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Ninh Hai waters (south Vietnam): a hotspot of reef corals in the western South China Sea

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Abstract. Reef geomorphology, species composition and community structure of reef-building corals of Ninh Hai (south central Vietnam) were investigated from 2003–2011, contributing towards development of an integrated, representative national and regional network of Marine Protected Areas. Ninh Hai hosts extensive and diverse fringing coral reefs covering more than 2,300ha, the result of favourable physico-chemical conditions of sea temperature, water clarity, and sediment levels. These well-developed fringing reefs are rare or absent in other parts of Vietnam, and hence provide a high degree of complementarity to the developing national MPA network. The fringing reefs of Ninh Hai are in relatively good condition (average live coral cover > 25%), comprised of some 310 species from 60 genera of reef-building coral, including 11 species and one genus (*Scapophyllia*) previously unknown from the western South China Sea. Coral community structure shows considerable differences with other reefs in Vietnam. With the adjacent dry coastal forest ecosystem, these reefs are now protected within the Nui Chua National Park, one of very few examples of integrated conservation management of a terrestrial–coastal marine ecosystem in Vietnam or indeed Southeast Asia. The regular presence of cool water upwelling during the summer months may provide a "refuge" against future reef degradation from extensive coral death from 'bleaching' during episode of elevated sea temperatures. These reefs may thus aid in replenishment of other reefs, via dispersal and recruitment of corals locally and regionally.

Key words. reef building corals, species richness, reef geomorphology, Ninh Hai coastal waters, Nui Chua National Park

INTRODUCTION

The Ninh Hai district of Ninh Thuan Province, is located in south central Vietnam (Fig. 1). With a shoreline of more than 40 km, the district includes 3 coastal communes. One of these, Vinh Hai commune, hosts the Nui Chua National Park, which covers most of the coastal waters and adjacent mountain area. The national park conserves an outstanding example of the coastal forest ecosystem of Vietnam, comprising a diverse array of habitats ranging from humid and dense forest, savanna and 'bonsai' trees, with floral composition of high significance, representing one of the few remaining dry forest protected areas in Southeast Asia (WWF Ref. HD-39 Project Brief). The area is relatively arid in comparison with many other coastal parts of Vietnam, with only episodic terrestrial run-off from rivers or streams. Further, the catchments of streams draining the Nui Chua National Park remain in good condition through forest conservation. This has helped to maintain the high clarity of adjacent coastal waters, which, with other favourable topographic, oceanographic and climatic factors, has facilitated the development of extensive coral reefs fringing the mainland coast of the district. The area receives moderate to high levels of wave energy seasonally, from wind- and typhoon-generated swells, and cool waters (< 24°C) in coastal upwellings during summer.

Coral reefs of this coastal area were first assessed in 2002, when WWF supported a survey of reef coral species richness, followed by a series of reef monitoring activities supported by provincial authorities. Extensive surveys were conducted in 2010, with funding provided initially by National Foundation for Science & Technology Development of Vietnam and subsequently by the UNEP/GEF project entitled "Demonstration of sustainable management of coral reef resources in the coastal waters of Ninh Hai district, Ninh Thuan province, Vietnam". Based on results of these various programs, the present paper documents reef coral species richness, community structure, reef development and other issues related to biodiversity management.

MATERIAL AND METHODS

Composition of the reef-building coral fauna. Rapid Ecological Assessment (REA) surveys of reef-building corals and other sessile macro-invertebrates were conducted by Lyndon DeVantier using SCUBA at 24 coastal fringing reef sites (Fig. 1) in June 2002 (four locations) and March 2003 (19 locations). Among them, 15 sites represented shallow waters (from 1–6 m) and nine sites were in deeper waters (from 6–14 m). At each site, the surveyors recorded an inventory of species or genera on water-proof data-sheets during the ca. 45 min swims (DeVantier et al., 1998). Sites were not identical in area surveyed, but all were less than 1

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ha and ranged across the substrate typically from the deeper to shallower reef slope or flat. At the end of each survey swim, the species inventory was reviewed, and each taxon was categorised in terms of its relative abundance in the community. The ranked categories were: zero = absent, one = rare, two = uncommon, three = common, four = abundant and five = dominant. These ordinal ranks approximate a log four scale, and reflect relative numbers of individuals in each taxon, rather than its contribution to benthic cover. The ranks are similar to those long employed in vegetation analysis (Barkman et al., 1964, van der Maarel, 1979, Jongman et al., 1997).

