify the majority of hard corals, fish, macro-algae, and as well as invertebrates to species level. In a few cases, however, the observations had to be categorized at genus level.

Table 2.1: Relative abundance categories used in the taxonomic inventories

Corals	**Fish (individuals/250m^2)**	**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)		

For the inventory method, sampling procedures were not changed between surveys, and divers remained the same to minimize the inherent individual biases (Edgar et al., 2004). Sampling sites were haphazardly placed at the same depth and areas in the two years of the survey, rather than at ‘fixed’ stations. The underlying proposition in the present work is that the observed changes if occurring can to a great extent be associated with human activities. Thus, attempts are made to relate trends in community and indicator composition with trends in human activities.

2.1.3. Socio-economic information

Approximately 5,138 people, with an equal distribution between male and female, live in six villages within the MPA. This population is young, with 36% under the age of 15. Education level of most adults is low, with only 64% having completed Grade I education, equivalent to primary school. The poverty index of households inside the MPA is not as low as in the other areas, and was ranked at 'medium' level following the National Living Standards (Thu, 2005).

Primary data on industrial activities, including eco-tourism, aquaculture and marine harvesting within the MPA were collected from scientific and annual technical reports of Hon Mun Authority, several Government Institutes, and Khanh Hoa province departments. The major references include Micheal, 2004, 2005; Nam, 2005; Nga, 2002a-c and Dinh, 2003, 2005a-b. To fill in some of the gaps of information and to obtain updates of the trends in household and industry activities, a new rapid survey was conducted in July 2006 for the present work. This information was obtained during un-structured interviews to 83 divers at eight diving clubs, to cover the activities of the tourism industry, to seven fish farmers and seven fishers who operated regularly within the MPA, and to five researchers associated with the MPA monitoring. The main questions in these conversations concerned the present status of the enterprise, expected future trends and links to tourism, and stakeholder's perception about reciprocal influence of human activities and MPA. Despite the small number of respondents, and the fact that most information collected was only qualitative, the field interviews gave additional information about the level and scope of user conflict.

2.2. Data analysis

The extensive inventories performed in the two years, 2002 and 2005, gave rise to large sets of species data, and these were treated separately for each major taxa or group (fish, corals, macro-algae and other invertebrates). Even within a single phylum the number of species could be very large, in some case in excess of 200. It is difficult to analyze such large amounts of observations, and multivariate techniques were instrumental to search for patterns in community data (Krebs., 1989). Community analyses might detect changes at whole community level that could be too difficult to detect even after the analyses of many individual species.

Multivariate ordination of observations with linear or uni-modal techniques allows an arrangement of species and environmental variables in a plane defined by two orthogonal (x-y) axes, such that similar species or environmental variables are close together, and dissimilar species or environmental variables are situated far part. This greatly facilitates the understanding and exploration of ecological patterns of distribution, and, furthermore, the testing of statistical associations. The choice of multivariate method of analysis depends to a large extent on the nature of the data and secondarily on the length of the statistical gradients, as some techniques assume uni-modal distribution of the response variables over long gradients, and other methods assume linear distributions, normally over shorter gradients (Ter Braak, 2002). Following methods recommended by Jan Leps & Petr Smilauer (1999), which were implemented in the software CANOCO 4.5 (Ter Braak, 2002), prior to ordination of the observations a preliminary Detrended Correspondence Analysis (DCA) was performed on the same observations to obtain information about the length of the statistical gradients. In practice, when the lengths of these gradients are approximately less than 4 standard deviations, linear techniques of the Principle Component Analysis (PCA)/Redundancy Analysis (RDA) are normally utilized. On the contrary, uni-modal techniques of the Correspondence Analysis (CA) and Canonical Correspondence Analysis (CCA) are recommended for longer gradients. However, when dealing with categorical data, only techniques of the CA/CCA family are recommended (Greenacre, 1994) and were used in this work, irrespective of gradient type. The present inventory observations consisted originally of both semi-quantitative (fish) and categorical (other phyla) data. Hence, both linear and uni-modal techniques were used in the present study. Statistical testing of the importance of environmental variables is also possible in CANOCO using e.g. Monte Carlo permutation tests. A Monte Carlo permutation test is a test of statistical significance obtained by repeatedly shuffling the samples (Ter Braak, 2002).

The observations from the inventory studies were summarized into matrices of species or higher taxa of four assemblages: fish (34 families, 207 spp.), corals (312 spp.), invertebrates (71 spp.) and macro-algae (36 spp.), and these were referred to as ‘species’ or dependent variables. The resulting matrix had 16 (sample) rows, which were defined by the respective environmental or supplementary environmental variables. The 16 samples (4x2x2) were accounted for by four locations, two depth strata, and two years, and these were also the environmental or independent variables. The supplementary environmental variables were dummy variables that coded for location, depth and year, and were useful to provide an alternative interpretation of the ordination. For most groups, the original observations were qualitative, and grouping to higher taxonomic levels than species level was impossible, or meaningless. Only the semi-quantitative observations recorded for fish could be back-transformed to the original measurement units: for instance, a density code of 3 corresponded to a density of 6-20 fish, and this was back-transformed to 13 fish, the average of the interval. This was performed for all intervals in the same manner. Posteriously, the numbers of individual species were summed across families, and the multivariate analyses were performed at that higher level because it was very difficult to understand and visualize the main trends for such a high number of species. In addition, an attempt was made to analyze changes in the fish assemblages more related to their functional ecology than to their taxonomic structure. Thus, the different fish species were grouped into four trophic groups using the same methods as for grouping into family level. The four trophic groups were those suggested by FishBase 2007 (Froese & Pauly, 2007): levels 2, 2-3, 3-4 and 4-5 correspond to purely herbivorous fish, omnivorous fish, carnivorous fish and top-predators, respectively. Whenever possible the exact or average trophic level was attributed to a fish species, if that information was available from FishBase 2007. Alternatively, the trophic level of closely related species (ecologically) in the same genus or family were utilized.

Prior to the different multivariable analyses, the density numbers of any group considered (at species, family or trophic level) were log-transformed (log X+1). In the multivariable analyses were that option was available, automatic down-weighing of rare species, families or groups was chosen. The presence of rare species often disturbs the understanding of the main structural changes in the communities. This was a larger concern in the present study than finding rare indicator species.

The statistical package Cano Draw 4.5 was used to analyze graphically the combination of sample and species observations, as well as their association to environmental and supplementary environmental variables (Ter Braak, 2002). Samples and variables were displayed on the same ordination charts in a form of point-arrow biplots or triplots. Despite the formal differences between multivariate techniques, interpretation of the multivariate charts follows similar principles. In general in RDA, the longer the arrow the higher is the importance of the environmental variable for the ordination of the samples. Arrows that are laid in opposite directions represent variables that are negatively associated, and arrows that point in similar direction are positively associated. Similarly, samples located close to the head of the arrow are those that are most positively associated with that variable (Borcard, 2004). Similarly in CCA, **s**ites are at the centroids of species: the site found near the point representing the centroid of a qualitative explanatory variable is more likely to possess the state ‘1’ (or high score) for that variable. Site points that are close to one another are likely to be relatively similar in their species relative frequencies. When species are the goal of interpretation, a species found near the centroid of a qualitative explanatory variable is likely to be found frequently or in larger abundances in the sites possessing the state ‘1’ for that variable. Species points that are close to one another are likely to have relatively similar relative frequencies in the sites (Borcard, 2004).

3. RESULTS

3.1. Aquaculture

3.1.1. Location, cages and species

The main culture sites in Nha Trang Bay MPA are Vung Me, Tri Nguyen, and to a lesser extent Hon Mot, Dam Bay, Bich Dam and Vung Ngan (Figure 3.1). Due to the construction of the VinPearl resort, and other tourism expansions in SW and N Hon Tre, most of culture cages located at Vung Me have been moved to other areas. In addition, some households in Tri Nguyen visited during the survey informed that they moved culture cages to Vung Ngan because of water pollution, mainly oil pollution from the shipping traffic in and out Cau Da port, or uncontrolled discarding of daily waste into the water by some farmers. Since then, Vung Ngan (NW Hon Mot) is becoming a major culture area. Owning to their geographical distribution, the areas and sites used for biodiversity assessment may correspond to different levels of impacts from aquaculture. The station of N Hon Mieu is the nearest to a city and port, therefore, in more close exposure to pollution from the shipping traffic and land run-off. N Hon Mieu is also the most affected by aquaculture from Tri Nguyen; the site of SW Hon Mot is the closest to the extensive culture area (Vung Ngan) and may be impacted by the organic load resulting from waste or uneaten fishfeed. The other areas, including SW Hon Mun and E Hon Tre seem to be far from culture zones, and thus may have suffered less from aquaculture-related activities.

There was a dramatic increase in the number of cages as well as in the total culture area, from 1,675 cages in 2001 to 5,096 cages in 2004, an increase of nearly 204% in 3 years (Kinh, 2004). About 30.1% of the families within the MPA engaged in lobster cultivation with an average of 2.5 cages per family. This contributes to a significant part of the total yearly income, accounting for 54% of total household income (Thu, 2005).

During the interviews the farmers informed that lobster is the major culture species due to its high sale price. Four lobster species, including *Panulirus ornatus, P. longipes, P. homarus* and *Panulirus stimpsoni* were being cultured within the Bay (Dinh, 2005c). Other culture species common elsewhere, such as groupers *Epinephelus malabaricus, E. tauvina*, squid *Sepioteuthis lessioniana* and seaweed *Kappachycus alverezii,* were rarely farmed. To diversify aquaculture production, one enterprise, AIG- Marine Culture Group, plans to grow 15 selected marine species, including soft shell swimming crab, seahorse, seaweed, green mussel, lobster, pearl oyster, Babylon, abalone, cobia, grouper, sea cucumber, clown fish, sand bass, sea bass, and tiger shrimp broodstock (AIG- Marine Culture Group., 2002).

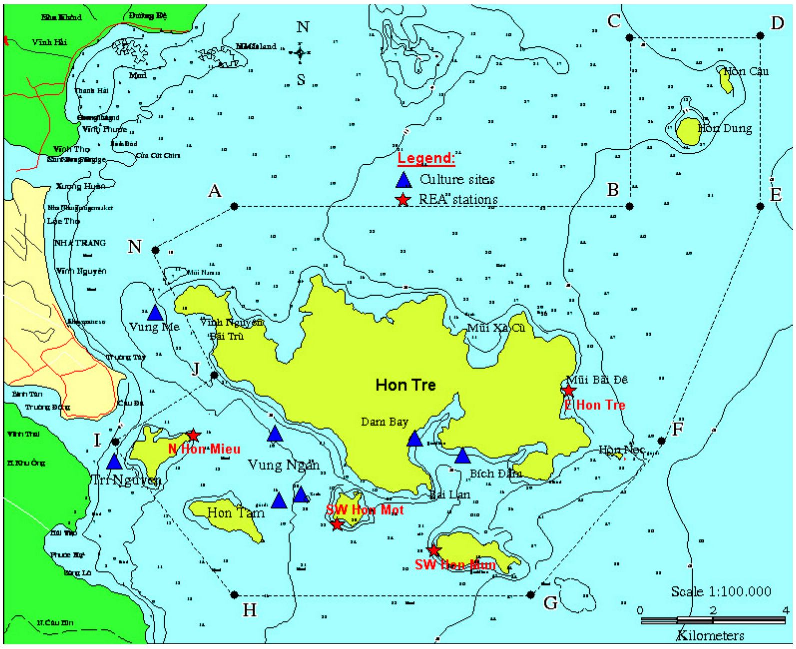


Figure 3.1: Map showing the culture sites and biodiversity assessment stations

3.1.2. Types of culture, seed and food

Type of culture

Presently, there are two main types of culture in operation within the MPA: cage and floating cultures. However, within each of these main types of culture there is a wide variation among the households with respect to the culture area, seed's size, seed density, and daily feed input. These differences are dictated by the farmed species, personal preference, and financial ability. In general, the survival rate in lobster culture is high in spite of signals of water pollution. For example, survival ranged from 70-95% at Hon Mot, but it was even higher at Dam Bay, 90-100% (Nga, 2002a; Nga, 2002c). Together with information reported by Nga (2002a; 2002c), the interview survey showed some features of two culture types:

i. The cage culture is characterized by a low original investment, low survival, as well as low economic efficiency when compared to the floating raft culture. A culture cage is made of a frame outside and nets inside. The frame, with square or rectangle shape, is made of iron, bamboo, or wood. It divides the cage into several compartments with the total area 6-16m^2 per cage. The cage is anchored and lifted far from the seabed by bases that staked into seabed. Normally, there is an interval of approximately 20-50cm from the cage bottom to seabed (Nga, 2002a).

ii. Conversely, the floating raft culture is characterized by a more expensive investment, but it results in high survival rate, as well as higher economic efficiency. The culture raft is put together from small separate cages with square or rectangle shape, the average 4 small cages per floating raft. The raft is also fixed to the bottom with anchors, but unlike the cage it floats on the water surface with buoys and wooden frame. The average surface area of a small cage in the Dam Bay and in the Bich Dam is $15.9m^2$ and $10.8m^2$, respectively, and the corresponding sizes of floating rafts are $56.4m^2$ or $44.9m^2$ (Nga, 2002c).

In 2002, 29% of the local households engaged in aquaculture and ran about 55% of the existing cages (Kinh, 2004). The present observations suggest, however, that recently, 'outsider' ownership has increased rapidly, but that cages owned by local islanders still remain. More intensive culture using floating rafts requires higher investment. However, local islanders confided that they haven't got enough money for investment, despite recent attempts from the Government Banks to provide credit schemes and loans. During the interview survey performed many of the local farmers stated that they preferred fixed cages because they are less expensive. Floating cages were mostly owned by people living outside the MPA. However, insiders are increasingly adopting floating cages for culture instead of fixed cages. It was not possible to quantify the relative proportions of floating and fixed cages existing at present in the area.

Seed source

Attempts have been made to raise lobster from artificial seed, so far with only limited success (Tung, 2002). Current aquaculture practices rely, hence, solely on wild-caught seed-stocks. Rapid development of lobster and marine fish cultures has dramatically increased the demand for seed (Figure 3.2). According to the farmers interviewed, seeds can be obtained several ways:

i. Seeds are bought directly from fishermen. If their size is small as 'a bamboo toothpick' they are nursed with a high density in nursing cages till they reach the expected size. Then they are released into cages or floating rafts for commercial grow-out.

ii. Using fishing gears, farmers collect seed themselves.

iii. Professional seed collectors operate inside or outside the MPA, using mainly hookah diving or trawls, and then sell them to households.

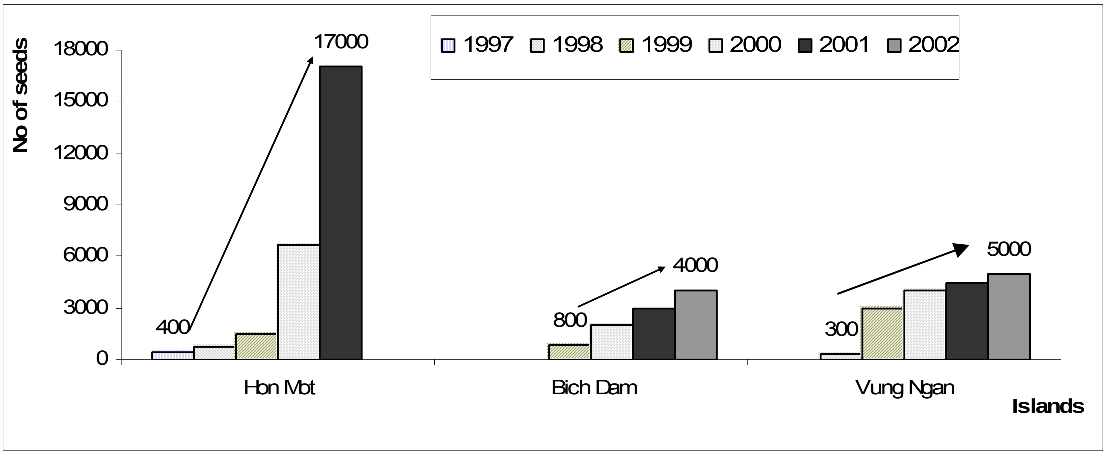


Figure 3.2: An increase in the lobster seed demand, 1997-2002

[Sources: Data cited from (Nga, 2002a; Nga, 2002b; Nga, 2002c)]

Many local farmers stated that seed nursing was more common before. But depletion of the native seed, along with a low survival rate in nursing caused by the water pollution, has led to an increasing reliance on the purchase of seeds from professional seed collectors in recent times. As an example, one farmer revealed that he had bought 400 of a total 500 lobster seeds from a professional collector. Unlike this farmer, most households had difficulties to precisely quantify the different sources of their seeds. But, the majority stated that, given the choice, they preferred the native seed that had been supplied directly by fishers or collected by themselves due to higher quality and lower price.

Food source

Artificial feed trials were conducted for grouper culture, and testing of formulated diets for lobster culture has only just entered the research phases (Tung, 2002). Thus, instead of artificial feed, ‘trash fish’ are being used extensively as feed. The food conversion rate, or the ratio of the weight gained by the farmed stock to the weight of ‘trash-fish’ fed, is low, about 1/20-1/25 for lobster and 1/6-1/10 for grouper. Consequently, an estimated total of 6,650 tons trash fish has been annually used for lobster culture (Kinh, 2004; Tung, 2002). During the field interview in 2006, most of households revealed that formulated diets were not commercially available. ‘Trash fish’, including lizard fish, red big eye, pony fish, small shrimp, small squid, and mollusk were frequently used. The households can buy food directly from fishermen, at local market or they can collect it themselves. To ensure better digestibility, all food sorts are cut into small pieces and put into culture cages or culture floating rafts one or two times a day. In the past, most of the leftover food dissipated directly into the water. However, this problem is being reduced nowadays by putting food into a net with small mesh size. In addition, most farmers stated that they remove food rests more frequently from the cages and into a dustbin or container

3.1.3. Perceptions of the local aquaculture community

One of four main components of MPA pilot project is to improve livelihoods for local people through developing MPA associated human utilization patterns in adequate way. Since the establishment of MPA, the access to traditional fishing grounds has been restricted, and aquaculture development was considered among the most suitable options for alternative income.

There were few different perceptions about the impact of aquaculture activities to the MPA, and vice versa, among the local people interviewed during the field survey in 2006. The number of respondents was, however, too low for a dedicated statistical analysis. Many farmers perceived their activities as environmentally friendly since they started collecting feed leftovers, and thereby improving water quality. Many farmers stated that they did not get any significant benefits from the MPA pilot project, for example, "*the MPA did not prevent the water pollution*" or *"the MPA did not improve the seed source"*. However most believed that *"if Nha Trang Bay MPA is well managed, it will create a good seed source"*.