The method was identical to that employed during reef biodiversity assessments in many other areas of the Indo-Pacific, including Hon Mun Marine Protected Area (MPA), Nha Trang Bay (Vo et al., 2002). It thus provides the opportunity for comparisons of species diversity, composition and community structure, and of the complementarity of these different areas in terms of their coral communities. Although 'semi-quantitative', this method has proven superior to more traditional quantitative methods (transects, quadrats) in terms of biodiversity assessment, allowing for the active searching for new species records at each site, rather than being restricted to a defined quadrat area or transect line. Additional inventories of hard coral species, but excluding assessment of relative abundance, were also conducted in 2011 and 2012 at 4 sites as indicated in Fig. 1.

Stony (hard) corals greater than 5 cm colony diameter were identified to species level wherever possible, based on the taxonomic work of Veron & Pichon (1976, 1980, 1982), Veron et al. (1977), Veron & Wallace (1984), Veron (1986, 1993, 1995, 2000), Wallace & Wolstenholme (1998), and Wallace (1999), otherwise genus and growth form (e.g., *Porites* sp. of massive growth-form). Extensive use of digital underwater photography aided identifications, and a collection of specimens of taxonomically difficult species was made, to confirm field identifications. Small samples, usually < 10 cm on longest axis, were removed from living coral colonies in situ. This generally causes little long-term impact to the corals, which can replace the removed sample through growth. Living tissues were removed from the samples with household bleach. The dried specimens were examined and identified, as far as possible to species level, using the taxonomic references cited above. Several specimens require additional detailed study. All specimens are housed at the Institute of Oceanography at Nha Trang, Vietnam.

Taxonomic issues. With the rapid, continuing development of molecular genetic taxonomic tools, scleractinian coral systematics is currently in a state of considerable flux. Taxonomic revision, particularly at family and, to a lesser extent, generic and species levels, is ongoing, with various proposals for nomenclatural changes (see e.g., Fukami et al., 2008, Benzoni et al., 2012, Budd et al, 2012). Pending widespread acceptance of recent proposed taxonomic changes, we have followed the taxonomy of Veron (2000) herein.

Site groups defined by community type were generated by hierarchical cluster analysis using abundance ranks of all corals in the inventories. Following the trials of various clustering algorithms and transformations, the analysis used Euclidean Distance as the clustering algorithm and complete linkage as the fusion strategy on fourth-root transformed data to generate site groups of similar community composition and abundance. The clustering results were plotted as a dendrogram to illustrate the relationships among sites in terms of levels of similarity among the different community groups.

Reef geomorphology. The distribution and geomorphology of coral reefs were studied in 2011, using the manta tow technique for shallow reef areas (< 5 m depth) and a robot camera (MicroGrov Gnom) for deeper waters. In total 59 tows were pulled along the whole shoreline of the district and 270 points with the grid of 250 m were observed to the