3.2. Fishing

3.2.1. Coral reef fishing

According to statistical data, there were about 380 and 527 motorized fishing boats in operation in the MPA in 2002 and 2005, respectively, with an average of 200 fishing days per year per boat. Most of them were small boats with the length from 5 to 14.2m, horsepower capacity mainly from 6-80 Hp, and few boats with over 100 Hp. However, there are strong suspicions that the total number of fishing boats was underestimated: it is not known how many boats registered outside are presently operating inside the MPA. With regard to the employment status of fishers 46% of them own their boats, while the remaining 54% work as hired crew members (Dinh, 2005a; Dinh, 2005b; Tung, 2002). There is a substantial in-migration of fishers during the main fishing seasons to meet labour demands. Immigrating fishers mainly found in the boats operating large nets at night, such as purse seine nets, push nets, lift nets, and lobster nets. Approximately 3,797 tons of fish and 84,573 individuals of lobster seed were caught in 2003 (Dinh, 2003). Fishing within the MPA is characterized by a diversity of gears and species, but is mostly small-scale in size. For example, 25 species and groups of fish were caught alone by purse seiners targeting anchovy (Dinh, 2005c). A total of eleven main fishing gears are being operated within the MPA. All purse seine, bottom trawl and luring purse seine are conducted by large boats, which are mostly owned by fishers coming from outside harbours, adjacent to the MPA. Although regulations on fishing management within the MPA water zone came into effect in 2002, poison and blast fishing were still conducted illegally by several divers and poor fishers in 2003 (Dinh, 2003). These illegal fishing practices were, however, not detected in the monitoring programme in 2005 (Dinh, 2005a; Dinh, 2005b; Tuan, 2005b).

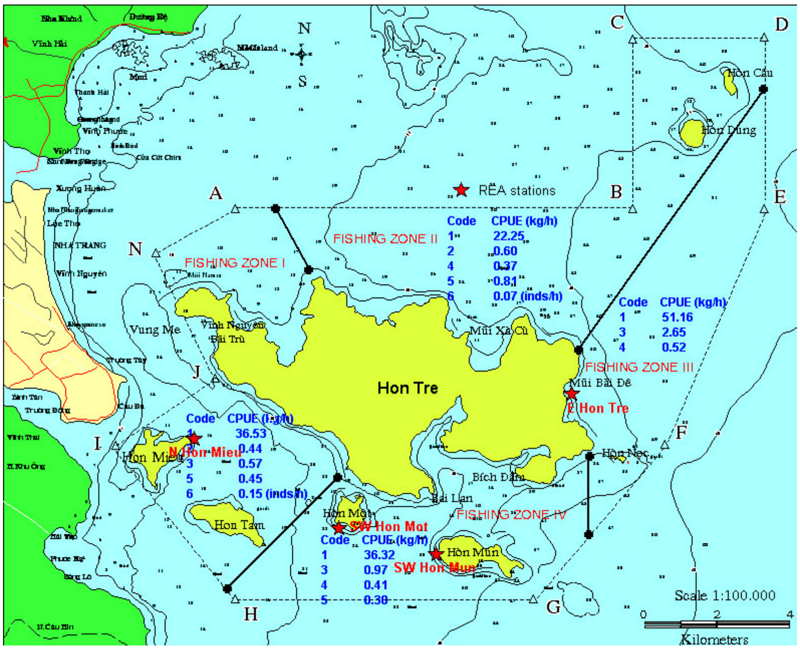


Figure 3.3: Map showing four fishing monitoring zones (I, II, III and IV) and biodiversity assessment stations

[Sources: Data calculated and cited from (Dinh, 2005a; Dinh, 2005b)]

Note: 1-Purse seine, 2-Trammel nets, 3-Lift nets, 4-Longline, 5-Hookah diving (fish), 6-Hookah diving (lobster)

Owing to the different statistical grid utilized to gather information on fishing activities it is difficult to match exactly fishing areas to the sampling stations for bio-diversity assessment. But, Hon Mieu falls within fishing zone I, Hon Tre in fishing zone III, and both Hon Mot and

Hon Mun fall coarsely into fishing zone IV. As stated by some MPA researchers during the interviews the core zones of the MPA seem to be too narrow, and even these areas are probably largely affected by the fishing activities taking place in adjacent waters. The gears most frequently utilized in these adjacent areas include the purse seine, lift nets, trammel nets, longline and hookah diving. The station of E Hon Tre is far from the land and, seems to be the one more greatly impacted by fishing at present.

3.2.2. Fleet structure

The statistical data on the structure of the fleet operated within the Nha Trang Bay were collected by Thu (2005). Based on the total length, fishing fleets were divided into three groups, including ≤ 8 m, 8-10 m and ≥ 10 m. Most boats built since 2002 were of medium size, or 8 - 10m, with a dramatic increase in the total number of boats from 2002 to 2005 (Figure 3.4 left). Simultaneously, there have been slight declines in the proportion of small boats (≤8 m) and large boats (>10 m). The change in horsepower of the vessels from 2002 to 2005 was not so substantial, but there was a trend for an increase in the high powered group (>30 Hp), and reduction in the low (≤20 Hp) and the medium power (>20 to ≤30 Hp) groups (Figure 3.4 middle). Figure 3.4 (right) shows three groups of the remaining lifespan of all boats operated by residents, including <50%, ≥50 - ≤70% and >70% of remaining life. The percentage of boats in good (>70%) and medium conditions (≥50 - ≤70%) has decreased, while the percentage of boats in bad condition (<50%) dramatically increased in the period of 2002- 2005.

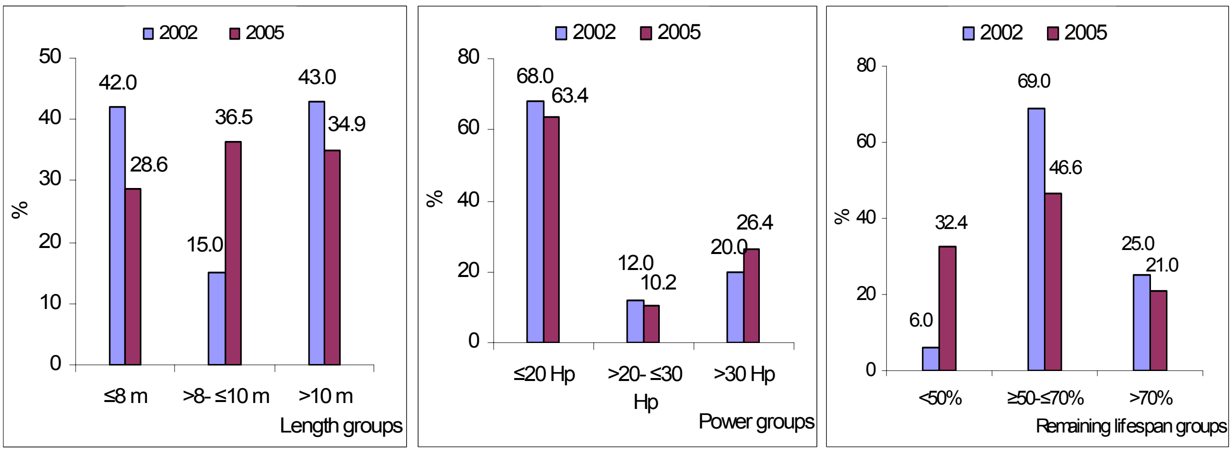


Figure 3.4: Distribution of length groups (m) (left), power groups (Hp) (middle) and remaining lifespan groups (%) (right) of fishing boats, 2002 and 2005. Source: (Thu, 2005)

3.2.3. Results of fishing activity

The annual fishing monitoring programme from December, 2002 to August, 2005 conducted by Dinh *et al.* under contract from the Nha Trang Bay MPA Authority showed that 39 major fish families were caught by nine fishing gears within MPA, in 2005 (Appendix 1). Some species that could be fished concurrently by several gears seemed to suffer the highest fishing pressures, including Carangidae, Clupeidae, Nemipteridae, and Scombridae. Thus, dominant reef fish families, such as Labridae, Pomacentridae, Scaridae that are mainly targeted by hookah diving (about 54 boats) do not seem to have suffered increased pressure from 2002 to 2005. Among the 34 families that were recorded in biodiversity assessment programs in 2002 and 2005, 17 families were listed as commercially exploited in 2005. There were some changes in catch per unit effort (CPUE) of insider-fishing boats during the two fishing seasons, the northeast monsoon (October to March) and the southwest monsoon (April to September). In northeast monsoon season, CPUE of purse seine and stick-held dip nets increased dramatically from 2003 to 2005, from 5.15 to 39.26 kg/hour and from 12.19 to 16.93 kg/hour, respectively. In contrast, the CPUE of lobster lift nets decreased from 2.34 inds/hour in 2003 to 0.58 inds/hour in 2005. A significant increase in CPUE of purse seine nets was also recorded in southeast monsoon season, from 16.15 to 33.45 kg/hour. For the other fishing gears, CPUE changes from 2003 to 2005 were minor (Dinh, 2003; Dinh, 2005a; Dinh, 2005b).

3.3. Tourism

3.3.1. Types of tourism and places

The field survey performed in 2006 indicated that the two prevalent models of tourism in Nha Trang Bay are the island tour and the sea tour. Island tourism occurs when visitors go to the expected places by boat and then visit the island on foot. Contrastingly, the sea tourism happens when tourists travel by boat and stop for sea bathing, swimming, diving and other relaxed activities in the sea.

Previous studies of Michael (2004; 2005) showed that there is a diversity of tourist activities, and the main locations of these are shown in Figure 3.5. The most common places for island tourism are Tri Nguyen, Hon Tam, north Hon Tre and Hon Mun. Diving takes mostly place at Hon Mun, and to a lesser extent at Hon Tam, Hon Noc, Hon Mot and Bai Lan. Swimming, with or without snorkelling-gear, takes mostly place at Hon Mun, Hon Tam and Bai Lan.

Northeast Hon Tam is the destination for sport activities such as jet-skiing, parasailing, and banana boats. Currently, over 100 tourism boats, powered by 50 HP engines and smaller speed boats are operated within the MPA. The statistical data for 2005 provided by the Cau Da Tourism Management Company during the field trip in 2006, indicates that most visitors went to Tri Nguyen (<55%), followed by Hon Tam (<27%), Hon Mot and Hon Mun (<18%). Only a small part of the visitors visited other places.

The few tourist operators interviewed in the field had somewhat contradictory views about the MPA and its zonation regime. Some of them hoped that new areas for diving were opened soon, particularly the beautiful coral reef sites at NE Hon Mun. Others argued that the current zoning was appropriate, but that an opening of new areas to tourism should be considered in a more long-term perspective.

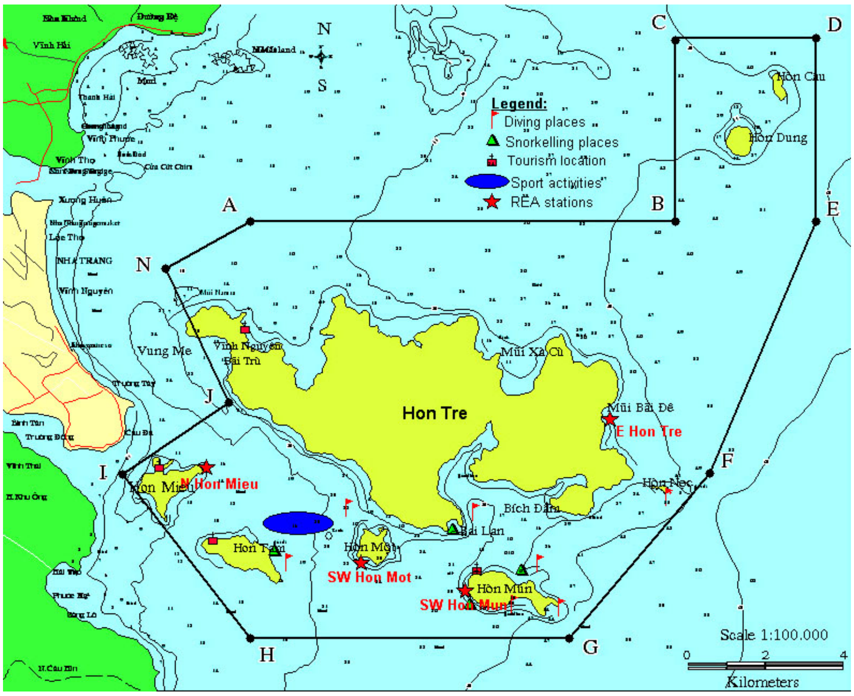


Figure 3.5: Map showing the tourism sites and biodiversity assessment stations

The different areas and stations utilized for the biodiversity assessment programme in 2002 and 2005 are differently influenced by tourism activities (Figure 3.5). North Hon Mieu lies closest to the city and port and is the most affected by general boat traffic. It may also have suffered most from island tour-related activities in Tri Nguyen; the station of SW Hon Mun is near to tourism centers and is frequently affected by divers, general sport activities, and swimmers; SW Hon Mot has a general frequency of divers and swimmers; E Hon Tre lies farthest from the continental shore and, hence, any kind of tourism activities are rare there.

3.3.2. Volume of tourist activities

The estimated revenue of Nha Trang tourism was over US$ 41 millions (equivalent to 643,738 million VND) in 2005, and contributed to 40.95% in GDP of the Khanh Hoa province. There was an annual increase in the number of visitors in terms of domestic and foreign ones after one decade (1995-2005), from 317,000 to 902,468 visitors. Khanh Hoa province's tourist development strategy is to reach to 1,000,000 visitors (including 480,000 foreign tourists), and 7,250 tourist staff in 2010. The results of tourism activities also performed through indexes as the number of tourist staffs, total rooms, and guest days, as well as total revenue (Figure 3.6) (Khanh Hoa province., 2006).

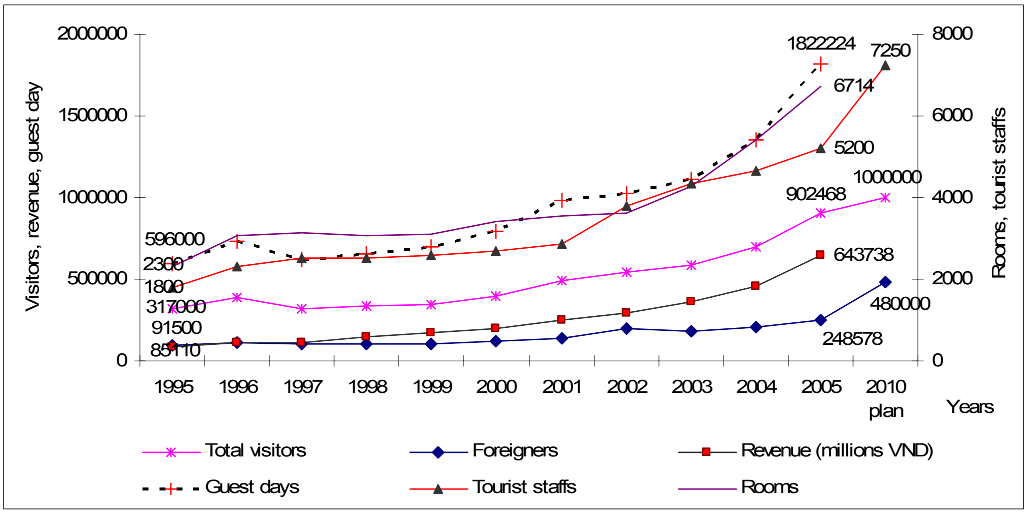


Figure 3.6: Results of tourism industry of Nha Trang city, 1995-2005 and in plan of 2010

Source: (Khanh Hoa province., 2006)

The number of divers has increased. Presently nine diving clubs have regular operation within the MPA water with about a total 100 divers per day and often serve approximately 9,800 dive trips annually. Most divers were foreigners, 13,500 foreigners compared with 4,500 Vietnamese divers (Michael, 2005). On the daily survey carried out in July 2006, a total number of 83 divers were observed at eight diving clubs and Cau Da tourism port. This corresponded to 7 to 22 divers per diving club per day.

3.3.3. Tourism with the MPA and the local community

According to the tourism managers interviewed, tourism activities affect directly the MPA through three main ways: (1) damage to coral reef, (2) pollution of the water, and (3) collection of marine organisms and curios. According to the respondents attempts have been made to limit the damage to coral reefs through conservation awareness-training to divers and swimmers, or by increased awareness and control during diving by instructors or dive-masters. This includes, e.g. informing the divers or swimmers about MPA regulations before the onset of the dives, or execution of dive-instruction in places devoid of coral reefs. However, breaking of coral reefs by tramping still occurred. Tourism boats in general complied well with the MPA regulations; but, trans-boarding tourists from large to small boats during the visits to islands still causes damage to the branching coral colonies that live in shallow water.

MPA regulations dictate that daily wastes be put into a dustbin or container onboard tourism boats. However, waste is still thrown directly into the sea, especially by domestic visitors. In addition, discarded plastic, polymer bags and drinking bottles left in the islands eventually spill into the sea. Thus, tourism managers agreed that despite standing efforts to instruct users to avoid littering, tourism still has a small direct detrimental effect on the MPA. They also considered that pollution will diminish the attraction of MPA, particularly with the foreigners who, according to Michael (2004), are more flexible to choose alternative tourist destinations.

Some tourism managers revealed that more shells of snails and bivalves have been found on the islands and coral reefs in recent times. It seems that this is damage caused by crew or passengers of tourist boats, but the reason for this behavior remains unclear.

Regarding the overall contribution of the MPA to the attractiveness of Nha Trang Bay, many tourists and tourism managers stated that "*if the MPA will be well managed, e.g. more beautiful coral reefs, unpolluted water etc, there will be more increasing in the number of visitors*". These respondents also expressed their opinions about the MPA management efficiency, as well as about the present status of biodiversity. According to them, the current Monitoring, Control and Surveillance practice was not deterrent enough to efficiently control the whole MPA water area. This seemed to be particular true from the end of 2005 and onwards, when the administration of the MPA was handed over to the Khanh Hoa province and MCS activities slackened. As a consequence illegal fishing arouse, and poaching has been taking place in the core zone. Responses were also somewhat contradictory with regard to the present status of the reefs. Thus, some of the respondents stated that "*less fish and more 'ghost net' were found*" on the coral reefs. Contrastingly, others revealed that "*more small fish or juveniles have appeared at some coral reefs within MPA in recent time*".

Regarding other impacts of the tourist sector to the local community, Michael (2004; 2005) summarized the developments of the community-based tourism activities that have been encouraged and supported by the MPA Authority. This included the organization of food hygiene and cookery courses at Hon Mot, courses in English for tourist-attendants at Hon Mot and Hon Mieu in 2004-2005, and the development of a new design of a basket boat with a glass bottom for underwater viewing. The objective of these activities is to help people find alternative employments, and this may have resulted in some fishers giving up destructive fishing and starting the operation of boats for tourists. However, the success of these activities is still limited. Thus, people living inside the MPA perceive that they have experienced limited benefits from tourism. On the other hand, the development of the tourism industry has had some large undesirable impacts for some populations living in Nha Trang Bay: this includes the relocation of villages, and subsequent upheaval in local livelihoods and changes in village culture (Michael, 2005; Michael, 2004).

3.4. Community analysis

3.4.1. Species composition

A simple method to investigate changes in species diversity was to assess the species richness, the total number of species of each taxon surveyed, in the two years of the Rapid Ecological Assessment. A total 36 species of macro-algae belonging to four phyla and 27 genera were found altogether. Rhodophyta was the dominant phylum, with high occurrence (20 spp.) at all locations, followed by Chrorophyta, with 8 spp., Phaeophyta, with 6 spp., and Cyanophyta, with 2 spp (Appendix 2). The total number of species of macro-algae observed in the whole MPA in 2002 and 2005 remained stable at 26 species, but there were marked changes in each site (Table 3.1). There was a strong increase in the number of species at SW Hon Mun (100%), N Hon Mieu (64%) and SW Hon Mot (45%), and a slight decline at E Hon Tre (15%).