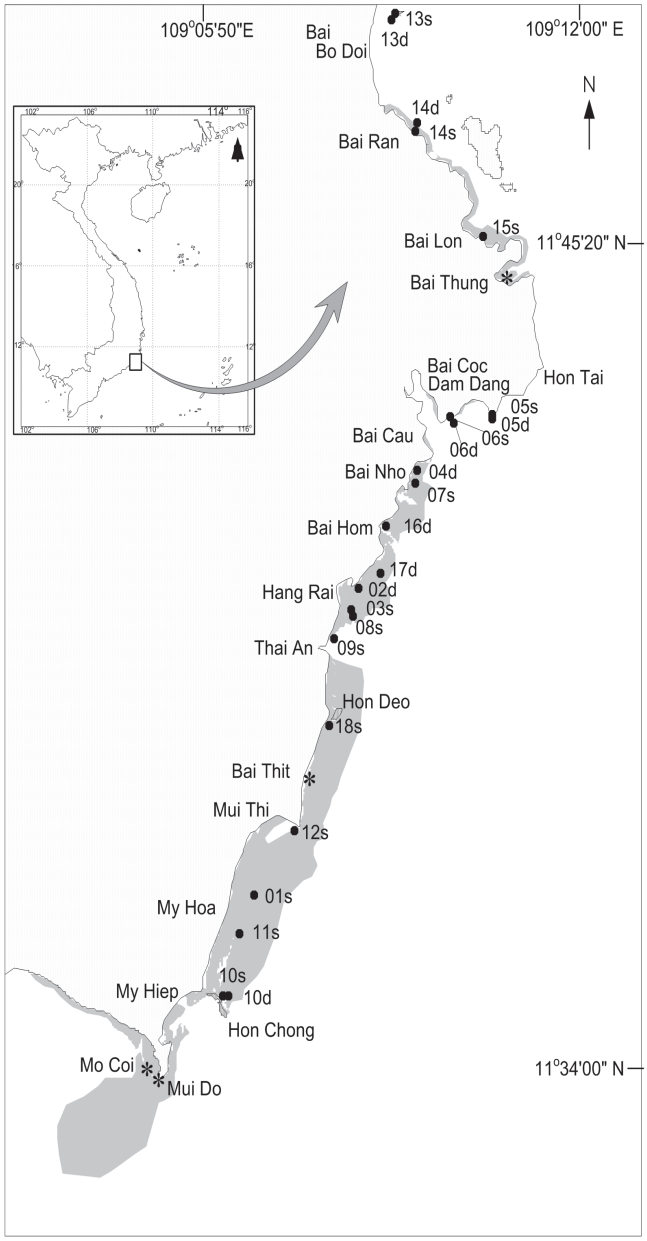

Fig. 1. Sites for inventory of reef building scleratinian corals (• in 2003 & 2004 and * in 2011 & 2012), and reef distribution in the Ninh Hai coastal waters

seaward edge of reefs, to a maximum of 30 m depth. For each tow of the manta tow technique and each point of the camera observation, the main substratum component and depth were recorded and then the map of reef distribution was drawn. The total reef area was calculated by map-based technique using MapInfo software.

Benthic cover. Surveys to assess benthic cover were conducted in 2011 and 2012 using SCUBA at 15 sites. Two 100 m long line transects were arranged at shallow (3–5 m) and deep (8–12 m) contours of each site. Cover of benthic components, including hard corals, soft corals and others as indicated in Reefcheck technique (Hodgson & Waddell, 1998) were recorded along 20 m of each of the four segments in the 100 m transect line using the point intercept method with an interval of 0.5 m.

RESULTS AND DISCUSSION

Species richness and communities of reef building scleractinian corals. The surveys in 2002 and 2003 indicated that for reef-building Scleractinia the average site diversity was 90 species (se. 4 spp., median 96 spp., range 54–124 spp.). This level of diversity compares favourably with other diverse Indo-West Pacific reef areas (e.g., other areas in south Vietnam, Australia's Great Barrier Reef, and parts of Indonesia). Richest sites, notably at Bai Nho, Bai Hom and Hang Rai (Fig. 1), supported > 100 coral species, high by world standards. High coral diversity was not depth specific, occurring at both shallow and deeper sites, notably at Bai Nho, representing highest known site diversity in Ninh Hai waters. The surveys in 2011 and 2012 recorded similar levels of species richness at four additional sites, with species number highest at Mui Do (82), followed by Bai Thit (70), Bai Thung (62) and poorest at Mo Coi (35 species).

In total, some 310 species, belonging to 60 genera, of 15 families of reef-building scleractinian corals were recorded. Identities of some species remain unconfirmed, and require further taxonomic work. The richest individual sites at Bai Nho, Bai Hom and Hang Rai supported more than one-third of total hard coral diversity of the area (>110 of 310 coral spp.). Overall species richness recorded in Ninh Hai coastal waters was consistent with its location on the south Vietnam coast, being less than that in Nha Trang Bay to the north (Hon Mun MPA), with some 350 reef-building coral spp. (Vo et al., 2002) and Bolinao, Philippines with 322 spp. (Licuanan, 2009) but higher than the Con Dao Archipelago to the south (with some 280 reef-building species, L. DeVantier, unpublished report to WWF Vietnam).

Species richness at Ninh Hai is consistent with previous interpretations of reef coral diversity in Vietnam (Vo & Hodgson, 1997; Vo, 1998). This trend in diversity is likely related to regional oceanography and habitat heterogeneity (particularly the wide range of habitats and different levels of exposure provided by the varied coastal and island topography.

Despite the taxonomic uncertainty that remains regarding several species, it is clear that Ninh Hai coastal waters are a hotspot of species richness of reef building corals at the locality level, supporting highly diverse coral communities. These communities are formed of a unique 'composite' fauna from several different biogeographic areas (e.g., South China Sea, Indo-West Pacific centre of diversity, East Asia and Indian Ocean) and show substantial differentiation from those to the north (Nha Trang Bay) and south (Con Dao Islands).

At the regional level, this south-central area of Vietnam, from Khanh Hoa Province in the north, is recognised as the most diverse in Vietnam for coral reef species (Vo & Hodgson 1997; Vo, 1998). This is attributable to widespread dispersal, suitable environmental conditions and broad habitat heterogeneity. The coral fauna shows strong links with the Indo-West Pacific diversity centre of Indonesia–Philippines. The biogeographic link to the Philippines and more northern areas of East Asia at Ninh Hai waters is less well defined than at Nha Trang Bay, although still present, as represented for example by the occurrence of *Montipora taiwanensis*. Of the 310 hermatypic Scleractinia recorded from Ninh Hai waters, 11 species are new distribution records for Vietnam and one genus *Scapophyllia* is newly recorded for the western coastal waters of the South China Sea, considering the previous records published by Vo et al. (2002), Latypov (2011) and others. The species recorded newly included:

Acropora convexa (Dana, 1846)
Acropora retusa (Dana, 1846)
Astreopora expansa Bruggemann, 1877
Astreopora macrostoma (Brook, 1891)
Montipora samarensis Nemenzo, 1967
Montipora taiwanensis Veron, 2000
Goniastrea minuta Veron, 2000
Podabacia motuporensis Veron, 1990
Hydnophora bonsai Veron, 1990
Scapophyllia cylindrica Edwards and Haime, 1848
Acanthastrea regularis Veron, 2000

Of the new distribution records for Vietnam, most had prior known distribution ranges restricted to the Indo-West Pacific centre of diversity of the Philippines–Indonesia–New Guinea (Veron, 2000). The new records increase taxon number of reef-building corals in south-central Vietnam (from latitude 13°N southward) to 424 species of 70 genera. The new tally of coral species richness indicates that this area (and Vietnam more generally) is more diverse than previously known (e.g., previous records of 366 species for the whole of Vietnam by Latypov, 2005 and 397 species for south Vietnam by Veron at al., 2009, and closer to the diversity centre in species composition.

The corals in Ninh Hai waters formed four major community 'types' (A–D, Fig. 2), broadly distributed in relation to incident environmental conditions (particularly depth, aspect and level of physical exposure). The analysis separated the communities strongly on depth, into two shallow and two deep community types. In general, communities A and B were composed entirely of shallow sites, accounting for all

shallow sites between them. Communities C and D were composed entirely by the deeper sites.