A total 71 species of invertebrates, classified into 37 families and 50 genera, were recorded altogether. Muricidae was the dominant family, with high occurrence (11 spp.), followed by

Conidae, with 5 spp., Fasciolariidae, with 5 spp. and Pteridae, with 4 spp. Most invertebrate families were represented with low diversity, with only one species found in each family (Appendix 3). There was a reduction in the total number of species of invertebrates observed in the whole MPA, from 52 species in 2002 down to 42 species in 2005, but there were large changes in each site (Table 3.1). There was a reduction in the number of species at E Hon Tre (36%), SW Hon Mot (30%) and SW Hon Mun (13%), and a slight increase at N Hon Mieu (13%).

Table 3.1: Taxonomic composition of four groups of organism in the four stations sampled by REA in 2002 and 2005 and trends in taxonomic richness

Organism groups	**Locations**	**Family**		**Genera**		**Species**			
		2002	**2005**	**2002**	**2005**	**2002**	**2005**	**Trend**	**Change (%)**
Macro-algae	N Hon Mieu	4	4	11	16	11	18	Up	63.64
	E Hon Tre	4	4	13	10	13	11	Down	-15.38
	SW Hon Mot	2	4	10	12	11	16	Up	45.45
	SW Hon Mun	1	4	5	9	5	10	Up	100.00
	MPA	**4**	**4**	**21**	**19**	**26**	**26**	**Stable**	**0.00**
Invertebrates	N Hon Mieu	12	16	15	18	16	18	Up	12.50
	E Hon Tre	12	11	16	13	22	14	Down	-36.36
	SW Hon Mot	15	13	22	17	27	19	Down	-29.63
	SW Hon Mun	18	15	21	20	23	20	Down	-13.04
	MPA	**26**	**29**	**36**	**37**	**52**	**42**	**Down**	**-19.23**
Fish	N Hon Mieu	21	19	51	36	83	52	Down	-37.35
	E Hon Tre	22	13	48	26	84	44	Down	-47.62
	SW Hon Mot	22	23	54	45	96	70	Down	-27.08
	SW Hon Mun	28	23	55	52	103	85	Down	-17.48
	MPA	**31**	**31**	**77**	**75**	**162**	**140**	**Down**	**-13.58**
Hard corals	N Hon Mieu	14	14	43	34	122	92	Down	-24.59
	E Hon Tre	15	14	50	46	187	177	Down	-5.35
	SW Hon Mot	15	15	39	38	126	146	Up	15.87
	SW Hon Mun	14	13	43	36	155	156	Up	0.65
	MPA	**15**	**15**	**59**	**53**	**274**	**256**	**Down**	**-6.57**

A total 207 species of fish belonging to 34 families and 93 genera were found in the study period. Five dominant families represented high occurrence at all locations, these are Labridae 43 spp., Pomacentridae 39 spp., Chaetodontidae 21 spp., Scaridae 16 spp. and Acanthuridae 11 spp. The families Aulostomidae, Diodontidae, Fistularidae, Pempheridae, Priacanthidae, Pseudochromidae, Synodontidae, and Zanclidae were rare, with only one species found in each family (Appendix 4). The total number of species of fish observed in the whole MPA slightly reduced from 162 species in 2002 down to 140 species in 2005, but there were large declines in the total number of species in each area (Table 3.1): E Tre Hon (48%), followed by N Hon Mieu (37%), SW Hon Mot (27%) and SW Hon Mun (17%).

A total of 312 species of hard corals, belonging to 15 families and 60 genera, were found altogether, but there were remarkable differences among the families (Appendix 5). Acroporiidae (98 spp.), Faviidae (66 spp.), Fungiidae (31 spp.) and Poritiidae (29 spp.) were the dominant families, with high occurrence at all locations. Trachyphylliidae, Astrocoeniidae and Oculinidae were rare families with 1-2 species observed in each family. The total number of species of hard living corals found in the whole MPA slightly declined from 274 species in 2002 down to 256 species in 2005 (Table 3.1). There was a decline at N Hon Mieu (25%) and E Hon Tre (5%), and a slight increase at SW Hon Mot (16%) and SW Hon Mun (1%).

3.4.2. Community structure

3.4.2.1. Macro-algae

The Canonical Correspondence Analysis (CCA) indicated a considerable association of the environmental variables Area and Year, but not necessarily of Depth, with the distribution of macro-algal species. Area and Year variables explained an important proportion of the overall variation in species-environment relationship, with cumulative percentages of 40% and 27% for axes 1 and 2, respectively. Overall, the first two axes explained 28% of the variability in macro-algal species data.

The biplot diagram resulting from the (CCA) ordination of macro-algae species is illustrated in Figure 3.7. Overall there was a clear and significant effect (P=0.014) of time, and this reflects on the distribution of the species in relation to the 2002-2005 gradient, which is indicated by two opposing vectors in the diagram. Species that were more relevant in 2002 tend to be distributed on the southwestern part of the chart, while those that gained expression in 2005 were more markedly represented on the northeastern area of the chart. Less affected macro-algae tended to take intermediate positions along this gradient. With regard to spatial effects, the stations of SW Hon Mun and SW Hon Mot seemed to have similar macro-algal compositions, and are represented on the upper left part of the chart. These two areas differed markedly in species composition from the other areas: species on the lower left part of the chart were more abundant at the Hon Tre island, while those on the lower right part of the chart had a larger representation in the station of the Hon Mieu island. In addition, some rare species were recorded, but it was difficult to establish their association to specific sites or years. Such was the case of e.g. the algae *Titanophora pulchra, Padina tetrastromatica* in 2002, and of *Chnoospora implexa* in 2005.

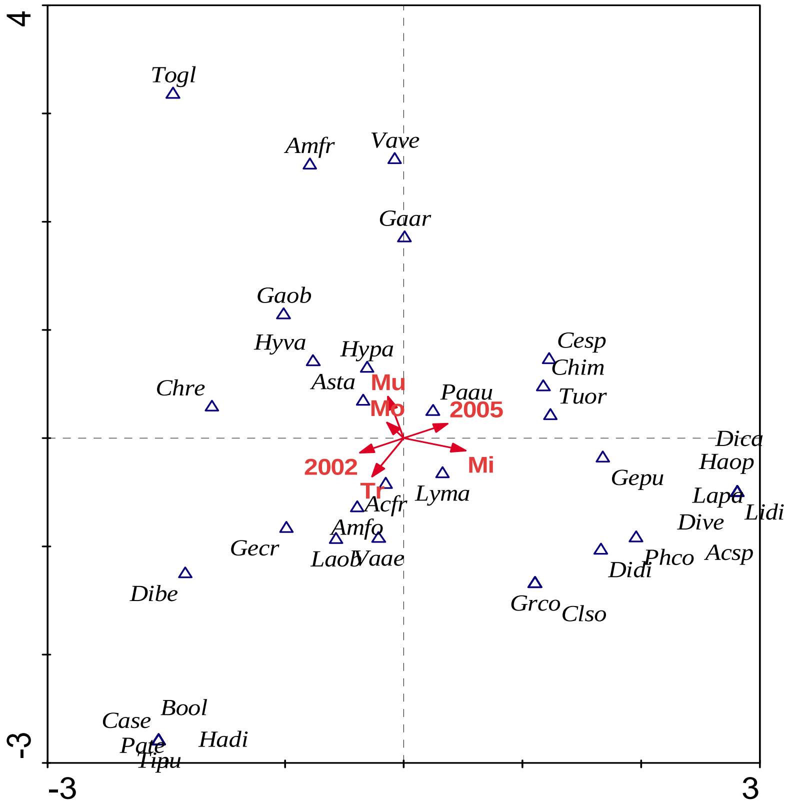


Figure 3.7: Macro-algae assemblage composition along a: CCA ordination diagram with macro-algae species (Δ), and environmental variables year and area (arrows). First axis is horizontal, second axis is vertical. Multivariate analyses (CCA) have indicated significant changes in algal assemblage composition from 2002 to 2005. Species names are coded by taking the first two letters of genus and the first two letters of species names: *Acsp=Acanthopora spicifera, Acfr=Actinotrichia fragilis, Amfo=Amphiroa foliacea, Amfr=A. fragilissima, Asta=Asparagopsis taxiformis, Bool=Bornetella oligospora, Case=Caulerpa serrulata, Cesp=Ceratodictyon spongiosum, Chim=Chnoospora implexa, Chre=Chondria repens, Clso=Cladophora socialis, Dica=Dictyophaeria cavernosa, Dive=D. verluysii, Dibe=Dictyota beccariana, Didi=D. dichotoma, Gaar=Galaxaura arborea, Gaob=G. oblongata, Gecr=Gelidium crinate, Gepu=G. pusillum, Grco=Gracilaria coronopifolia, Haop=Halimeda opuntia, Hadi=Halymedia dilatata, Hypa=Hypnea pannosa, Hyva=H. valentiae,*

Laob=Laurencia obtuse, Lapa=L. papillosa, Lidi=Liagora divariata, Lyma=Lyngbya majuscule, Paau=Padina australis, Pate=P. tetrastromatica, Phco=Phormidium corium, Tipu=Titanophora pulchra, Togl=Tylopiocladia glomerulata, Tuor=Turbinaria ornate, Vaae=Valonia aegagropila, and Vave=V. ventriosa. Area names are indicated as: Mi= N Hon Mieu, Mu=SW Hon Mun, Tre=E Hon Tre and Mo=SW Hon Mot

Monte Carlo permutation techniques were used to test the significance of the different environmental factors on algal species composition. Factors related to area, such as the dummy variables N Hon Mieu and SW Hon Mun were significant (P=0.002 and P=0.03, respectively), as was the time factor (year 2002, P=0.014), indicating that there were marked changes in the two years of the MPA survey. Contrastingly, there seemed to be no significant effects of the Depth factor (P=0.43). This was an unexpected result since clear trends in algal distribution with depth are normally assumed. Analyses of the interaction of the Depth factor (shallow or deep station) with all other factors (represented by dummy variables of areas and time) provided one single significant combination, Depth*2002 (P=0.012). This was interpreted as follows: basically there were no clear depth-related trends in algal distribution in any of the four stations; overall, however, depth-related trends could be detected (the significant interaction) in 2002; this last trend was not captured in 2005, a year characterized for a large blossoming and spread of macro-algae.

In attempt to further investigate the relationship among the three variables Depth, Area and Year the 16 (2x4x2) combinations of variables, the so-called supplementary environmental variables, were superimposed onto the plane resulting from the main ordination (Figure 3.8). For the sake of clarity the symbols representing species and environmental variables in Figure 3.7 are omitted from Figure 3.8, but the two figures can be super-imposed and the effects of the explanatory variables (the vectors) remain the same. From the figure it becomes clearer that the differences between shallow and deep stations in the same area are far shorter than the differences among areas and, more importantly, between years.

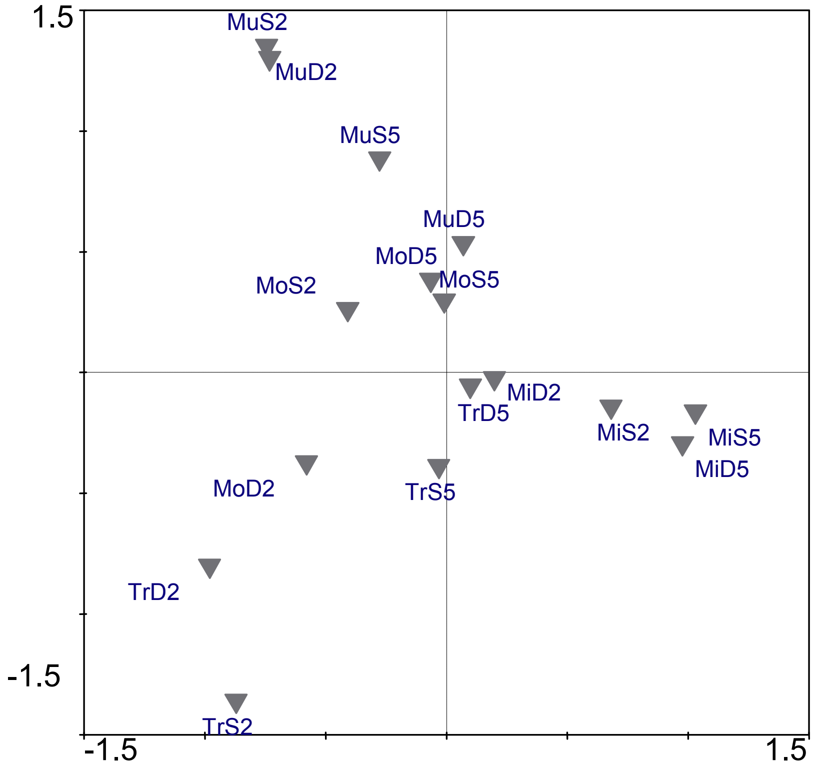


Figure 3.8: The supplementary environmental variables for the CCA ordination of the macro-algal data shown in the Figure 3.7. The observations plotted are dummy variables that correspond to combinations of the main environmental variables: variable names are coded by taking the first two letters of area name, depth (S=Shallow, D=Deep) and year (2=2002, 5=2005). E.g. MuS2=Mun shallow 2002, MuS5=Mun shallow 2005, MuD2=Mun deep 2002, MuD5=Mun deep 2005, and similarly for Tr (Tre island), Mi (Mieu island) and Mo (Mot island)

3.4.2.2. Invertebrates

The CCA showed a remarkable association of the environmental variables Area and Year, but not necessarily of Depth, with the distribution of invertebrate species. Area and Year variables explained an important proportion of the overall variation in species-environment relationship, with cumulative percentages of 36.2% and 30.1% for axes 1 and 2, respectively. Overall, the first two axes explained 23.5% of the variability in species data.

The biplot diagram resulting from the (CCA) ordination of invertebrate species is illustrated in Figure 3.9. Overall there was a clear and significant effect (P=0.002) of time, and this reflects on the distribution of the species composition in relation to the 2002-2005 gradient, which is indicated by two opposing vectors in the diagram. Species that were more relevant in

2002 tend to be distributed on the southeastern part of the chart, while those that gained expression in 2005 were more markedly represented on the northwestern part of the chart, e.g. the major species *Drupella cornus* in 2005. Less affected invertebrates tended to occupy intermediate positions along this gradient, e.g. the major species *Pedum spongdiloidium, Coraliophilla neritoidae.* With regard to spatial effects, the stations of SW Hon Mun, SW Hon Mot, N Hon Mieu and E Hon Tre seemed to have remarkably different invertebrate composition, and are represented in the four corners of the chart. In addition, some rare species were recorded, but it was difficult to link their representation to specific sites or years. Such was the case of e.g. the invertebrates *Cantharus undosus, Cypraea cylindra* and *Peristernia incarnata* in 2002, and of *Xenaturris cingulata, Trochus histrio* and *Modulus tectum* in 2005.

Monte Carlo permutation techniques were used to test the significance of the different environmental factors on invertebrate species composition. Factors related to area, such as the dummy variables E Hon Tre was significant (P=0.002), as was the time factor (year 2002, P=0.002), indicating that there were statistical significant changes in the invertebrate species composition in the two years of the biodiversity assessment. Again, there was a lack of statistical significance, (P=0.33) of the depth variable in the explanation the variation of the invertebrate species assemblage. Analyses of the interaction of the depth factor (shallow or deep station) with all other factors (represented by dummy variables of areas and time) provided no significant combinations. However some preliminary analysis of species-depth relationship was indicated. The station of E Hon Tre tended to form a single and isolated cluster; both shallow and deep sites of SW Hon Mot seemed to have suffered a great loss in species abundance. Contrastingly, the deep site of SW Hon Mun and shallow site of N Hon Mieu represented a slight increase (Figure 3.10).

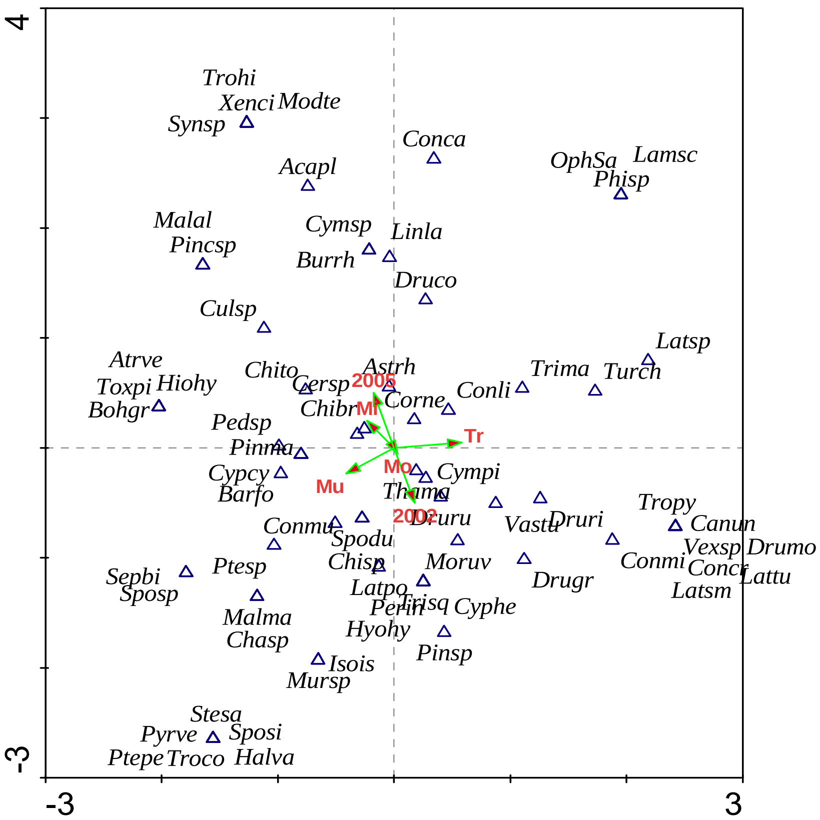


Figure 3.9: Invertebrate assemblage composition along a: CCA ordination diagram with invertebrate species variables (Δ), and environmental variables year and area (arrows). First axis is horizontal and second axis is vertical. Multivariate analyses (CCA) have indicated significant changes in invertebrate assemblage from 2002 to 2005. Species names are coded by taking the first three letters of genus and the first two letters of species names (except for *Pinctada sp=Pincsp*), e.g. *Concr=Conus cratus* etc (see taxonomic list in appendix 3, showing both codes and scientific names). Area names are indicated as: Mi= N Hon Mieu, Mu=SW Hon Mun, Tre=E Hon Tre and Mo=SW Hon Mot

To visualize the effects of the three environmental variables (Depth, Area and Year) the 16 combinations of variables that were defined as the supplementary environmental variables, were superimposed onto the plane resulting from the main ordination (Figure 3.10). For the sake of clarity the symbols representing species and environmental variables in Figure 3.9 are ignored from Figure 3.10, but the two figures can be super-imposed and the effects of the explanatory variables (the vectors) remain the same. From Figure 3.10 it becomes clearer again that the differences of invertebrates between shallow and deep stations of the same area are far shorter than the differences among areas, as well as between years (2002 and 2005).