Community A – Shallow acroporid community: This community occurred in shallow sites at: My Hoa (Sites 1s, 11s), Hang Rai (Site 3s), Bai Nuoc Ngot (Site 8s), Bai Nho S (Site 7s), Bai Lon (Site 15s), Mui Thi (Site 12s), and Hon Deo S (Site 18s). Community A was highly diverse, being composed predominantly by a rich assemblage of acroporids, notably foliose–encrusting–branching *Montipora* spp. including *M. aquituberculata*, *M. crassituberculata*, *M. peltiformis*, *M. delicatula*, *M. mollis*, *M. stellata*, *M. samarensis* and branching–staghorn–tabular *Acropora*, particularly *A. gemmifera*, *A. verweyi*, *A. valida*, *A. nana*, *A. intermedia* (formerly *A. nobilis*) and *A. hyacinthus*.

Community B – Shallow faviid community: This community occurred in shallow sites at: Hon Tai (Site 5s), Luoi Dang (Site 6s), Thai An Channel (Site 9s), Hon Chong (Site 10s), Bai Bo Doi (Site 13s), and Bai Ran (Site 14s). Community B was relatively depauperate in species diversity and much less dominated by acroporids, particularly foliose–digitate *Montipora* spp., than the other shallow community (A). Massive encrusting faviids, notably *Cyphastrea*, *Favia*, *Favites*, *Goniastrea* and *Montastrea* spp., and stout digitate *Acropora* spp. were more common.

Community C – Deep poritid–fungiid community: This community occurred in deeper sites at: Hon Tai (Site 5d), Luoi Dang (Site 6d), Hon Chong (Site 10d), Bo Doi (Site 13d), and Bai Ran (Site 14d). Community C was composed more predominantly by massive–encrusting corals, particularly poritids (*Porites*, *Goniopora* spp.), agariciids (*Pachyseris*, *Pavona* spp.), euphyllids (*Euphyllia* spp.), faviids and merulinids (*Hydnophora* spp.). Mushroom corals (fungiids) were also common.

Community D – Deep faviid–mussid–acroporid community: This community occurred in deeper sites at: Hang Rai (Sites 2d, 17d), Bai Nho (Site 4d) and Bai Hom (Site 16d). Community D was particularly diverse, being composed of a wide variety of species representing most of the major families. Common species included massive–encrusting species, notably mussids (*Acanthastrea*, *Symphyllia*, *Lobophyllia* spp.) and faviids (exceptional richness), and encrusting forms of *Montipora* spp. (mostly different species to those common in Community A). Community D also supports a large number of the new distribution records, and is particularly interesting from a biogeographic perspective.

Reef development and habitat diversity. Coral reefs fringe much of the shoreline of the district, stretching more than 36 km along the shoreline from Binh Tien in the north to My Hiep in the south (Fig. 1). Total area of coral reefs was estimated at approximately 2,332 ha with the reef width ranging from 70–3,000 m and to a depth of 30 m. Our categorisation of reef morphology in Ninh Hai coastal waters was based on the amount of biogenic reef development (after Hopley 1982, Hopley et al. 1989, Sheppard & Sheppard 1991, DeVantier et al. 1998) with four categories including (1) Coral communities developed directly on non-biogenic rock, sand or rubble; (2) Incipient reefs, with some calcium carbonate accretion but no reef flat; (3) Reefs with moderate flats (<50 m wide); and (4) Reefs with extensive flats (> 50 m wide).

There was major variation in levels of recent (Holocene) reef development within Ninh Hai coastal waters, ranging from coral communities with minimal reef accretion, incipient reef, small reef flat (<50 m width) to extensive reefs with reef flats of several hundred or thousands metres in the width. Details in reef morphology indicated that fringing reefs are very large in areas from Thai An – My Hoa with a breadth around 2,000 m. The reef morphology includes a large shallow reef flat and reef slope up to 18 m deep (Fig. 3a).

Further north, levels of reef development declined, with a narrow reef flat along the shoreline from Bai Thung to Bai Ran and non-reefal coral communities at Bai Bo Doi and reefs outside Vinh Hy. Hon Chong, a small island in the southern part, was also bordered by a non-reefal coral community. Fringing reefs with narrow flats also occurred along My Hiep shoreline in the south. An incipient reef (i.e., no reef flat development) occurred at Bai Nho (Fig. 3b) with a breadth of submerged reef of 700 m. Similarly, at Hang Rai (Fig. 3c) submerged reef extended offshore more than 1300 m and sloped up to 30 m in depth. The reefs in the most southern part of the district (Mui Do) have developed as submersed banks or non-reefal coral communities with the dimension of 3,500 m from the shoreline and 2,000 m width.