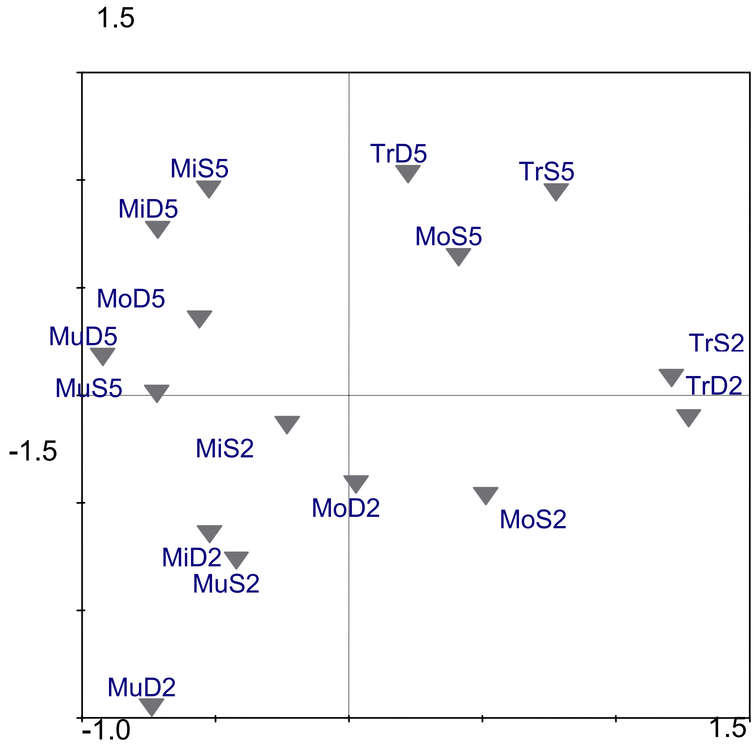


Figure 3.10: The supplementary environmental variables for the CCA ordination of the invertebrate data shown in the Figure 3.9. The observations plotted are dummy variables that correspond to combinations of the main environmental variables: variable names are coded as Figure 3.8

3.4.2.3. Fish

The Redundancy Analysis (RDA) indicated a considerable association of the environmental variables Area and Year, but not necessarily of Depth, with the distribution of fish families. Area and Year variables explained an important proportion of the overall variation in species-environment relationship, with cumulative percentages of 56.7% for axis 1 and 26.5% for axis 2. In general, the first two axes explained 36.8% of the variation in species data.

The biplot diagram resulting from the (RDA) ordination of fish families is illustrated in Figure 3.11. In general there was a statistical significant effect (P=0.006) of time, and this reflects on the distribution of the families in association with the 2002-2005 gradient, which is performed by two opposing vectors in the diagram. Most families lie on the right side of the chart, thus they tended to be more abundant in 2002, while families more to the right either were found in other areas or suffered less dramatic decline in numbers from 2002 to 2005. For instance, the clear decline of the most dominant families Pomacentridae, Scaridae, Labridae and Acanthuridae. Family Caesionidae underwent a slight increase. Less affected families tended to take intermediate positions along the 2002-2005 gradient. Such was the case of the families Haemulidae and Holothuridae that remained relatively constant from 2002 to 2005. In addition, Pseudochromidae, Diodontidae and Aulostomidae were families that although very rare in 2005 (1-2 individuals) had not been observed in 2002 at all.

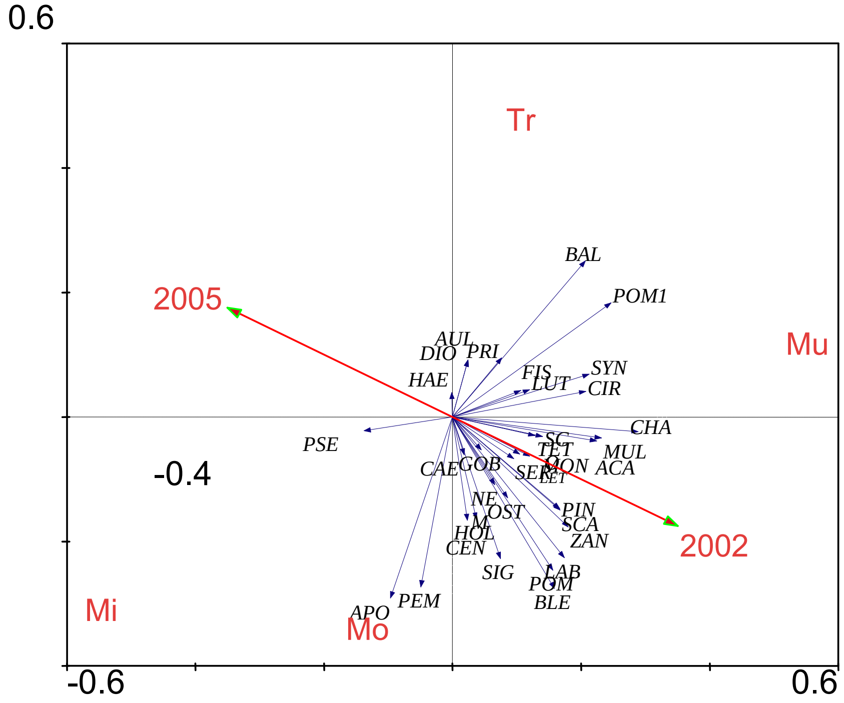


Figure 3.11: Fish families assemblage composition along a: RDA ordination diagram with fish families (black letters, green arrows), year (red letters, red narrows), and area (red letters). First axis is horizontal and second axis is vertical. Preliminary multivariate analyses (RDA) have indicated significant changes in fish assemblage composition from 2002 to 2005. Family names are coded by taking the first three letters of family names: *ACA=Acanthuridae, APO=Apogonidae, AUL=Aulostomidae, BAL=Balistidae, BLE=Blenniidae, CAE=Caesionidae, CEN=Centriscidae, CHA=Chaetodontidae, CIR=Cirrhitidae, DIO=Diodontidae, FIS=Fistulariidae, GOB=Gobiidae, HAE=Haemulidae, HOL=Holocentridae, LAB=Labridae, LET=Lethrinidae, LUT=Lutjanidae, MON=Monacanthidae, MUL=Mullidae, NEM=Nemipteridae, OST=Ostraciidae, PEM=Pempheridae, PIN=Pinguipedidae, POM=Pomacentridae, POM1=Pomacanthidae, PRI=Priacanthidae, PSE=Pseudochromidae, SCA=Scaridae, SCO=Scorpaenidae, SER=Serranidae, SIG=Siganidae, SYN=Synodontidae, TET=Tetraodontidae,* and *ZAN=Zanclidae.* Area names are indicated as: Mi= N Hon Mieu, Mu=SW Hon Mun, Tre=E Hon Tre and Mo=SW Hon Mot

Monte Carlo permutation techniques were used to test the significance of the environmental factors on fish family composition. Factors related to area, such as the dummy variables N

Hon Mieu were significant (P=0.018), as was the time factor (year 2002, P=0.006), indicating that there were remarkable changes in the two years of the MPA survey. Conversely, the depth factor seemed to support no significant effects in the explanation the variation of the fish assemblage (P=0.082). Despite utilizing analyses of the interaction of the factor depth (shallow or deep) with all other factors (represented by dummy variables of areas and time), the variation in fish composition can not be adequately explained by the depth variable. However, the observations provided the following interpretation: the deeper areas of E Hon Tre and N Hon Mieu seemed to be the most impacted from 2002 to 2005. In a second 'front' the shallow areas of E Hon Tre, SW Hon Mot, and N Hon Mieu, as well as the deep area of SW Hon Mot seemed to have suffered great changes in species composition from 2002 to 2005. Both the shallow and deep areas of SW Hon Mun seemed to have suffered some change from 2002 to 2005, but still remained in the area (right side of the graph) were most families are represented.

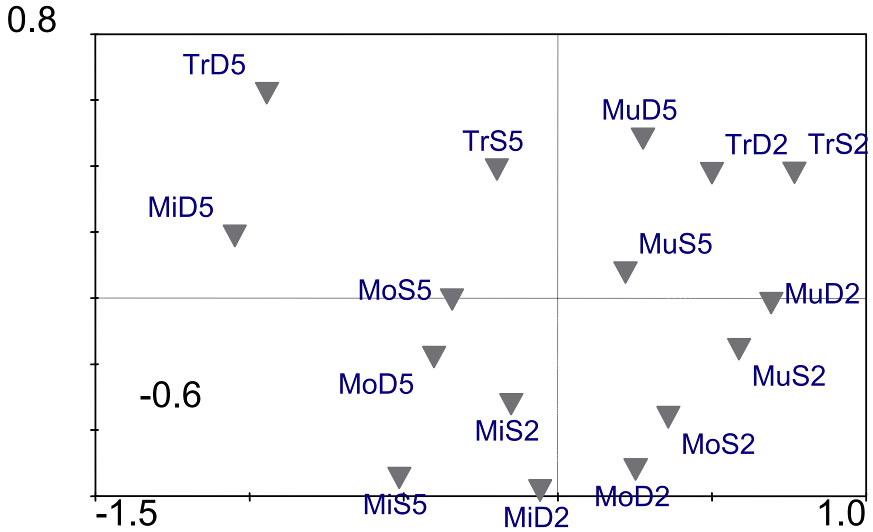


Figure 3.12: The supplementary environmental variables for the RDA ordination of the fish data shown in the Figure 3.11. The observations plotted are dummy variables that correspond to combinations of the main environmental variables: variable names are coded as Figure 3.8

To visualize the relationships among the three variables Depth, Area and Year, the 16 combinations of variables, the so-called supplementary environmental variables, were superimposed onto the plane resulting from the main ordination (Figure 3.12). For the sake of clarity the symbols representing species and environmental variables in Figure 3.11 are not plotted again from Figure 3.12, but the two figures can be super-imposed and the effects of the explanatory variables remain the constant. From Figure 3.12 it becomes clearer that the differences between shallow and deep stations in the same area are not as clear as the differences among areas and, more importantly, between years.

In attempt to further illustrate the fish composition change in relation to trophic composition, based on FishBase 2007 fish assemblage of the two years of the MPA survey are rearranged into four trophic levels, including pure herbivorous, omnivorous, carnivorous and top predators. These are coded as digits 2, 2-3, 3-4 and 4-5 in Figure 3.13, respectively. Overall there was a significant effect (P=0.006) of time, and this reflects on the distribution of the trophic level with regard to the 2002-2005 gradient, which is indicated by two opposing vectors in the diagram. Thus, 2002 characterized by the presence of pure herbivorous fish (level 2) and omnivorous fish (level 2-3). These suffered the greater degree of loss in 2005. The variations in trophic assemblages seemed not to be large among areas and depths (Figure 3.13).

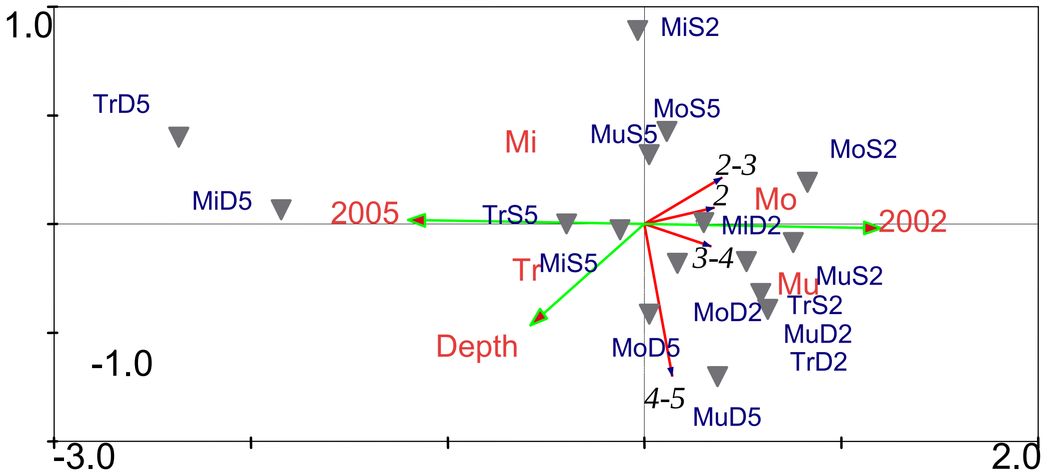


Figure 3.13: Trophic level composition along a: RDA ordination diagram with trophic levels (red arrows), year and depth (blue arrows) and area (red letters) as well as the supplementary environmental variables (▼), the observations plotted are dummy variables that correspond to combinations of main environmental variables: variable names are coded as Figure 3.8. First axis is horizontal and second axis is vertical. Preliminary multivariate analyses (RDA) have indicated significant changes in the trophic levels from 2002 to 2005. The trophic levels are identified base on FishBase 2007 (Froese & Pauly, 2007): *2=herbivorous, 2-3=omnivorous, 3-4=carnivorous,* and *4-5=top predators.* Area names are indicated as: Mi= N Hon Mieu, Mu=SW Hon Mun, Tre=E Hon Tre and Mo=SW Hon Mot

Although not so rich as earlier, SW Hon Mun was still characterized by the presence of top predators in 2005, and did not seem to be so greatly affected by the loss of fish at the bottom of the trophic chain. However, in deep site of SW Hon Mun there was a change from a system well populated by herbivorous and omnivorous fish to one more characterized by top predators and much less fish at the bottom of the chain, although not as dramatic as in the other areas. SW Hon Mot has a stronger relationship with the trophic levels than the areas of E Hon Tre and N Hon Mieu. Yet it seems that the sites of SW Hon Mot were little affected by the changes in trophic composition from 2002 to 2005.

3.4.2.4. Hard living coral

The CCA demonstrated a considerable association of the environmental variables Area, Year, and Depth, with the distribution of hard living coral species. The variables Area and Year, as well as Depth variable explained an important proportion of the overall variation in species-environment relationship, with cumulative percentages of 29.2% and 24% for axes 1 and 2, respectively. In general, the first two axes explained 27% of the variability in species data.

The scatter diagram resulting from the (CCA) ordination of hard coral species is demonstrated in Figure 3.14. Owing to the large number of species represented, and for the sake of clarity, the environmental variables are omitted in this figure, but these are plotted again in Figure 3.15. Overall there was a clear and significant effect (P=0.01) of time, and this reflects on the distribution of the species in relation to the 2002-2005 gradient, which is indicated by two opposing vectors in the diagram. Species that were more relevant in 2002 tend to be distributed on the northwestern part of the diagram, while those that gained expression in 2005 were more markedly represented on the southeastern part of the diagram. Less affected hard corals tended to take intermediate positions along this gradient, as e.g. the species belonging to two major families Acroporiidae, Poritiidae, which remained constant. With regard to spatial effects, the stations of SW Hon Mun, SW Hon Mot and N Hon Mieu normally clumped together on the upper left part of chart. Thus, they seemed to have similar patterns in species composition. These three stations differed markedly in species composition from the E Hon Tre station, which represented more abundant with species on the lower right part of the chart. Moreover, many rare species were found, but it was difficult to match their association to specific sites or years. Such was the case of 38 coral species that were only recorded in 2005, e.g. the corals *Porites annae, Pociilopora danae, Lobophyllia flabelliformis, Fungia fralinae, Stylophora subseriata*.

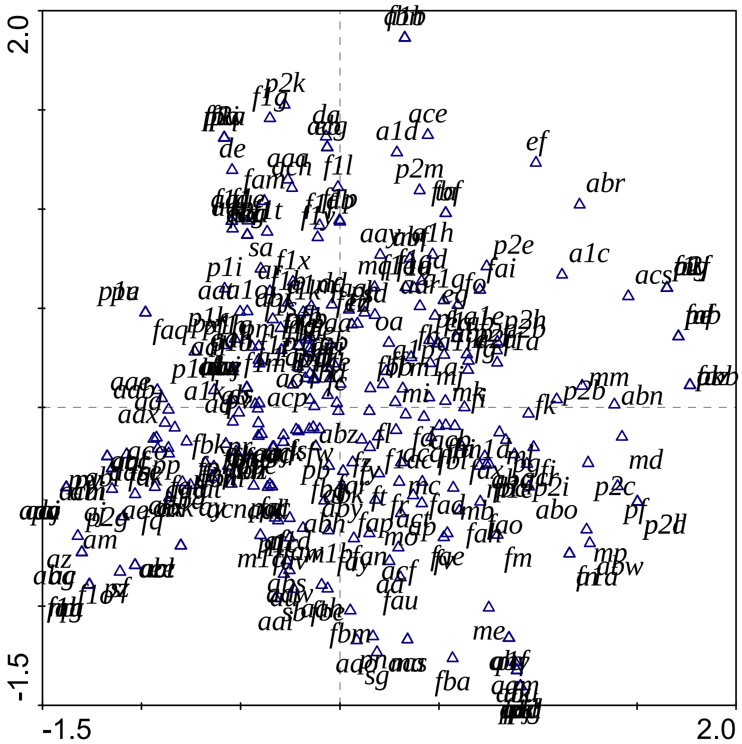


Figure 3.14: Hard living coral assemblage composition along a**:** CCA ordination diagram with hard living coral species (Δ). First axis is vertical, second axis is horizontal. Multivariate analyses (CCA) have indicated significant changes in coral assemblage composition from 2002 to 2005. For each family, species names are firstly ranked alphabet, species codes then are coded by taking the first letter of family name and adding steeply the letters a, b, c…., aa, ab…e.g. *aa=Acropora abrotanoides, ab=A. aculeus…*If families have a same first letter, adding 1, 2…the end of first letter; such was the case of families, e.g. Agariciidae: *a1a=Coeloseris mayeri, a1b=Gardineroseris planulata etc* (see taxonomic list of codes and scientific names in appendix 5)

Monte Carlo permutation techniques were used to test the significance of the different environmental factors on hard coral species composition. Factors related to area, such as the dummy variables N Hon Mieu and E Hon Tre were significant (P=0.01 and P=0.002, respectively), as was the time factor (year 2002, P=0.01), implicating that there were significant changes in the two years, 2002 and 2005. Effects of the depth factor were statistically significant (P=0.002) in the explanation the variation of most of species composition, except for species belonging to two major families Fungiidae and Poritidae. With regard to depth effects, both sites of E Hon Tre remained itself, the deep site of SW Hon

Mun seemed to represent a great increase. On the contrary, the shallow of N Hon Mieu was suffered the decline in abundance of species assemblage.

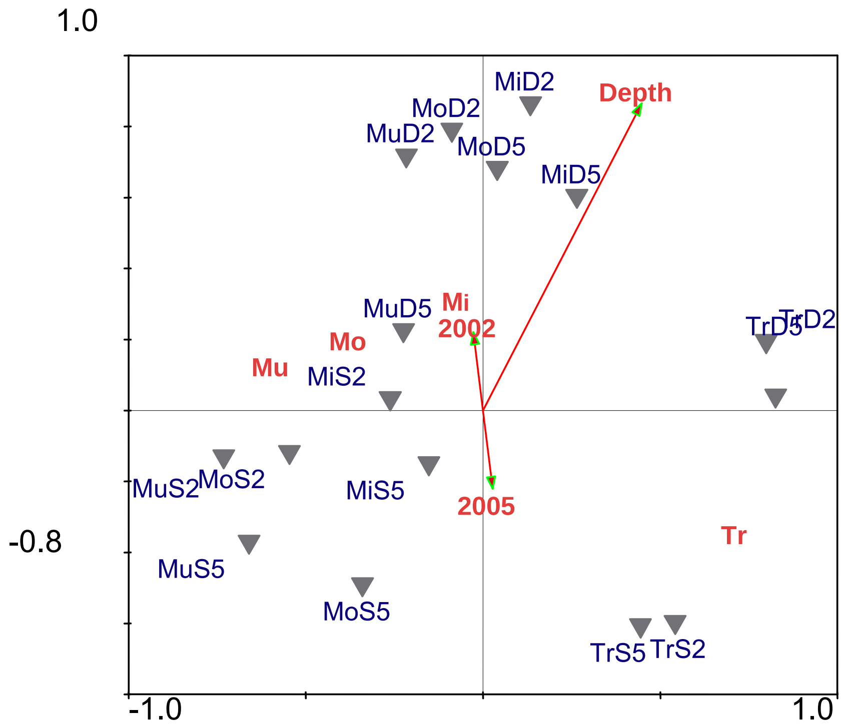


Figure 3.15: Environmental variables: area (red letters), year and depth (red arrows), and the supplementary environmental variables (▼) for the CCA ordination of the hard coral data shown in the Figure 3.14. The observations plotted are dummy variables that correspond to combinations of the main environmental variables: variable names are coded as Figure 3.8. Area names are indicated as: Mi= N Hon Mieu, Mu=SW Hon Mun, Tre=E Hon Tre and Mo=SW Hon Mot

In attempt to further investigate the relationship among the three variables Depth, Area and Year, the 16 (2x4x2) combinations of variables, the so-called supplementary environmental variables, were superimposed onto the plane resulting from the main ordination (Figure 3.15). For the sake of clarity the symbols representing species variables in Figure 3.14 are not plotted again from Figure 3.15, but the two figures can be super-imposed and the effects of the explanatory variables (the vectors) remain the same. From the figure it becomes clearer that the differences in hard living coral assemblages between shallow and deep stations in the same area are as important as the differences among areas and between years.

4. DISCUSSION

4.1. Community changes in the MPA

Most monitoring work routinely performed in the Nha Trang Bay MPA involves the annual assessment of the density of indicator species or groups (Tuan, 2005c). In the period 2002 to 2005 that monitoring programme has detected significant increases in cover of fleshy seaweeds (indicator of nutrient pollution), and significant declines in fish density, mainly families Chaetodontidae and Haemulidae (indicator of overfishing, blast fishing, poison fishing and aquarium collection), as well as in the density of the invertebrate *Stenopus hispidus* (indicator of aquarium collection) and of the hard coral cover at Hon Vung (indicator of blast fishing, poison fishing and nutrient pollution). The indicator surveys have not been able to capture substantial changes in hard coral cover at other sites, or of groupers and lobsters (indicator of overfishing, blast fishing, poison fishing and nutrient pollution) (Hodgson, 2002). The most impact areas detected are, in accordance with these surveys, SW Hon Mieu, N Hon Tam and Hon Vung. These yearly monitoring surveys are performed using Reefcheck methodology, a specific indicator species-oriented transect methodology (Hodgson, 1999; Hodgson, 2002). Its advantages are that it is a quick and cheap methodology that does not require great taxonomical expertise, and can, thereby, be easily incorporated into community-based ecological monitoring programmes (Hodgson, 2002; Tuan, 2002c). However, the great variability of the density indices among replicates observed in the former studies of Nha Trang Bay, often with coefficients of variation between 40-90%, will make difficult the detection of significant changes, even for large effect sizes. It will be substantially more difficult to demonstrate the small changes in variables expected to be found in a three year recovery period. The statistical power of these surveys can only be increased whether by increasing the number of replicates, an expensive strategy, or by improving the design of the survey and treatment of the data. One possible means to reduce the variance of the observations is to include in these rapid assessment surveys some of the consistent local indicators suggested in the present study as representatives of change in Nha Trang Bay.

The qualitative and semi-qualitative inventory data utilized in the present work differs from the indicator monitoring surveys, and was collected and firstly summarily described by Tuan *et al.* (2005a). However, their treatment of the data was just introductory, and, in some instances, not easily described or understood. These authors only utilized single-variable techniques, which render the assessment of community changes difficult. The same inventory data were subjected to formal multi-variable analyses in the present work, using techniques that are robust even for purely qualitative information. In contrast to the transect data obtained with Reefcheck methodology, the present ecological information obtained by REA lacks replication in the field. This because, it is exceedingly more expensive in expertise, and time-consuming, to perform whole species-inventories of four ecological groups, even for a single transects. It was hoped and assumed that the large number of species considered, consisting of short and long-lived organisms, sessile and nektonic, would somehow integrate, both spatially and temporarily, the major trends occurring in each of the areas surveyed. While this cannot be demonstrated in the absence of replicates, the spatial and temporal patterns detected in the present work seemed to be consistent across ecological and trophic groups. The pattern and scope of change in communities varied among locations of the MPA, conservation regime, ecological groups, and, to a smaller extent, by depths surveyed. Still, powerful multivariable statistical techniques can absorb and compensate for these sources of variability.

The island of Hon Mun is a tourist center frequently visited by divers and snorkelers. However, Hon Mun is at the core of the MPA and receives plenty of attention and coverage from monitoring, control and surveillance (MSC) programmes implemented by the MPA Authority. In addition, both the installation of boat moorings and the improved education and awareness among the visitors have contributed to reducing the damage to coral reefs. In practice, tourism does not seem to substantially influence the biological communities at Hon Mun directly. Other human utilization activities are presented at relatively modest levels comparing with other areas. Consequently, the communities of Hon Mun did not show strong signals of decline in bio-diversity from 2002 to 2005. There were even some positive tendencies, such as the slight increase of invertebrate and coral abundances in the deep site of Hon Mun in 2005. A slight increase of invertebrate was mainly reflected in some dominant species, *Chicoreus torrefactus, Pteria sp* and *Drupella cornus.* Some new species even appeared in 2005. A slight restoration of hard corals of the major family Faviidae occurred in the deep site of Hon Mun, but some rare families, such as Oculinidae and Astrocoeniidae appeared as well. Nevertheless, the observations in this study indicated increase of macro-algae and a reduction of fish at Hon Mun in 2005. The temporal changes of these two groups were derived from the fluctuations of most families or species. But for the case of fish assemblage, a clearer decline was often shown in small fish, or in fish at the bottom of the trophic chain. For example, in the deep site the dominant families Pomacentridae, Labridae and Chaetodontidae significantly reduced from 359.5 down to 167.5 inds/250m^2, from 115 down to 51.5 inds/250m^2 and from 63.5 down to 15.5 inds/250m^2, respectively in the study period. It has been documented in other areas of the world that absence of herbivorous fish or invertebrates may lead to overgrow of corals by macro-algae, which in normal conditions would be kept at minimal levels by the grazers. The most probable reason for this trophic cascade in Nha Trang Bay is fishing, whether by aqua culturists or by commercial fisherman, inside or, most probably, outside the relatively narrow core ring of the reserve. However, the effects of this fishing in the fish assemblage of the core zone at Hon Mun did not seem to be strongly detrimental as, e.g., in 2005 top predators, such as *Fistularia commersonii, Aprion virescens, Synodus binnotatus* and *Aulostomus chinensis* were still relatively frequent. This is in partial agreement with the findings of Claudet *et al* (2006) and Mosquera *et al* (2000) who claim that at the early stages of establishing protected areas or no-take zones, the restoration initially pertains to larger fish sizes because large fish usually respond quicker to protection (by immigration). Thus, it seems that the implementation of a core zone at Hon Mun, followed by relatively intensive information and surveillance campaigns has, at least, slowed strongly down the rate of depletion of important ecological groups.

The islands of Hon Mieu and Hon Mot are located in the immediate vicinity of the city and port, and are centers for marine aquaculture and tourism. Thus, most of the associated human activities create a high level of environmental stress on these areas. A high turbid plume extending into the sea is produced by seasonal flooding of the Cai river-North of Nha Trang city, by landfill for building the golf course, new hotels, new restaurants at SW and N Hon Tre. In previous studies (Latypov, 2006; Tuan, 2002f) confirm that substantial quantities of fine silts are found on the deeper coral reef slopes at Hon Mieu and Hon Mot. Observations from 2002 to 2005 showed a marked increase in macro algae abundance and a significant decline in fish density at Hon Mieu and Hon Mot. These are both probable symptoms of nutrient enrichment and lack of herbivorous grazing fishes (e.g. Parrotfishes, Damselfishes), the latter probably a consequence of exaggerated fishing (Figure 3.13; Appendix 6). The temporal tendency of the two species assemblage at Hon Mieu and Hon Tre was found in most of species and higher taxa. For fish, this negative trend seemed to be clearer for the previous dominant families, Pomacentridae, Scaridae, Labridae and Acanthuridae. These two islands also showed similar development patterns with regard to other ecological groups: invertebrates, corals; and were often depicted close to each other, i.e. had similar ecological assemblages, in the plots of the multivariable analyses. Unfortunately, the marine communities at Hon Mieu and Hon Mot may continue to drift in an undesirable direction: the total number of tourists is forecasted to increase in the recent future, and this may give rise to increase in fishing and aquaculture pressure. Increase in the construction of tourism facilities may also produce habitat loss and more sediment that are the detriment for the coral reef's heath. Furthermore, Nha Trang port has expanded, and the shipping traffic in and out of port has become more frequent.

The island of E Hon Tre lies furthest away from tourism and aquaculture activities. It also the most isolated from the land, ports, new tourism expansion zones (N and SW Hon Tre) and run-off from the Cai river. Hence, influences from human activities in this region would seemingly be considered low. Following the rezoning regime in 2005, E Hon Tre belongs now to the core zone MPA. In practice, inspections and monitoring from the MPA Authority have not regularly reached this region since 2005. At the present stage E Hon Tre could be considered an 'open-access' fishing zone. Consequently the fish abundance at E Hon Tre was reduced more here than in other areas, and the fish assemblage in the deep site exhibited a great loss due to a probable higher impact from fishing pressure. At this area, the great loss of herbivorous and omnivorous fish, particularly Parrotfishes (Scaridae), Damselfishes (Pomacentridae) and Surgeonfishes (Acanthuridae) can possibly be considered as the sole reason the overgrowth of macro-algae in 2005. However, from the observations of invertebrate and coral abundances in 2002 and 2005, multivariable analysis (CA/CAA) indicated the consistence of invertebrate and coral assemblages at E Hon Tre (Figure 3.10; 3.15). Thus, these groups may not have been affected as much by human activities as the fish-algae cascading groups.

4.2. Study and methodological aspects

Studying MPA effectiveness by species or by taxa is important but not sufficient from an ecosystem-based perspective (Claudet et al., 2006). Changes in the composition of the assemblage of the whole four groups of organism (macro-algae, invertebrates, fish and corals) have to be assessed across the boundaries of the MPAs. The permutational multivariate analysis of variance allowed the production of a diagnostic on the evolution of the entire species assemblage with respect to MPA establishment. By this way, the changes of the MPA three years after its establishment were only assessed in relation to fisheries goals (i.e., effects on fish abundances and sizes) and conservation goals (i.e., effects on species richness and diversity). Many other aspects could have been investigated, such as the socio and economic impacts of the MPA people community (Carter, 2003; Pelletier et al., 2005). Linkages between ecological, socio and economic systems often give an insight to direct and immediate feedbacks (Brown et al., 2001). Pomeroy *et al* (2004) recommends that studies on MPAs have to be performed using three kinds of indicators: the biophysical, socio-economic and governance indicators. Other previous researches (Fazey, 2005; Jameson, 2002) suggest that studies on MPA also have to be more and more multidisciplinary, however this must be done with clear planning, monitoring, evaluation and links with policy and management of the MPA.

The present study of the status of the MPA in 2005 also does not capture the spillover of individual species, or whole assemblages, from and to the MPA, a factor often considered in the planning of reserves. There are some field studies on spillover status of fish within the MPAs. Such was the study of Attwood & Bennett (1994) in the De Hoop reserve (South Africa), among 1,008 tagged fish (*Dichistius capensis)* inside the MPA, after 5.5 years, 828 tagged fish were recaptured within 5km and the remaining were recovered from 25 to 1,040km of where they were released. In another study, Ramos-Espla (1994) showed 50-85% higher catches close to the Tabarca marine reserve (Spain) after six years of protection. The present results are based on the assumption that the MPA's water area was closed completely in terms of emigration and immigration during the study period. During the consultations with experts from the Nha Trang Bay MPA Authority they suggested that clear signs of migration of fish between protected and adjacent areas would not become noticeable before another three years have passed. With regard to spillover, the Merritt Island National Wildlife Refuge at Cape Canaveral, Florida, USA needed about eighteen years for substantial spillover of fish from the reserve into the adjacent recreational fishery (1962-1980) (Commonwealth Australia., 2003) or in the MPA at Sumilon Island in Philippines, Alcala (1988) and Alcala & Russ (1990) indicated the evidence for fish biomass spillover after ten years of establishments. Furthermore, in a previous study of the Nha Trang Bay MPA Nam (2005) suggests that the spillover effects would start manifesting only in 2006. Therefore, along with an expanded survey area, and an increase in the replication of the observations, the spillover aspect must be addressed by setting observation stations both inside and outside the MPA.

In general, the results of the multivariate analyses of density data showed significant differences from 2002 to 2005 in the four groups of organism: macro-algae, invertebrates, fish and corals. While clear effects of Area were normally found in the analyses, other effects were either difficult to demonstrate or to incorporate into the analyses. An apparent intriguing finding in the present data was the possible minor role of depth on the composition of the species assemblages of macro-algae. This could have been brought about by two factors: one is the relatively good transparency of the water in Nha Trang Bay, about 11m (Aquaculture Faculty., 2005). This makes macro-algae have a wider vertical distribution. Secondly, the samples were not taken at two widely separated depth zones, but as a part of sequential transect (2-7m and 8-20m). It might be that similarity in community composition at intermediary depths along the 2-20m gradient has had an excessive weight in the analysis, and thereby disguised any real differences between the shallowest and deepest observations (Dam Duc Tien, HIO, pers. com). Another weakness of the analyses was that, owing to the lack of spatial detail, the fishing data, the aquaculture data and the visitor (tourist) data could not match the details of the reef species data. The lack of data on human activities for specific locations, e.g. how many visitors frequently visited Hon Mun island? How many culture cages were regularly operating at Hon Mot? hindered the inclusion of these data in the multivariate analyses. Hence, the present work does not investigate which human utilizations affected most each area or depth level. By the same token, it is difficult from the present information to make sharp judgments about the most impacting human activities, or to answer questions about the sustainability of the different practices. The associations of possible cause and effects discussed below are indicial, rather that conclusive.

4.3. Conservation aspects and indicators for management

The main conservation aims of the MPA were to protect and maintain of biological diversity, and of natural and associated cultural resources, and to manage through legal or other effective means (IUCN, 1994). World Commission on Protected Areas (WCPA) (1998) informs "*the goal of MPAs is to conserve the biological diversity and productivity (including ecological life support systems) of the ocean*". It is difficult however to ascertain if they were achieved, or more realistically, if we are going along the right path to reach that aim. This is common state during the initial evaluation of MPA programmes. For example, the Mimiwhangata Marine Park (New Zealand), Denny (2004) showed no difference in abundance or size of the snapper (*Pagrus auratus)* that was the most heavily targeted species and no significant difference in the overall fish assemblages between the inside and adjacent control areas in 18 years (1984-2002). Another study showed only non-significant differences in most of the benthic assemblages between the protected and unprotected areas in the MPA of Torre Guaceto (Southern Adriatic Sea, Italy) in more than 10 years (Fraschetti et al., 2005). A study of reefs at risk in Southeast Asia shows that only 14% of 332 MPAs were effectively managed, and the remaining were partially or inadequately managed (Burke, 2002). Further, Kelleher (1995) indicates fewer than 10% of existing MPAs achieve their management goals and objectives. MPAs generally are being established in the lack of clearly defined objectives, or have multiple, and sometimes conflicting objectives. Indeed, rarely is there a single reason for reserve designation (Carr, 2000), while the opposite should be the rule: protecting effectively species requires prioritization. Hence, it is difficult to test the efficacy of poorly defined aims of protection or it is difficult in quantifying MPA effectiveness. Protection can improve abundance or size of some species, but target species are very often predator species and thus there will be higher predation pressure on the preys inside the MPA, leading to changes in the fish assemblage (Francour, 1994). In the present study, some (weak) signs of stability or resilience of the fish assemblage in the small core zone at Hon Mun exist, and these have been stressed by the MPA Authority as a token of success (Tuan, 2005a): these signs are the existence of populations of top predators in 2005 (Figure 3.13). Another sign of restoration is a slight increase in the hard corals its absence could be, on the contrary, indicative of blast fishing, poison fishing and/or nutrient pollution in the deep site of SW Hon Mun in 2005 (Hodgson, 2002). However, three years after establishment seems short to detect clear changes in the biodiversity of the whole reef.

According to McClanahan (1994), the population changes are frequently associated with major changes in the ecological structure and processes of the coral-reef ecosystem. The causes of these fluctuations in population abundance are seldom known or known insufficiently. In practice, human have had more less an influence in these community changes. McClanahan also reveals that determining the causes of these changes is often difficult due to high spatial variability in coral reef and the lack of replicate human management ‘treatments’ which allow for statistical detection of human influence apart from the frequently synergistic influences of natural events (McClanahan, 1994). Despite the short duration of the time-series utilized in the present work, some clear patterns emerged, and these patterns of presence or absence can be used to suggest locally adapted indicator species or groups (Table 4.1). These indicators have had significant associations in terms of abundance with one species or species groups or management actions that are defined as associated organisms or actions. Associated trends (positive or negative) in table 4.1 are referred when the indicator and its associated organisms change in same or opposite direction, respectively. Thus, fluctuation tendency of indicator can be utilized to predict the change of its associated organisms or management level. For instance, the brown alga *Turbinaria ornate* is normally kept at low densities by herbivorous fish, but once these are removed this alga tends to 'blossom'. When left un-matched it often grows rapidly in water environment with high nutrient input.

Table 4.1: Simple indicators of ecological status derived from the present study and relationship to previous observations and trends in MPAs elsewhere

Indicators	Associated organisms or actions	Associated trend	References
Brown alga *Turbinaria ornata*	Herbivorous/high nutrient	Negative/positive	(Amsler, 2001; University of Hawaii., 2001)
Herbivorous fish	Protection scenario	Negative	(Claudet et al., 2006; Mosquera et al., 2000)
Carnivorous, top predators	Protection scenario	Positive	(Claudet et al., 2006; Mosquera et al., 2000)
Fish: *Ctenochaetus striatus*	Fish: *Cephalopholis argus, Epinephelus merre*	Negative	(Froese & Pauly, 2007)
Fish: *Siganus argenteus*	Fish: *Epinephelus merra*	Negative	(Froese & Pauly, 2007)
Coral-eating snail *Drupella cornus*	Low to intermediate abundance of Labrid (Labridae) and Balistid (Balistidae)	Negative	(Froese & Pauly, 2007)
Red macro alga *Ceratodictyon*	Grow only in symbiosis with the tropical sponge *Haliclona*	Positive	(Donelle A. Trautman., 2006)

spongiosum	*cymaeformis,* forms a tightly anastomosed.		
Light brown alga *Padina australis*	Eaten by crabs, snails and all kinds of fish and shrimp	Negative	(William Magruder., 2007)

4.4. Implications for management

With a basis on the previous descriptions of the MPA (Tuan, 2002b; Tuan, 2005b), eight human utilization activities within the Nha Trang bay are commonly identified as probable agents of change in diversity. These are diving, other tourism activities (snorkelling, swimming, sport activities), aquaculture (lobster culture), commercial fishing, urban proximity, tourism expansion, shipping and navigation, as well as agricultural runoff from the Be river and the Cai river. The present study focused solely on the development and status of the aquaculture, fishery and tourism industries in recent years. However, even if direct cause-effect relationships could not be demonstrated, the present review suggests that it is very likely that, overall, the MPA community was negatively impacted by human activities in the period 2002 to 2005, i.e. after the creation of the protected area.