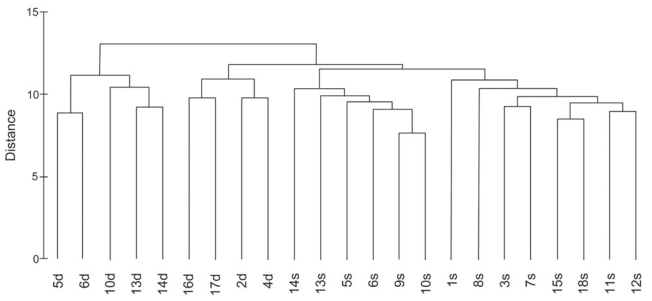

Fig. 2. Dendrogram of similarity in coral community types, derived from the species–abundances (4th root transformed) of corals in 24 sites using Eucidean distance and complete linkage.

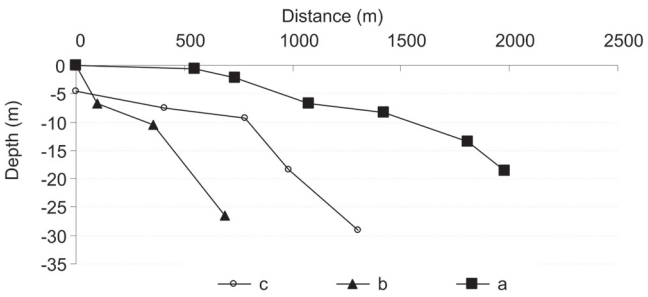

Fig. 3. Vertical transects of the reef with large reef flat at My Hoa (a) and incipient reefs at Bai Nho (b) and Hang Rai (c).

Table 1. Dimensions of coral reef areas in the Ninh Hai coastal waters.

Locations	Area (ha)	Breadth (m)	Length (m)	Maximum Depth (m)	Reef Development	% of Total Shoreline Length
Bai Bo Doi	0.8	37	330	7	Non-reefal coral community (shoreline)	0.9
Bai Ran – Bai Thung	155.8	400	10,200	10	Narrow reef flat	28.2
Reefs around Vinh Hy bay	3.9	70	1,200	7	Non-reefal coral community (shoreline)	3.3
Bai Nho	141.5	857	3,730	26	Incipient reef	10.3
Hang Rai	182.9	1140	3,650	30	Incipient reef	10.1
Thai An- My Hoa	972.3	2050	10,760	20	Large reef flat	29.7
Hon Chong	3	100	300	4	Non-reefal coral community (island)	0.8
South Hon Chong – Mui Do	92	500	3,000	7	Narrow reef flat	8.3
Mui Đo	715.9	3,600	1,350	14	Non-reefal community (submersed bank)	3.7
My Hiep	64.27	600	1,700	6	Narrow reef flat	4.7
Total	2,332.4		36,220			100.0

Measurement of shoreline bordered by different types of reef development (Table 1) show that the fringing reefs with reef flats of varying breadth and development are dominant along the Ninh Hai coast (large flats occur at 29.7 % and small flats at 49.2% of reefs respectively, 70.9% in total, with incipient reefs representing 20.4%). Total percent of non-reefal coral communities (shoreline, island and submersed) are only 8.7% of total.

The extent of fringing reef development in Ninh Hai coastal waters is very different from reefs in other coastal areas of Vietnam. Following Vo & Hodgson (1997), true coral reef framework is found primarily on offshore islands, usually located on the protected side of each island and "coral gardens" (non-reefal coral communities and incipient reefs) are dominant (68–100% studied reefs) in Tonkin Gulf (Cat Ba Islands of Hai Phong city), central coastal waters of Quang Nam–Da Nang and Khanh Hoa provinces and the Gulf of Thailand (Kien Giang province). In the case of Nha Trang bay (nearby, northward of Ninh Hai waters), there is little true reef accretion in most areas and most coral communities are developed directly on sub-litoral basalt boulders or bedrock (Vo et al., 2002). The differentiation of reef morphology along Ninh Hai district, taking account of the dominance of typical fringing reefs, suggests that this area has longer history of, and more favourable physical condition for, reef development, in comparison with other coastal waters of Vietnam.