Table 4.2: Matrix of probable trade offs between the level of each human utilization pattern and the potential impacts in each area

Agents/areas	Hon Mun	Hon Mieu	Hon Mot	E Hon Tre
Diving	High	Low	Medium	Low
Other tourism	Medium	High	Medium	Low
Aquaculture	Low	High	High	Low
Fishing	Low	Medium	Medium	High
Urban proximity (sewage etc)	Low	High	High	Low
Tourism expansion	Low	Medium	Medium	Low
Shipping, maritime	Low	High	Medium	Low
Agricultural runoff (fertilizers etc)	Medium	High	High	Low

The high prevalence of fishing and fishing-related aquaculture activities are, most probably, main obstacles to the restoration of MPA's biodiversity in the study period. Major influences of fishing to the MPA were derived from the increase in the number of fishing boats from 380 boats in 2002 to 527 boats in 20005, overfishing and poaching in a core zone in recent time. Meanwhile, a rapid development in the number of culture cages from 1,675 in 2001 to 5,096 in 2004, a high demand on wild seeds and utilization of 'trash fish' as preferred foods for culture were considered as the main impacts of mariculture to the MPA. The "*Temporary Regulation and Zoning Scheme*" (2002) suggests a detailed zoning of fishing areas and regimes. However, this zonation is not respected in practice. Further, experts interviewed during the present field survey in 2006 often stated that the present ratio between total core zone's area and whole MPA's area is relatively low (Red colour areas in Figure 1.2). There are some examples to illustrate this ratio elsewhere in more successful protected areas (Table 1.2), such is the case of two MPAs in Australia (Commonwealth Australia., 2003). In this case, an area corresponding to 'no-take' zone was enlarged from 2% to 4.6% of the entire Great Barrier Reef Marine Park (GBRMB) or 30% of the entire area of the Lord Howe Island Marine Park has a very high level of protection, prohibiting all forms of fishing and other extractive activity. Thus, allowing the free fishing, except for trawl and destructive fishing, in buffer zones and transition zones of Nha Trang Bay MPA will eventually create large negative influences that will prevent the recovery of fish assemblages, and consecutive grazing of macro-algae and restoration of corals, following cascading effects. On the other hand, according to Mr. Nguyen Van Long (NIO, pers.com) the reason for the slow rate of restoration within the MPA is because it began with a low biodiversity level when it was established. However, there is a lack of obvious evidence from the present study to substantiate his suggestions: in fact, for many ecological groups and areas, density and diversity actually declined strongly from 2002 to 2005. Also according to Mr. Nguyen Van Long (NIO, pers.com), the lack of more extensive network of protected areas along the coast is detrimental. These separated protected areas could either produce propagules or receive propagules of populations (Goeden, 1979) from each other, and give rise to a global positive effect. There are grounds to believe that the existence of a mosaic of protected areas could have beneficial effects from practical and theoretical work in other settings (Baker, 1996; Robert, 1991; Roberts, 2000). However, potential impediments to success of the extensive network also exist, and these include weaknesses in critical connections between habitats or an increased 'loss rate' of populations from core zones to adjacent habitats owing to the greater perimeter-to-area ratio of many small MPAs (de Martini, 1993; Fairweather, 1993). We have at present too little information about the population and community dynamics in the

Bay to positively identify which model of protected area (a single large reserve v. a mosaic of smaller core areas) would suit best the overall aims of the MPA.

Economical study (Nam, 2005) clearly suggests that the net benefit of Nha Trang Bay area in a 'with management scenario' would be considerably higher compared to the 'without management scenario' or 'unsustainable use'. This is a result of increase in two main factors: healthier marine ecosystems sustain more productive capture fisheries/aquaculture; and preserved marine ecosystems (particularly reefs) attract more number of tourists and coastal tourism increases regardless of marine conservation initiatives. However, intensively and effectively managing the MPA is costly. The Nha Trang Bay MPA was established in 2002 with initial funding coming mostly from an international donor, DANIDA (Denmark). At the end of 2005 external funding by donation was terminated. One of the biggest challenges for existence of the MPA is maintaining the sustainability of finance (Vinh et al., 2003). The present funding for running of the MPAs derives mostly from 'conservation fees' or 'visitors fee' applied to tourists. In reality, the tourism industry can be seen as a 'flagship' of Khanh Hoa province economy, with an annual contribution of around 40% to the GDP of province in recent years (Khanh Hoa province., 2006). While tourism can be highly beneficial to the economy of the province and to the MPA in particular, it may also have negative indirect feedbacks to the MPA in the form of increasing pressure for fishing or aquaculture, or other disturbing human activities. Quantification of this linkage, could not be achieved in the present study, but must be a priority for future managerial studies. Further, it should also be given high priority in the Nha Trang MPA, and other MPAs in the planning, to perform studies that quantify the sustainability of a high tourism-load vis-à-vis ecological achievement in the coral reef ecosystems.

5. CONCLUSION

The present study is a re-assessment of data from inventories performed at four locations at the start (2002) and three years after the enforcement of a marine protected area in coral reefs. It is normally difficult to find marked and consistent changes in such short period of time. The results of the surveys were also hampered by the lack of replicates, which can be difficult to implement for full inventories. Nonetheless, the trends observed seemed to be consistent across taxonomic and ecological groups, including large sessile organisms that integrate environmental disturbances over longer periods of time.

Overall, and irrespective of depth, there was an increased cover of the reef by macro-algae, and a simultaneous decrease in the diversity and density of the hard-corals, other macro-invertebrates and fish. Thus, the increase in algal cover seemed to be consistent with reduced grazing, particularly by herbivorous fish.

The patterns and intensity of change differed, however, with the location of the inventory stations and their particular zonation regime. Two sampling stations were located in the fringing reefs of the islands of Hon Mieu and Hon Mot. These islands are situated in the buffer zone of the MPA, and close to the city of Nha Trang. They are, thereby, the most affected by shipping, silting, and activities related to fishing and mariculture, as well as general tourism. The major trends observed in these two locations were the decline in the number of species and density of fish, and the reverse for macro-algae. Of particular notice were the substantial declines in the density of all species of macro-invertebrates in the deep reef of Hon Mot, and of fish in the deep site of Hon Mieu, in 2005.

The island of Hon Mun lies in the core zone of the MPA, and a slight recovery was observed in the density of invertebrates and corals in the deep sites. The latter showed also a higher diversity than in baseline studies, even though macro-algae were also more frequent. Despite the general decline in both diversity and density of fish in the reef, most trophic levels were still adequately represented, including purely carnivorous fish. This island is the showcase of the MPA, is heavily visited by tourists, particularly for diving and snorkelling, and is situated further offshore from the city and other human disturbances.

The fringing reef investigated in the island of Hon Tre lies in the core zone most distant from the coast, and is apparently the most pristine area of the MPA, with a low tourism load. However, unlike in Hon Mun, enforcement of regulations is poor and there are reports of widespread illegal fishing and collection activities, particularly by hookah-divers. Probably as a consequence, the density of fish of all families and trophic groups showed the largest decline of all sites investigated. However, the change in the species richness of hard corals, as well as in the density of hard corals and invertebrates, was less marked.

The direct impact of tourism does not seem markedly prejudicial to the reef communities, and the tourism industry seems motivated to improve their practices to higher environmental standards. On the contrary, both the mariculture and the fishing activities seem to have been growing unchecked. While one of the goals of implementation of the MPA was to improve the livelihood of the locals, through e.g. credit to small-scale mariculture, the present observations suggest that floating cage aquaculture of lobster, the type of capital-intensive enterprise only afforded by outsiders, is becoming increasingly important. This is a more intensive type of farming than the traditional cage culture, and probably far more demanding on wild seed and feed, which consists of large amounts trash fish caught in the area.

Three years after the implementation of this small pilot MPA both the diversity and density of the reef communities seem, paradoxically, to be generally declining. While this work does not give conclusive evidence of the match between increasing human activities and decreasing reef community complexity, there is a preponderance of evidence that calls for a re-assessment of the management plan for the MPA. Particular emphasis should be given to the allowable load of human activities and its relationship to the size and zonation regime of the protected area.

REFERENCES

AIG- MARINE CULTURE GROUP. (2002). Proposed plan for AIG marine culture activities in the MPA (April 4, 2002). In *Aquaculture report No.7. Hon Mun Marine Protected Area Pilot Project*.

ALCALA, A. C. (1988). Effects of marine reserves on coral fish abundance and yields of Philippine coral reefs. *Ambio* **17,** 194-199.

ALCALA, A. C., RUSS, G.R.,. (1990). A direct test of the effects of protective management on abundance and yield of trophical marine resources. *Jounal du Conseil International pour l'Exploration de la Mer* **47,** 40-47.

AMSLER, C. D. (2001). Induced defenses in macroalgae: the herbivore makes a difference *J. Phycol* **37,** 353-356.

AQUACULTURE FACULTY. (2005). Summary report on water monitoring of Nha Trang Bay MPA. In *Aquaculture report No 12*. Nha Trang University.

ATTWOOD, C. G., BENNET, B.A.,. (1994). Variation in dispersal of Galjoen (*Coracinus capensis)* (Teleostei: Coracinidae) from a marine reserve. *Canadian Journal of Fisheries and Aquatic Science* **16,** 227-240.

BAKER, J., SHEPHERD, S., EDYVANE, K.,. (1996). The use of marine fishery reserves to manage benthic fisheries, with emphasis on the South Australian abalone fishery. In: Baker. J (2000): *Guide to Marine Protected Area*. Department for environment and heritage. Government of South Australia (ed. J. Bridgland).

BORCARD, D. (2004). Multivariate analysis (March), Departement de sciences biologiques. Universite de Montreal. C.P. 6128, succursale Centre Ville. Montreal QC. H3C 3J7, Canada. daniel.borcard@umontreal.ca.

BROWN, K., ADGER, W. N., TOMPKINS, E., BACON, P., SHIN, D. & YOUNG, K. (2001). Trade-off analysis for marine protected area management. *Ecological Economics* **37,** 417-434.

BRYANT, D., BURKE, L., MC MANUS, J. & SPALDING, M. (1998). Reefs at risk: A map based indicator of threats to the World's coral reefs. Washington DC: WRI, ICLARM, WCMC and UNEP.

BURKE, L., SELIG, L., SPALDING, M.,. (2002). *Reefs at risk in Southeast Asia. In: Pomeroy, R.S (2005). How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected area. Ocean&Coastal Management 48, 485-502*.

CARR, M. H. (2000). Marine Protected Areas: Challenges and opportunities for understanding and conserving coastal marine ecosystem. *Environmental Conservation* **27,** 106-109.

CARTER, D. W. (2003). Protected areas in marine resource management: another look at the ecoomics and research issues. *Ocean & Coastal Management* **46,** 439-456.

CHARLES, S., MARK, S.,. (2003). Chagos Conservation Management Plan. British Indian Ocean Territory Administration-Foreign &Commonwealth Office, London.

CHEUNG, C. P. S. & TUAN, V. S. (1993). Survey report on the biodiversity, resources utilization and conservation potential of Hon Mun, Nha Trang, South Central Vietnam. . In *Vietnam marine conservation southern survey team*. Gland, Switzerland: WWF.

CLAUDET, J., PELLETIER, D., JOUVENEL, J. Y., BACHET, F. & GALZIN, R. (2006). Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: Identifying community-based indicators. *Biological conservation* **130,** 349-369.

COMMISSION ON GEOSCIENCES-ENVIRONMENT AND RESOURCES (CGER). & OCEAN STUDIES BOARD (OSB). (2001). *Marine Protected Areas: Tools for Sustaining Ocean Ecosystem. p.156*. National Academy of Sciences.

COMMONWEALTH AUSTRALIA. (2003). The benefits of marine protected areas. In *Derpartment of the environment and heritage-Australian Government*.

DE MARTINI, E. (1993). Modeling the potential of fishery reserves for managing Pacific coral reef fishes. *Fishery Bulletin* **91,** 414-427.

DENNY, C. M., BABCOCK, R.C.,. (2004). Do partial marine reserves protect reef fish assemblages. *Biological conservation* **116,** 119-129.

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 Application* **8,** 480-496.

DINH, H. B., HOA, T T H. (2005c). Review on status of exploitation of Marine resources in Nha Trang Bay. Institute of Oceanography, Nha Trang, Viet Nam.

DINH, H. B., VU, N P U., QUANG, V V. (2003). Results of fishing monitoring in Nha Trang Bay Marine Protected Area. Institute of Oceanography, Nha Trang, Khanh Hoa.

DINH, H. B., VU, N P U., QUANG, V V. (2005a). Resuts of fishing monitoring in Nha Trang Bay Marine Protected Area on south wind season (07/2005-08/2005) (part 3-fishing yield). Institute of Oceanography, Nha Trang, Khanh Hoa.

DINH, H. B., VU, N P U., QUANG, V V. (2005b). Results of fishing monitoring in Nha Trang Bay Marine Protected Area on north win season (12/2004-01/2005). Institute of Oceanography, Nha Trang, Khanh Hoa.

DINH, H. B., VU, N P U., QUANG, V V. (2005d). Field survey by fishermen's fishing boat in Nha Trang Bay Marine Protected Area. Institute of Oceanography, Nha Trang, Viet Nam.

DONELLE A. TRAUTMAN., R., HINDE.,. (2006). Sponge/Algal Symbioses: A diversity of associations, vol. 4, pp. 521-537. Springer Netherlands.

EDGAR, G. J., BUSTAMANTE, R. H., FARINA, J. M., CALVOPINA, M., MARTINEZ, C. & TORAL-GRANDA, M. V. (2004). Bias in evaluating the effects of marine protected areas: the importance of baseline data for the Galapagos Marine Reserve. *Environmental Conservation* **31,** 212-218.

ENDEAN, R. & STABLUM, W. (1975). Population explosions of Acanthaster planci and associated destruction of the hard coral cover of reefs of the Great Barrier Reef. *Environmental Conservation* **2,** 247-256.

FAIRWEATHER, P., MCNEILL, S.,. (1993). Ecological and other scientific imperatives for marine and estuarine conservation. In: Baker.J (2000). Guide to Marine Protected Area. Department for environment and heritage. Government of South Australia (ed. J. Bridgland).

FAZEY, I., FISCHER, J., LINDENMAYER, D.,. (2005). What do conservation biologists publish? *Biological conservation* **124,** 63-73.

FRANCOUR, P. (1994). Pluriannual analysis of the reserve effect on ichtyofauna in the Scandola natural reserve (Corsica, Northwestern Mediterranean). *Oceanologica Acta* **17,** 309-317.

FRASCHETTI, S., TERLIZZI, A., BUSSOTTI, S., GUARNIERI, G., D'AMBROSIO, P. & BOERO, F. (2005). Conservation of Mediterranean seascapes: analyses of existing protection schemes. *Marine Environmental Research* **59,** 309-332.

FROESE, R. & PAULY, D. (2007). FishBase. In *World Wide Web electronic publication. www.fishbase.org, version (02/2007).*

GOEDEN, G. B. (1979). Biogeographic theory as a management tool. *Environmental Conservation* **6,** 27-32.

GREENACRE, M., BLASIUS, J.,. (1994). *Correspondence Analysis in the Social Sciences, p. 51*. Academic press LTD, Harcourt Brace&Co., Publishers, London.

HODGSON, G. (1999). A global assessment of human effects on coral reef. *Marine Pollution Bulletin* **38,** 345-355.

HODGSON, G., J, LIEBELER. (2002). The global coral reef crisis- Trends and solutions. In *Science-Education-Management*, pp. 77.

HOI, N. C., YET N H & THANH D N (1998). Scientific base for marine protected area planning. In Vietnamese. Hai Phong Institute for Oceanography, Hai Phong.

HON MUN AUTHORITY. (2002). Temporal regulation of Hon Mun Marine Protected Area management. Draft to Khanh Hoa province people committee. In Vietnamese, pp. 5.

IUCN. (1994). Guidelines for Protected Area Management Categories. Commission on National Parks and Protected Areas, with the assistance of the World Conservation Monitoring Centre, Gland, Switzerland.

IUCN. (1995). *Application of IUCN Protected Area Management Categories: Draft Australian Handbook: In: J.L. Baker B.Sc.M.Env.St (2000): Guide to Marine Protected Areas. Department for environment and heritage. Government of South Australia*.

IUCN VIETNAM PROGRAM. (2001). Minimum sized project brief. Hon Mun MPA pilot project.

J E N VERON. (2000). *Corals of the World*. Australian Institute of Marine Science.

J L BAKER B SC M ENV ST. (2000). Guide to Marine Protected Area. In *Department for environment and heritage-Government of South Australia*.

JAMES E. MAGAROS, D. C. P., GRETA AEBY, DAVE GULKO, JEAN KENYON, DARIA SICILIANO&DAN VANRAVENSWAAY. (2004). 2000-2002 Rapid Ecological Assessment of Corals (Anthozoa) on Shallow Reefs of the Norhwestern Hawaiian Islands. Part 1: Species and Distribution. *Pacific Science* **58,** 211-230.

JAMESON, S. C., TUPPER, M.H., RIDLEY, J.M. (2002). The three screen doors: Can marine "protected" areas be effective? *Marine Pollution Bulletin* **44,** 1177-1183.

JAN LEPS. & SMILAUER, P. (1999). *Multivariate Analysis of Ecological Data*. Faculty of Biological Sciences. University of South Bohemia. Ceske Budejovice.

KELLEHER, G., BLEAKLEY, C., WELLS, S. (1995). A Global Representative System of Marine Protected Areas. *The Great Barrier Reef Marine Park Authority, The World Bank, IUCN, Washington DC, USD*.

KHANH HOA PROVINCE. (2006). Results of tourist activities in 2001-2005. http://www.nhatrang-travel.com/v_pages/intro/overview.asp.

KINH, T., THU H V T., ET AL. (2004). Aquaculture management solutions in Hon Mun MPA. In *Hon Mun MPA pilot project-Aquaculture report No.13*. Hon Mun Authority.

KREBS. (1989). *Ecological Methodology*. R.R. Donnelley&Sons Company, New York, United States of America.

LATYPOV, Y. Y. (2006). Changes in the Composition and Structure of Coral Communities of Mju and Moon Islands, Nha Trang Bay, South China Sea. *Russian Journal of Marine Biology* **32,** 269-275.

MCCLANAHAN, T. R. (1994). Coral-eating snail Drupella cornus population increases in Kenyan coral reef lagoons. *Marine Ecology Progress Series* **115,** 131-137.