Coral coverage. The values on cover of hard corals *Acropora* and non-*Acropora*; soft corals are displayed in Fig. 4. Mean live coral cover (both hard and soft corals) for 15 study sites in 2011 and 2012 was 28.8% (SE=3.6) with large range of cover among sites. Soft coral was only dominant in the submerged bank at Mui Do with cover of 21.6% (SE = 3.8) and was very low in other reefs with mean value for all of 1.7% (SE = 1.6). Mean cover of *Acropora* corals was around 6.8% (SE = 2.2) and non-*Acropora* was 19.8% (SE = 3.6), resulting in total hard coral cover of 25.6% (SE = 2.0).

The total coral cover was typically highest on large reef flat sites, but on the remaining reefs, the situation was complicated, with two likely drivers. Some reefs such as Bai Bo Doi, Bai Ran, Bai Cau in the northern coast were covered by large amounts of coral rubble (25.7, 20.6, and 42.5% respectively), indicating reef damage under physical disturbance, with resulting low coral cover. Additionally, low coral cover at Hon Chong and Dam Dang resulted from less development of corals in these non-reefal communities, attributable to the attachment of non-*Acropora* corals directly on rock or stone.

Summer upwelling. Hydrological studies have indicated the existence of a strong upwelling centre during May to September annually in the coastal waters of Ninh Thuan and Binh Thuan provinces in south Vietnam, including Ninh Hai district. This upwelling results in the decline of sea temperature, with average surface temperature of 24°C in July (see La & Vo, 1997). Although a survey during the

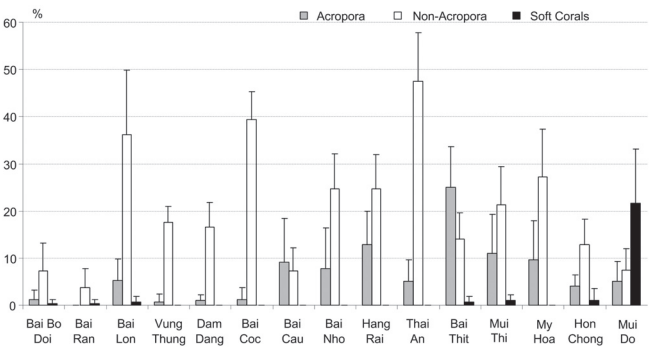

Fig. 4. Diagram showing covers of corals at 15 study sites along Ninh Hai district.

major mass bleaching event of 1998 found that some corals inside the upwelling area were susceptible to bleaching, the impact was not serious and not as long-lasting as that in Con Dao Islands. There, 37% of coral colonies, on average, were susceptible to bleaching and 14% of corals died in October 1998 (see Vo, 2000). It is clear that Ninh Hai coastal waters with the short time of declined water temperature in summer, due to upwelling may provide a "refuge" for dispersal and recruitment of corals in coastal waters of Vietnam and potentially for other reefs in the South China Sea, against reef degradation caused by extensive coral bleaching. Hence we suggest that survival of coral communities in Ninh Hai waters can play an important role for dispersal and recruitment of corals not only locally and in the coastal waters of Vietnam but also partly on a regional level, for other reefs in the South China Sea. Coral reef conservation in Ninh Hai coastal waters may, therefore, also help to support resilience of coral communities in the South China Sea more generally, due to ecological effects of the upwelling phenomena.