MICHAEL, H., TU H T N V.,. (2005). Report on changes within the tourism industry affecting Nha Trang Bay Marine Protected Area, August, pp. 12. Hon Mun MPA pilot project.

MICHAEL, H., TU, H.T.N.V. (2004). Tourism activity management plan for Nha Trang Bay Marine Protected Area. In *Eco-tourism report No.1, July*, pp. 25. Hon Mun MPA pilot project.

MOSQUERA, I., COTE, I. M., JENNINGS, S. & REYNOLDS, J. (2000). Conservation benefits of marine reserves for fish populations. *Animal Conservation* **4,** 321-332.

NAM, P. K., HERMAN C, ET AL.,. (2005). Financial sustainability of the Hon Mun Marine Protected Area. Lessons for other marine parks in Vietnam. University of Economics, Ho Chi Minh City.

NGA, T. N. M., DUYEN, C T T.,. (2002a). Rapid survey on skills and understanding of aquaculture practices in Hon Mot. In *Aquaculture report No.1, March*. Hon Mun MPA pilot project.

NGA, T. N. M., DUYEN, C T T.,. (2002b). Rapid survey on skills and understanding of aquaculture practices in Vung Ngan. In *Aquaculture report No 2*. Hon Mun MPA pilot project.

NGA, T. N. M., DUYEN, C T T.,. (2002c). Rapid survey on skills and understanding of aquaculture practices in Bich Dam and Dam Bay. In *Aquaculture report No.3*. Hon Mun MPA pilot project.

PELLETIER, D., GARCIA-CHARTON, J. A., FERRARIS, J., DAVID, G., THEBAUD, O., LETOURNEUR, Y., CLAUDET, J., AMAND, M., KULBICKI, M. & GALZIN, R. (2005). Designing indicators for assessing the effects of marine protected areas on coral reef ecosystems: a multidisciplinary standpoint. *Aquatic Living Resources* **18,** 15-33.

POMEROY, R. S., PARKS, J.E &WATSON, L.M (2004). *How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness*. IUCN Publications Services Unit, United Kingdom.

RAMOS-ESPLA, A. A., MCNEILL, S.E.,. (1994). The status of marine conservation in Spain *Ocean & Coastal Management* **24,** 125-138.

ROBERT, C., POLUNIN, N.,. (1991). Are marine reserves effective in management of reef fisheries? *Reviews in Fish Biology and Fisheries* **1,** 65-91.

ROBERTS, C. M., HAWKINS, J.P.,. (2000). *Fully-protected marine reserves: a guide*. WWF Endangered Seas Campain, 1250 24th Streat, NW, Washington, DC 20037, USA.

SALM, R. V. (1980). The genus-area relation of corals on reefs of the Chagos Archipelago, Indian Ocean. In: Baker.J (2000). Guide to Marine Protected Area. Department for environment and heritage. Government of South Australia (ed. J. Bridgland).

SALM, R. V. (1984). Ecological boundaries for coral reef reserves: Principles and guidelines. *Environmental Conservation* **11,** 7-13.

SALM, R. V., CLARK, J.R., SIIRILA, E.,. (2000). Marine and Coastal Protected Areas-A guide for planners and managers (Third eddition), pp. 46, 180-181. International Union for Conservation of Nature and Natural Resources, Switzerland.

SERVICIO PARQUE NACIONAL GALAPOGOS. (1998). Management plan for conservation and sustainable use of the Galapagos Marine Reserve. Galapagos island, Ecuador.

SPALDING, M., RAVILIOUS, C., GREEN, E. P.,. (2001). *World atlas of coral reefs*. United Nations Environment Programme World Conservation Monitoring Center.

TALAUE., M., MANUS. (2000). Transboundary diagnostic analysis for the South China sea. In *EAS/RCU technical report series No.14*. Bangkok, Thailand: UNEP.

TER BRAAK, C., SMILAUER, P.,. (2002). *CANOCO 4.5. Software for Canonical Community Ordination. Microcomputer Power*. Ithaca, New York, USA.

THU, H. V., ET AL. (2005). Socio-economic impact assessment of the Hon Mun MPA project on local communities within the MPA, pp. 54. Hon Mun Authority, Nha Trang.

TUAN, V. S., DEVANTIER L M ET AL. (2002c). Coral reef monitoring of Hon Mun Marine Protected Area, Nha Trang Bay, Vietnam. In *Baseline assessment and training of the community-based monitoring team*. Institute of Oceanography, Khanh Hoa.

TUAN, V. S., DEVANTIER L M ET AL. (2002f). Marine and coastal habitats of Hon Mun Marine Protected Area, Nha Trang Bay, Viet Nam. In *Basicline survey-Biodiversity Report No 5*, Khanh Hoa.

TUAN, V. S., DEVANTIER L M ET AL. (2005a). Biodiversity of the Nha Trang Bay MPA, Khanh Hoa, Vietnam. Reassessment 2002-2005. In *Hon Mun MPA pilot project-Biodiversity Report No.12*.

TUAN, V. S., DEVANTIER, L. M., LONG, N. V., TUYEN, H. T. & HOA, N. X. (2005b). Marine and coastal habitats of Nha Trang Bay Marine Protected Area, Khanh Hoa, Vietnam. Reassessment 2002-2005. In *Hon Mun MPA pilot project. Biodiversity report No.13*.

TUAN, V. S., DEVANTIER, L. M., LONG, N. V., TUYEN, H. T., HOA, N. X. & HOANG, P. K. (2002e). Coral reef of the Hon Mun Marine Protected Area, Nha Trang Bay, Vietnam 2002: Species composition, community, structure, status and management recommendations. In *Technical report to IUCN-Hon Mun MPA pilot project*. Institute of Oceanography.

TUAN, V. S., DEVANTIER, L M ET AL.,. (2002a). Shallow water habits of Hon Mun Marine Protected Area, Nha Trang Bay, Vietnam: Distribution, extent and status 2002. In *Collection of Marine works special issue on the Ocassion of the 80th Anniversary of the Institute of Oceanography (1922-2002)*, vol. 12. Science and Technique Publishing House, Nha Trang City, Khanh Hoa province.

TUAN, V. S., DEVANTIER, L. M ET AL. (2005c). Ecological Monitoring of Nha Trang Bay Marine Protected Area, Khanh Hoa, Viet Nam. Reassessment 2002-2005. In *Hon Mun Marine Protected Area Pilot Project. Biodiversity Report No.15*. Nha Trang Institute of Oceanography, Khanh Hoa.

TUNG, H. (2002). Improving local livelihoods through sustainable aquaculture in Hon Mun marine protected area, pp. 39. IUCN, Ha Noi.

UNIVERSITY OF HAWAII. (2001). Algae: Native, invasive elsewhere-Turbinaria ornata (Turner) J. Agardh 1821-Botany Department. http://www.hawaii.edu/reefalgae/invasive_algae/phaeo/turbinaria_ornata.htm.

VINH, C. T. (2003a). A participation of local community in management zoning in Marine Protected Area. A lesson from Nha Trang Bay MPA. In Vietnamese, pp. 16.

VINH, C. T. (2005). The experience in Nha Trang Bay MPA management from the results of Hon Mun MPA pilot project (Vietnamese) (ed. Le Doan Dung.).

VINH, C. T., BERNARD O'CALLAGHAN.,. (2001). Hon Mun Marine Protected Area pilot project- A case study from Viet Nam. First national round table. http://www.mekong-protected-areas.org/vietnam/honmun.htm.

VINH, C. T., CALLAGHAN, B. O., TRUONG, K. & THU, H. V. T. (2003). Key Approaches to the Conservation and Management of the Biodiversity of the Hon Mun Marine Protected Area in Vietnam. In *East Asia Sea Congress, 8-12, December 2003*, Malaysia.

WILKINSON, C. (2000). Appraising a proposal on Hon Mun Marine Protected Area pilot project. Australian Marine Science Institute. In: Documents and appendix of Hon Mun MPA pilot project. Ha Noi, Vietnam, March 2000.

WILLIAM MAGRUDER., J., HUNT.,. (2007). Seaweeds of Hawaii. http://www.bluforman.com/intertidal/test/species/speciesPages/groups/brownGreenAlgae/Padinaaustralispage.htm.

WORLD COMMISSION ON PROTECTED AREAS (WCPA). (1998). *Guidelines for Marine Protected Areas*. CARDIFF University and IUCN.

APPENDICES

Appendix 1: Fish composition caught by nine different gears at Nha Trang Bay MPA in the year 2005

Order	Families	English names	Fishing gears
1	Apogonidae	Cardinalfishes	Trawl net, hookah diving
2	Ariommatidae	Ariommatids	Anchovies purse seine
3	Carangidae	Jacks and pompanos	Light purse seine, anchovies purse seine, light lift net, hand hook and line, trawl net, line net, hookah diving
4	Centropomidae	Snooks	Longline
5	Chaetodontidae	Butterflyfishes	Hookah diving
6	Clupeidae	Sardines	Anchovies purse seine, trawl net, line net
7	Cynoglossidae	Tonguefishes	Trawl net
8	Engraulidae	Anchovies	Anchovies purse seine, purse net, light lift net
9	Gerreidae	Mojarras	Trawl net
10	Gobiidae	Bobies	Trawl net
11	Hemiscyllidae	Bamboo sharks	Longline
12	Holocentridae	Squirrelfishes, soldierfishes	Hookah diving
13	Labridae	Wrasses	Hookah diving
14	Leiognathidae	Slimys, slipmouths	Trawl net
15	Lethrinidae	Emperors	Longline
16	Lutjanidae	Snappers	Hookah diving, hand hook and line
17	Monacanthidae	Filefishes	Light purse seine
18	Mugilidae	Mullets	Trawl net, line net
19	Mullidae	Goatfishes	Trawl net, hookah diving
20	Muraenidae	Morray eels	Both hookah diving
21	Muraenesocidae	Pike congers	Longline
22	Nemipteridae	Threadfin breams	Hand hook and line, hookah diving, trawl net
23	Platycephalidae	Flatheads	Hand hook and line
24	Pomacentridae	Damselfishes	Hookah diving
25	Priacanthidae	Bigeyes, catalufas	Trawl net, light purse seine, anchovies purse seine, light lift net, hand hook and line
26	Rachycentridae	Cobia	Longline

27	Scaridae	Parrotfishes	Hookah diving
28	Sciaenidae	Drums, croakers	Trawl net
29	Scombridae	Tunas, mackerels	Light purse seine, anchovies purse seine, light lift net
30	Serranidae	Groupers	Trawl net, hand hook and line, hookah diving
31	Siganidae	Rabbitfishes	Trawl net, light purse seine, anchovies purse seine, light lift net, line net, hand hook and line, hookah diving
32	Sillaginidae	Smelt-whitings	Trawl net
33	Sphyraenidae	Barracudas	Light purse seine, line net
34	Strombidae	Strombids	Hookah diving
35	Synodontidae	Lizardfishes	Trawl net
36	Terapontidae	Grunters or tigerperches	Trawl net, line net, hookah diving, hand hook and line
37	Tetraodontidae	Globe-fish	Trawl net, light purse seine, hookah diving
38	Trichiuridae	Cutlassfish	Light purse seine, anchovies purse seine, light lift net, hand hook and line, trawl net, line net
39	Turbinidae	Turbinids	Hookah diving

[Sources: Information cited from (Dinh, 2005c; Dinh, 2005d). English names cited from FishBase 2007 (Froese & Pauly, 2007)]

Appendix 2: Macro-algae species composition at Nha Trang Bay MPA in the years 2002 and 2005

Phylum	**Genera**	**Species**	**Species codes**	**2002**	**2005**
Chrorophyta	Bornetella	*oligospora*	Bool	+	
	Caulerpa	*serrulata*	Case	+	
	Cladophora	*socialis*	Clso	+	
	Dictyophaeria	*cavernosa*	Dica		+
		verluysii	Dive		+
	Halimeda	*opuntia*	Haop		+
	Valonia	*aegagropila*	Vaae		+
		ventricosa	Vave		+
Cyanophyta	Lyngbya	*majuscula*	Lyma	+	+
	Phormidium	*corium*	Phco	+	+
Phaeophyta	Chnoospora	*implexa*	Chim		+
	Dictyota	*beccariana*	Dibe	+	
		dichotoma	Didi	+	+
	Padina	*australis*	Paau	+	+

		tetrastromatica	Pate	+	
	Turbinaria	*ornata*	Tuor	+	+
Rhodophyta	Acanthophora	*spicifera*	Acsp		+
	Actinotrichia	*fragilis*	Acfr	+	+
	Amphiroa	*foliacea*	Amfo	+	+
		fragilissima	Amfr	+	+
	Asparagopsis	*taxiformis*	Asta	+	+
	Ceratodictyon	*spongiosum*	Cesp	+	+
	Chondria	*repens*	Chre	+	
	Galaxaura	*arborea*	Gaar		+
		oblongata	Gaob	+	+
	Gelidium	*crinale*	Gecr	+	+
		pusillum	Gepu	+	+
	Gracilaria	*coronopifolia*	Grco	+	
	Halymedia	*dilatata*	Hadi	+	
	Hypnea	*pannosa*	Hypa	+	+
		valentiae	Hyva	+	+
	Laurencia	*obtusa*	Laob	+	+
		papillosa	Lapa		+
	Liagora	*divariata*	Lidi		+
	Titanophora	*pulchra*	Tipu	+	
	Tolypiocladia	*glomerulata*	Togl	+	
		Total		**26**	**26**

Appendix 3: Invertebrate species composition at Nha Trang Bay MPA in the years 2002 and 2005

Families	**Genera**	**Species**	**Species codes**	**2002**	**2005**
Acanthasteridae	Acanthaster	*planci*	Acapl		+
Arcidae	Barbatia	*foliata*	Barfo	+	+
Bucinidae	Cantharus	*undosus*	Canun	+	
Bursidae	Bursa	*rhodostoma*	Burrh	+	+
Cerithiidae	Cerithium	*sp*	Cersp	+	+
Chamidae	Chama	*sp*	Chasp	+	
Columbellidae	Pyrene	*versicolor*	Pyrve	+	
Conidae	Conus	*capitaneus*	Conca		+
		cratus	Concr	+	
		lividus	Conli	+	+
		miles	Conmi	+	
		musicus	Conmu	+	+
Coralliophilidae	Coraliophilla	*neritoidea*	Corne	+	+
Costellariidae	Vexillum	*sp*	Vexsp	+	

Cymatidae	Cymatium	*pileare*	Cymsp	+	
		sp	Cympi		+
Cypraeidae	Cypraea	*cylindra*	Cypcy	+	
		helvola	Cyphe	+	
Diadematidae	Diadema	*setosum*	Diase		+
	Hiotissa	*hyotis*	Hiohy		+
Fasciolariidae	Latiolagena	*smaragdula*	Latsm	+	
	Latirus	*polygonus*	Latpo	+	+
		sp	Latsp	+	+
		turritus	Lattu	+	
	Peristernia	*incarnata*	Perin	+	
Haliotidae	Haliotis	*varia*	Halva	+	
Holothuridae	Bohadschia	*graffei*	Bohgr		+
Isognomidae	Isognomon	*isognomum*	Isois	+	
Malleidae	Malleus	*albus*	Malal		+
		malleus	Malma	+	
Modulidae	Modulus	*tectum*	Modte		+
Muricidae	Chicoreus	*brunneus*	Chibr	+	+
		sp	Chisp	+	
		torrefactus	Chito	+	+
	Drupa	*grossularia*	Drugr	+	
		morum	Drumo	+	
		ricina	Druri	+	+
		rubusidaeus	Druru	+	+
	Drupella	*cornus*	Druco	+	+
	Morula	*uva*	Moruv	+	+
	Murex	*sp*	Mursp	+	
	Thais	*mancinella*	Thama	+	+
Mytilidae	Septifer	*bilocularis*	Sepbi	+	+
Ophidiasteridae	Linckia	*laevigata*	Linla		+
	Ophidiasteridae	*sp*	OphSa		+
Oreasteridae	Culcita	*sp*	Culsp		+
Oystreidae	Hyotissa	*hyotis*	Hyohy	+	
Pectinidae	Pedum	*spongdiloideum*	Pedsp	+	+
Phillididae	Phillidia	*sp*	Phisp		+
Pinnidae	Atrina	*vexillum*	Atrve		+
	Pinna	*sp*	Pinsp	+	
	Steptopinna	*saccata*	Stesa	+	
Pteridae	Pinctada	*martensii*	Pinma	+	
		sp	Pincsp		+
	Pteria	*penguin*	Ptepe	+	
		sp	Ptesp	+	+

Spondylidae	Spondylus	*ducalis*	Spodu	+	
		sinensis	Sposi	+	
		sp	Sposp	+	+
Strombidae	Lambis	*scopius*	Lamsc		+
Synaptidae	Synapta	*sp*	Synsp		+
Toxopneustidae	Toxopneutes	*pileolus*	Toxpi		+
Tridacnidae	Tridacna	*maxima*	Trima	+	+
		squamosa	Trisq	+	
Trochidae	Trochus	*conus*	Troco	+	
		histrio	Trohi		+
		pyramis	Tropy	+	
Turbinidae	Astrea	*rhodostoma*	Astrh	+	+
	Turbo	*chrysostomus*	Turch	+	+
Turridae	Xenaturris	*cingulata*	Xenci		+
Vasidae	Vasum	*turbinellus*	Vastu	+	+
		Total		**52**	**42**

Appendix 4: Fish species composition at Nha Trang Bay MPA in the years 2002 and 2005

Families	**Genera**	**Species**	**2002**	**2005**
Acanthuridae	Acanthurus	*blochii*	+	
		lineatus	+	+
		nigrofuscus	+	+
		pyroferus	+	+
		sp	+	
	Ctenochaetus	*binotatus*	+	
		striatus		+
		strigosus		+
	Naso	*annularis*	+	+
		lituratus	+	
	Zebrassoma	*scopas*	+	+
Apogonidae (*)	Apogon	*sealei*		+
		sp	+	
	Archamia	*sp*	+	
	Cheilodipterus	*artus*	+	
		macrodon		+
		quinquelineatus	+	+
Aulostomidae	Aulostomus	*chinensis*		+
Balistidae	Balistapus	*undulatus*	+	+
	Sufflamen	*bursa*	+	
		chrysopterus	+	+
Blenniidae	Ecsenius	*bicolor*	+	

	Meiacanthus	*grammistes*	+	
	Plagiotremus	*rhynorhynchus*	+	+
Caesionidae	Caesio	*cunning*	+	+
	Pterocaesio	*sp*	+	
		tile	+	
		trilineata		+
Centriscidae	Aeoliscus	*strigatus*	+	+
Chaetodontidae (*)	Forcipiger	*longirostris*	+	+
	Heniochus	*chrysopterus*	+	
		varius	+	
	Chaetodon	*auriga*	+	
		auripes	+	+
		barronessa	+	+
		citrinellus	+	+
		kleinii	+	+
		lunula	+	
		melannotus	+	
		mertensii	+	
		octofasciatus	+	
		ornatissimus	+	+
		plebeius	+	+
		punctatofasciatus	+	+
		speculum	+	+
		trifascialis		+
		trifasciatus	+	+
		unimacualtus	+	
		unimacuminatus	+	
		rafflesii	+	
Cirrhitidae	Cirrhilichthys	*falco*	+	+
	Paracirrhites	*arcatus*	+	
		forsteri		+
Diodontidae	Diodon	*hystrix*		+
Fistulariidae	Fistularia	*commersonii*	+	+
Gobiidae (*)	Amblyeleotris	*wheeleri*	+	
	Valenciennea	*strigata*		+
Haemulidae	Plectorhinchus	*chaetodonoides*		+
		gaterinoides	+	
Holocentridae (*)	Myripristis	*sp*	+	
	Sargocentron	*cornutus*	+	
Labridae (*)	Anampses	*caeruleopunctatus*	+	
		melanurus	+	
		meleagris		+