Biodiversity management related issues. The present studies have confirmed that reefs in the coastal waters of Ninh Hai district are highly diverse (>300 reef-building coral species), and are in relatively good condition (average live coral cover >25%, with no major recent damage; but also see later in respect of more northern reefs). The reefs support 11 new distribution records for Vietnam, some of which are considered to be globally uncommon or rare. Coral communities in these waters show considerable differences in species composition and community structure from those further north (Nha Trang Bay), and from other reefs in Vietnam; and thus provide a high degree of complementarity in development of an integrated, representative national and regional MPA network. The reefs also support coral populations of regional significance in terms of maintenance and replenishment.

Almost all coral reefs along the Ninh Hai district are managed by Nui Chua National Park, which is designed for terrestrial and marine biodiversity conservation. Recently, zoning for management of the marine component has been developed by local authorities (Fig. 5). The zones are generally well conceived, and well sited in terms of conserving reef locations of highest conservation value (high species richness and coral cover). The reefs between Thai An and Bai Nho are particularly diverse (representing communities A and D) and their inclusion in the 'Restricted zone' is well supported by the present assessment. In all these respects, the MPA zoning scheme should provide a sound framework for ecologically sustainable development.

Many of the top ranking sites in terms of their conservation values are already included in the 'Restricted zone', notably providing excellent representation of the diverse shallow and deep communities A and D. However, communities B and C are not presently represented in any of the sites surveyed in the 'Restricted zone', but do occur in the adjacent 'Tourism zone' at the sites to the north of Vinh Hy bay. Providing additional regional conservation value, an adjacent sandy beach Bai Thit (between the villages of My Hoa and Thai An) is one of the few remaining mainland nesting sites for marine turtles in the coastal waters of Vietnam. Large fringing reefs in good to excellent condition immediately nearshore from these beaches are critical habitats for turtles in the pre-nesting period, and should receive more effective protection.

The zoning scheme of Nui Chua National Park has not included the northern part of the district, where some reefs exhibited high levels of rubble cover and relatively poor assemblages of corals (e.g., at Bai Bo Doi and Bai Ran). Most of this damage was likely attributable to coral feeding by Crown-of-Thorns starfish, outbreaks of which were observed in many reefs in south central waters of Vietnam during 2002–2004 (Vo et al., 2008). The survey in 2003 recorded large numbers (hundreds to thousands) of starfish at one reef, Bai Ran. These were causing significant damage to coral communities there. Coral predation by the starfish notwithstanding, other impacts were minor to negligible. These included local human impacts from blast and poison fishing and anchoring. These require concerted management intervention from the Nui Chua National Park Authority, with consideration given to enlarging zone scheme

Fig. 5. Marine zoning of the Nui Chua National Park.

to cover the northern part of the district, and improvement of management effectiveness.

Because of the generally high water clarity (>10 m visibility), undeveloped adjacent coastline (National Park) and scenic beauty, the area offers great opportunities for ecologically sustainable tourism. Sensible development of eco-tourism will provide benefits for conservation of important reef resources and marine turtles, and also socio-economic benefits to the relatively small local human population, distributed in the three villages of My Hoa, Thai An, and Vinh Hy. Great opportunities exist for development of eco-tourism activities, including half-day to 2 day canoe ('sea kayak') trips from the coastal villages of Thai An and Vinh Hy; snorkeling–diving trips; and motor boat 'picnic' cruises to some of the deserted beaches (e.g., Bai Nho, Bai Lon). To the north of Vinh Hy lagoon, the steep ocean cliffs offer spectacular viewing, and the secluded beaches further north (Bai Lon) provide good snorkeling and swimming locations. Overnight ocean kayaking adventures along this coast offer excellent tourism potential comparable to that already occurring along the coastline of the Hawaiian Island of Kauai. Future SCUBA dive tourism may also be developed, as the relatively easy access and clear waters provide good opportunities for diving.

With increasing coastal development in Vietnam and elsewhere in Southeast Asia, relatively few mainland fringing reef sites remain in such good to excellent condition. In Ninh Hai district, the Nui Chua National Park and marine zoning plan provide excellent protection for stream catchments and from inappropriate development and should facilitate conservation of reef resources, providing local communities remain supportive of the zoning and management plan.

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