	Bodianus	*axillaris*	+	+
	Cheilinus	*chlorourus*	+	+
		diagrammus	+	
		faciatus	+	
		oxycephalus	+	
		sp	+	
		trilobatus	+	+
		unifasciatus	+	+
		unimaculatus		+
	Cheilio	*sp*		+
	Choerodon	*anchorago*	+	
	Cirrhilabrus	*lineatus*		+
		punctatus		+
	Epibulus	*insidiator*	+	+
	Gomphosus	*varius*	+	+
	Halichoeres	*hortulanus*	+	+
		margaritaceus		+
		marginatus	+	+
		melanochir		+
		melanurus	+	+
		ornatissimus		+
		prosopeion	+	+
		sp	+	
		trimaculatus	+	+
	Hemigymnus	*fasciatus*	+	+
		melapterus	+	+
	Labrichthys	*unilineatus*	+	+
	Labroides	*bicolor*	+	+
		dimidiatus	+	+
	Macropharyngodon	*meleagris*	+	+
	Novaculichthys	*taeniourus*		+
	Pseudocheilinus	*hexataenia*	+	+
	Pseudojuloides	*cerasinus*	+	
	Thalassoma	*hardwicke*	+	+
		lunare	+	+
		lutecens	+	+
		quinquelineatus	+	+
	Stethojulis	*bandanensis*	+	
		strigiventer		+
Lethrinidae (*)	Lethrinus	*harak*	+	+
		nebulosus		+
Lutjanidae (*)	Aprion	*virescens*		+

	Lutjanus	*ehrenbergi*	+	
Monacanthidae (*)	Aluterus	*scriptus*		+
	Amanses	*scopas*		+
	Oxymonacanthus	*longirostris*	+	
	Paraluteres	*prionurus*		+
	Pervagor	*janthinosoma*	+	+
Mullidae (*)	Parupeneus	*barberinus*		+
		indicus	+	+
		multifasciatus		+
	Upeneus	*tragula*	+	+
	Mulloides	*vanicolensis*	+	+
Nemipteridae (*)	Monotaxis	*grandoculis*	+	
	Scolopsis	*bilineatus*	+	+
		ciliatus	+	+
		lineatus	+	+
		margaritifer	+	
Ostraciidae	Ostracion	*cubicus*		+
		indicus	+	
		meleagris	+	
Pempheridae	Pempheris	*oualensis*	+	+
Pinguipedidae	Parapercis	*clathrata*	+	
		cylindrica	+	+
Pomacanthidae	Centropyge	*sp*	+	
		tibicens	+	+
		vrolikii	+	+
Pomacentridae (*)	Abudefduf	*benganlensis*		+
		septemfasciatus	+	
		sexfasciatus	+	+
		sordidus	+	
		vaigiensis	+	+
	Amblyglyphidodon	*curacao*	+	+
	Amphiprion	*clarkii*	+	+
		perideraion	+	+
	Chromis	*margaritifer*	+	+
		sp		+
		ternatensis	+	
		viridis	+	+
		weberi	+	+
		xanthura	+	+
	Chrysiptera	*rollandi*		+
	Dascyllus	*aruanus*	+	
		reticulatus	+	+

		trimaculatus	+	+
	Dischistodus	*sp*		+
	Hemiglyphidodon	*plagiometopon*	+	+
	Neoglyphidodon	*melas*	+	+
		nigrogris	+	
		sp	+	
	Plectroglyphidodon	*dickii*	+	+
		lacrymanus	+	+
		nigrogris		+
	Pomacentrus	*amboinensis*	+	+
		bourroughi		+
		chrysurus	+	+
		coelestis	+	
		emarginatus	+	
		lepidogenys	+	+
		moluccensis	+	+
		nigromarginatus		+
		sp1	+	+
		sp2	+	+
	Pomacentrus	*vaiuli*	+	
	Stegastes	*lividus*	+	+
		nigricans	+	
Priacanthidae (*)	Priacanthus	*hamrur*	+	
Pseudochromidae	Labracius	*cyclophthalmus*		+
Scaridae (*)	Hipposcarus	*longiceps*	+	+
	Scarus	*bleekeri*	+	
		chameleon		+
		dimidiatus	+	+
		flavipectoralis		+
		forsteni	+	+
		frenatus	+	
		ghobban	+	+
		globiceps	+	
		microrhinos	+	
		niger	+	+
		rivulatus		+
		schlegeli		+
		sordidus	+	+
		sp	+	+
		spinus	+	+
Scorpaenidae	Pterois	*volitans*	+	
Serranidae (*)	Aethaloperca	*rogaa*	+	

	Cephalopholis	*argus*	+	
		boenak	+	+
		urodeta		+
	Diploprion	*bifasciatus*	+	+
	Epinephelus	*merra*	+	+
	Grammistex	*sexlineatus*		+
	Plectropomus	*laevis*	+	
Siganidae (*)	Siganus	*argenteus*		+
		guttatus	+	
		sp	+	
		spinus	+	+
		virgatus	+	+
Synodontidae (*)	Synodus	*binnotatus*	+	+
Tetraodontidae (*)	Arothron	*nigropunctatus*	+	
	Arothron	*hispidus*		+
	Canthigaster	*valentini*	+	+
Zanclidae	Zanclus	*cornutus*	+	+
	Total		**162**	**140**

Note: (*) seventeen families are listed in fished composition in 2005

Appendix 5: Coral species composition at Nha Trang Bay MPA in the years 2002 and 2005

Families	**Genera**	**Species**	**Species codes**	**2002**	**2005**
Acroporidae	Acropora	*abrotanoides*	aa	+	+
		aculeus	ab	+	+
		acuminata	ac	+	+
		anthocercis	ad		+
		aspera	ae	+	+
		austera	af	+	+
		breuggemanni	ag		+
		cerealis	ah	+	+
		cophodactyla	ai	+	
		copiosa	aj	+	+
		cuneata	ak	+	+
		cytherea	al	+	+
		dendrum	am	+	+
		digitifera	an	+	+
		divaricata	ao	+	+
		donei	ap	+	+
		elseyi	aq	+	+
		exquisita	ar	+	
		florida	as	+	+

formosa	at	+	+
gemmifera	au	+	+
globiceps	av	+	
grandis	aw	+	
humilis	ax	+	+
hyacinthus	ay	+	+
indonesia	az	+	+
insignis	aaa	+	+
latistella	aab	+	+
loripes	aac	+	+
lutkeni	aad	+	+
microclados	aae	+	+
microphthalma	aaf	+	+
millepora	aag	+	+
monticulosa	aah	+	+
nana	aai	+	+
nasuta	aaj	+	+
nobilis	aak	+	+
palifera	aal	+	+
palmerae	aam	+	+
paniculata	aan		+
papillare	aao		+
parilis	aap	+	
pectinatus	aaq	+	
plana	aar	+	+
polystoma	aas	+	+
prostrata	aat	+	
proximalis	aau	+	
pulchra	aav	+	
robusta	aaw	+	+
rosaria	aax	+	+
samoensis	aay	+	+
sarmentosa	aaz	+	+
secale	aba	+	+
selago	abb		+
spicifera	abc	+	
subulata	abd		+
tenuis	abe	+	+
tizardi	abf	+	
valenciennesi	abg	+	+
valida	abh	+	+
vaughani	abi	+	

		vermiculata	abj	+	+
		verweyi	abk	+	+
		willisae	abl	+	
		yongei	abm	+	+
	Astreopora	*cucullata*	abn	+	
		gracillis	abo	+	+
		listeri	abp	+	+
		myriophthalma	abq	+	+
		suggesta	abr	+	
	Montipora	*aquituberculata*	abs	+	+
		caliculata	abt		+
		confusa	abu	+	+
		corbettensis	abv	+	
		danae	abw	+	+
		digitata	abx	+	
		efforescens	aby	+	+
		floweri	abz	+	+
		foveolata	aca	+	
		grisea	acb	+	+
		hirsuta	acc	+	
		hispida	acd	+	+
		hoffmeisteri	ace		+
		informis	acf	+	+
		millepora	acg	+	+
		mollis	ach	+	
		monasteriata	aci	+	+
		nodosa	acj	+	
		peltiformis	ack	+	
		porites	acl		+
		spongodes	acm	+	
		spumosa	acn	+	+
		stellata	aco	+	
		tuberculosa	acp	+	+
		turgescens	acq	+	+
		undata	acr	+	+
		verrucosa	acs	+	+
		vietnamensis	act	+	+
Agariciidae	Coeloseris	*mayeri*	a1a	+	+
	Gardineroseris	*planulata*	a1b	+	
	Leptoseris	*explanata*	a1c	+	+
		mycetoseroides	a1d	+	+
		yabei	a1e	+	

	Pachyseris	*gemmae*	a1f	+	
		rugosa	a1g	+	+
		speciosa	a1h	+	+
	Pavona	*cactus*	a1i	+	+
		clavus	a1j	+	
		decussata	a1k	+	+
		duerdeni	a1l	+	+
		explanulata	a1m	+	+
		frondifera	a1n	+	
		maldivensis	a1o	+	+
		varians	a1p	+	+
		venosa	a1q	+	+
Astrocoeniidae	Stylocoeniella	*armata*	a2a	+	+
		guentheri	a2b	+	+
Dendrophylliidae	Tubastraea	*sp1*	da	+	+
	Turbinaria	*frondens*	db	+	+
		mesenterina	dc	+	
		peltata	dd	+	+
		reniformis	de	+	+
Euphylliidae	Euphyllia	*ancora*	ea	+	+
		cristata	eb	+	+
		divisa	ec	+	+
		glabrescens	ed	+	+
		yaeyamensis	ee		+
	Physogyra	*lichtensteini*	ef	+	
	Plerogyra	*sinuosa*	eg	+	+
Faviidae	Barabattoia	*amicorum*	fa		+
		laddi	fb	+	+
	Cyphastrea	*chalcidicum*	fc	+	+
		japonica	fd	+	+
		microphthalma	fe	+	+
		serailia	ff	+	+
	Diploastrea	*heliopora*	fg	+	+
	Echinopora	*gemmacea*	fh		+
		lamellosa	fi	+	+
		pacificus	fj	+	+
	Favia	*danai*	fk	+	+
		favus	fl	+	+
		helianthoides	fm		+
		lizardensis	fn	+	+
		maritima	fo	+	+
		matthaii	fp	+	+

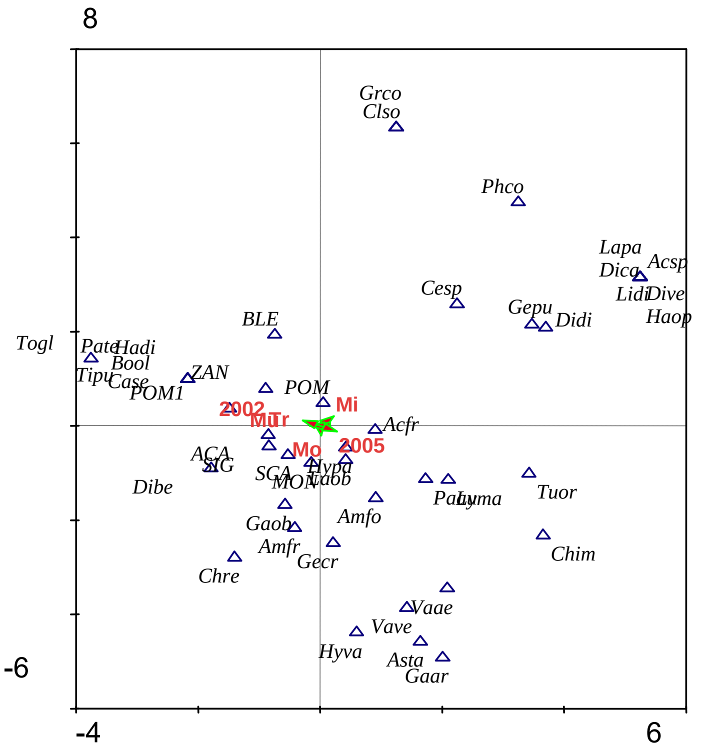
	maxima	fq	+	+
	pallida	fr	+	+
	rotumana	fs	+	+
	rotundata	ft	+	+
	speciosa	fu	+	+
	stelligera	fv	+	+
	truncatus	fw	+	+
	veroni	fx	+	+
	vietnamensis	fy	+	+
Favites	*abdita*	fz	+	+
	acuticolis	faa		+
	bestae	fab	+	+
	chinensis	fac	+	+
	complanata	fad	+	+
	flexuosa	fae	+	+
	halicora	faf	+	+
	paraflexuosa	fag		+
	pentagona	fah	+	+
	russelli	fai	+	+
	spinosa	faj	+	
	vasta	fak	+	+
Goniastrea	*aspera*	fal	+	+
	australensis	fam	+	+
	edwardsi	fan	+	+
	pectinata	fao	+	+
	retiformis	fap	+	+
Leptastrea	*bewickensis*	faq		+
	pruinosa	far	+	+
	purpurea	fas	+	+
	transversa	fat	+	+
Leptoria	*phrygia*	fau	+	+
Montastrea	*annuligera*	fav	+	+
	colemani	faw	+	+
	curta	fax	+	+
	magnistellata	fay	+	+
	salebrosa	faz		+
	valenciennesi	fba	+	+
Oulastrea	*crispata*	fbb	+	+
Oulophyllia	*crispa*	fbc	+	+
	levis	fbd	+	
Platygyra	*acuta*	fbe		+
	contorta	fbf	+	

		daedalea	fbg	+	+
		lamellina	fbh	+	+
		pini	fbi	+	+
		ryukyuensis	fbj	+	+
		sinensis	fbk		+
		verweyi	fbl	+	+
		yaeyamaensis	fbm	+	+
	Plesiastrea	*versipora*	fbn	+	
Fungiidae	Ctenactis	*albitentaculata*	f1a		+
		crassa	f1b	+	+
		echinata	f1c	+	+
	Cycloseris	*cyclolites*	f1d	+	
		patelliformis	f1e	+	+
		sinensis	f1f	+	+
		somervillei	f1g	+	
		tenuis	f1h		+
		vaughani	f1i	+	
	Fungia	*concinna*	f1j	+	+
		danai	f1k	+	+
		fralinae	f1l		+
		fungites	f1m	+	+
		horrida	f1n		+
		klunzingeri	f1o		+
		moluccensis	f1p	+	+
		paumotensis	f1q	+	+
		repanda	f1r	+	+
		scabra	f1s	+	+
		scruposa	f1t	+	+
		scutaria	f1u	+	+
		spinifer	f1v	+	
		taiwanensis	f1w	+	
	Herpolitha	*limax*	f1x	+	+
		weberi	f1y	+	+
	Lithophyllon	*mokai*	f1z	+	+
		undulatum	f1aa	+	+
	Podabacia	*crustacea*	f1ab	+	+
	Polyphyllia	*talpina*	f1ac	+	+
	Sandalolitha	*dentata*	f1ad	+	+
		robusta	f1ae	+	+
Merulinidae	Hydnophora	*exesa*	m1a	+	+
		microconos	m1b	+	+
		rigida	m1c	+	+

	Merulina	*ampliata*	m1d	+	+
		scabricula	m1e	+	+
Mussidae	Acanthastrea	*brevis*	ma	+	+
		echinata	mb	+	+
		hemprichii	mc	+	+
		rotundoflora	md	+	+
		subechinata	me	+	+
	Australomussa	*rowleyensis*	mf	+	+
	Blastomussa	*wellsi*	mg	+	
	Cynarina	*lacrymalis*	mh		+
	Lobophyllia	*corymbosa*	mi	+	+
		flabelliformis	mj		+
		hataii	mk	+	+
		hemprichii	ml	+	+
		robusta	mm	+	+
	Scolymea	*vitiensis*	mn	+	
	Symphyllia	*radians*	mo	+	+
		recta	mp	+	+
		valenciennesii	mq	+	+
Oculinidae	Galaxea	*astreata*	oa	+	+
		fascicularis	ob	+	+
Pectinidae	Echinomorpha	*nishihirai*	p2a	+	
	Echinophyllia	*aspera*	p2b	+	+
		echinata	p2c	+	
		echinoporoides	p2d		+
	Mycedium	*elephantotus*	p2e	+	+
		robokaki	p2f	+	
	Oxypora	*crassispinosa*	p2g	+	+
		glabra	p2h	+	
		lacera	p2i	+	+
	Pectinia	*alcicornis*	p2j	+	
		ayleni	p2k	+	
		lactuca	p2l		+
		paeonia	p2m	+	
Pociiloporidae	Pociilopora	*damicornis*	p1a	+	+
		danae	p1b		+
		eydouxi	p1c	+	+
		kelleheri	p1d		+
		meandrina	p1e	+	
		verrucosa	p1f	+	+
		woodjonesi	p1g	+	+
	Seriatopora	*caliendrum*	p1h	+	+

		guttatus	p1i	+	+
		hystrix	p1j	+	+
	Stylophora	*pistillata*	p1k	+	+
		subseriata	p1l		+
Poritidae	Alveopora	*marionensis*	pa	+	
		spongiosa	pb	+	+
		tizardi	pc	+	
	Goniopora	*burgosi*	pd	+	+
		djiboutiensis	pe	+	+
		fruticosa	pf	+	+
		lobata	pg	+	+
		minor	ph	+	+
		planulata	pi	+	+
		somaliensis	pj	+	+
		stutchburyi	pk		+
		tenuidens	pl	+	+
	Porites	*annae*	pm		+
		attenuata	pn	+	+
		cumulatus	po	+	
		cylindrica	pp	+	+
		horizontalata	pq	+	
		latistella	pr	+	+
		lichen	ps	+	+
		napopora	pt		+
		negrosensis	pu	+	
		nigrescens	pv	+	+
		rugosa	pw	+	+
		rus	px	+	+
		sillimaniana	py	+	+
		solida	pz		+
		sp1	paa	+	+
		sp2	pab	+	+
		vaughani	pac		+
Siderastreidae	Coscinaraea	*columna*	sa	+	+
	Psammocora	*contigua*	sb	+	+
		digitata	sc		+
		haimeana	sd	+	+
		nierstraszi	se	+	+
		obtusangula	sf		+
		superficialis	sg	+	+
Trachyphylliidae	Trachyphyllia	*geoffoyi*	ta	+	
		Total		**274**	**256**

Appendix 6: CCA biplots with combining macro-algae assemblage and herbivorous, omnivorous fish



Herbivorous, omnivorous fish and macro-algae assemblage composition along a**:** CCA ordination diagram with species (Δ), and environmental variables area and year (arrows). First axis is vertical, second axis is horizontal. Multivariate analyses (CCA) have indicated significant exhibition of fish and macro-algae assemblage composition with years, 2002 and 2005. Species and area names were coded as Figure 3.7 and Figure 3.12