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on

Coral Reefs in the Coastal Waters of the South China Sea

VIET NAM



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INTRODUCTION

Viet Nam has a large marine area with more than 3,200km of coastline and more than 3,000 islands. Marine resources are significant in terms of livelihoods of coastal communities and development of the country. Located in the tropical monsoon area of South East Asia, marine waters of Viet Nam are characterised by high biodiversity of fauna and flora and high abundance of tropical ecosystems such as coral reefs, mangroves and seagrass beds. Among them, coral reefs are an important habitat in a large number of coastal areas, as well as offshore islands.

Many surveys of coral reefs in the South China Sea have been carried out since the establishment of the Institute of Oceanography of Viet Nam in 1922. Surveys were carried out from aboard De Lanessan's ship at Spratly and Paracel Islands from 1920-30. Results of these studies were published in scientific papers of Chevey (1926, 1928, 1931, 1935) and Krempf (1930). Subsequent surveys recorded the species composition of hard corals, and the structure and distribution of several coral reefs in Ha Long Bay, the Gulf of Thailand, Con Dao Island, the and coastal areas of central Viet Nam (Serene, 1937; Dawydoff, 1952). Most scientific studies during the first half of the 20th century were conducted by foreign scientists and published in French.

From 1955 to 1975, few studies on coral reefs were conducted. Significantly, there were two studies at Nha Trang Bay: the first described the coral reef communities of the Bay (see Tran Ngoc Loi, 1962); and the second resulted in the production of a document on the taxonomy of soft corals in the area (see Tixier-Durivault, 1970).

Many government-funded research programmes were conducted in collaboration with the Soviet Union during the period 1975 to 1990. Basic studies on coral reef distribution, structure, and species composition were undertaken as part of these collaborative research initiatives. Documentation of this work published in the scientific literature provide basic information regarding coral distribution, coral reef communities, reef-building coral species composition, and the status of coral reefs in Viet Nam's coastal areas and at the Spratly Islands (see Latypov 1982, 1987, 1990, 1992, 1995; Nguyen Huy Yet 1991, 1993, 1994, 1996; and Vo Si Tuan and Nguyen Huy Yet, 1995, Vo Si Tuan and Phan Kim Hoang, 1996, Vo Si Tuan, 1998).

From 1991 to date, coral reef studies have focused on the collection of data and information to enable sound decision making with regard to issues such as biodiversity conservation, determination of sustainable resource use levels, and the establishment of marine protected areas. Results of surveys conducted by the Worldwide Wide Fund for Nature (WWF) and the Institute of Oceanography during the 1990s provided a basis for the identification of seven highly biodiverse coral reef sites for inclusion in a system of marine protected areas in Viet Nam. Other studies funded by the Government of Viet Nam's and conducted by the National Center for Natural Science and Technology developed baseline information for an additional 8 MPA sites. At the time of writing, Government was considering a system of 15 coral reef MPAs. Coral reef management in Viet Nam has achieved some preliminary successes, particularly at the Con Dao and Nui Chua National Parks, and the Hon Mun Protected Area.

The abovementioned research has also assisted in improving understanding of geozoology and in biodiversity zoning based on reef-building corals (Malioutin and Latypov 1991; Vo Si Tuan 1998). Results of studies on coral reef degradation and threats have been summarised in some publications (Vo Si Tuan, 2000a, b; Nguyen Huy Yet *et al.*, 2000). Coral reef monitoring has been implemented since 1998, and at the time of writing 11 sites were involved in the monitoring network with financial support from the Government of Viet Nam, UNEP, WWF, and Total Foundation (Vo Si Tuan, 2002a, Vo Si Tuan *et al.*, 2005). There has been much recent interest in coral reef rehabilitation, and related activities have received some support from the government.

The “Doi Moi” process has encouraged a high rate of economic growth in Viet Nam, but has also caused threats to the marine environment and resources. Recent decades have seen increased degradation of coral reef ecosystems and over-exploitation of associated resources. As such there has been a strong recent emphasis on biodiversity conservation and sustainable use of resources in Viet Nam over the past decade.

PHYSICAL FEATURES

Temperature

Spanning through 8 degrees of latitude from approximately 8 N-16 N, water temperature generally increases from the north to the south. Oceanographic surveys indicate that there are three different water masses in the coastal waters of Viet Nam, including the Tonkin Gulf, the South central and South eastern areas, and the Gulf of Thailand, with two boundaries, namely Ca Mau Cape and Varella Point (approximately 13°N). There is a sharp reduction in water temperature during winter in the waters of north Varella Point. In general, the temperature of Vietnamese coastal waters is favorable for coral reef development, except in areas of the Tonkin Gulf where winter temperatures reach 18°C. The wide range of temperatures between water masses has resulted in significant differences in the species richness of hard corals from the north to the south.

River influence and sedimentation

Along the coastline of Viet Nam, there are two large river mouths: (1) the Red River mouth; and (b) the Mekong river mouth. The coastal areas in the general vicinity of these river mouths are devoid of coral reefs due to high quantities of sediments entering the coastal water bodies. Smaller rivers also influence nearshore waters, especially during the rainy season. Turbidity surveys indicate that the South central area has the highest transparency in both seasons (La Van Bai, 1991). The influence of rivers and associated sediment loads is the main factor limiting the distribution in Viet Nam.

Circulation

The surface water circulation of the South China Sea depends on the monsoon regime, and generally flows southwest in summer and northeast in winter. In the offshore areas of Viet Nam, currents change direction according to the wind regime. At the basin scale, water circulation in the central South China Sea supports the exchange of water between the western and eastern boundaries. Coastal water currents are very complicated, and largely depend on the coastline, seabed topography, and river influence. There is permanent North-South current in central Viet Nam, which starts at approximately 17° North. Current systems in Tonkin Gulf are complex with minimal exchange with southern water masses is limited (Vo Van Lanh, *unpublished information*).

Coastline change in geological history

Following existing approach, recent coral communities depend on geological process happening during recent 18,000 years with change of sea level. Geological surveys highlighted an old coastline at depths of approximately 100m in Vietnamese waters of the South China Sea (Saurin, 1962). With this depth, a large area of the west South China Sea was mainland in that period, including Tonkin Gulf, southeastern shelf and Gulf of Thailand. Development of coral reefs has changed a lot during increase and decrease of sea levels with change of coastline and depth. In parallel, diversity of coral communities at present time also depends on survival and dispersal again sea level change during history.

Seabed topography

Viet Nam's coastal waters are characterised by an abundance of small islands. There are approximately 2,000 islands in the Tonkin Gulf, which provide favourable conditions for coral reef development. Central and southern waters have a number of large, offshore islands, which are almost all surrounded by coral reefs. There are also many submerged banks along the continental shelf of Viet Nam's central and southern regions where coral reef could develop.

CORAL REEF DISTRIBUTION AND MORPHOLOGY

Distribution and characteristics of coral reefs

The geographic location and environmental conditions of Vietnamese coastal waters are generally highly suitable for the growth of coral reef building species, except in some areas affected strongly by river inputs with low salinity and high turbidity. Coral reefs are normally located in shallow, coastal waters, particularly adjacent to islands with hard substrates (Figure 1). However, the morphology and diversity of coral reefs in Viet Nam vary significantly by location.

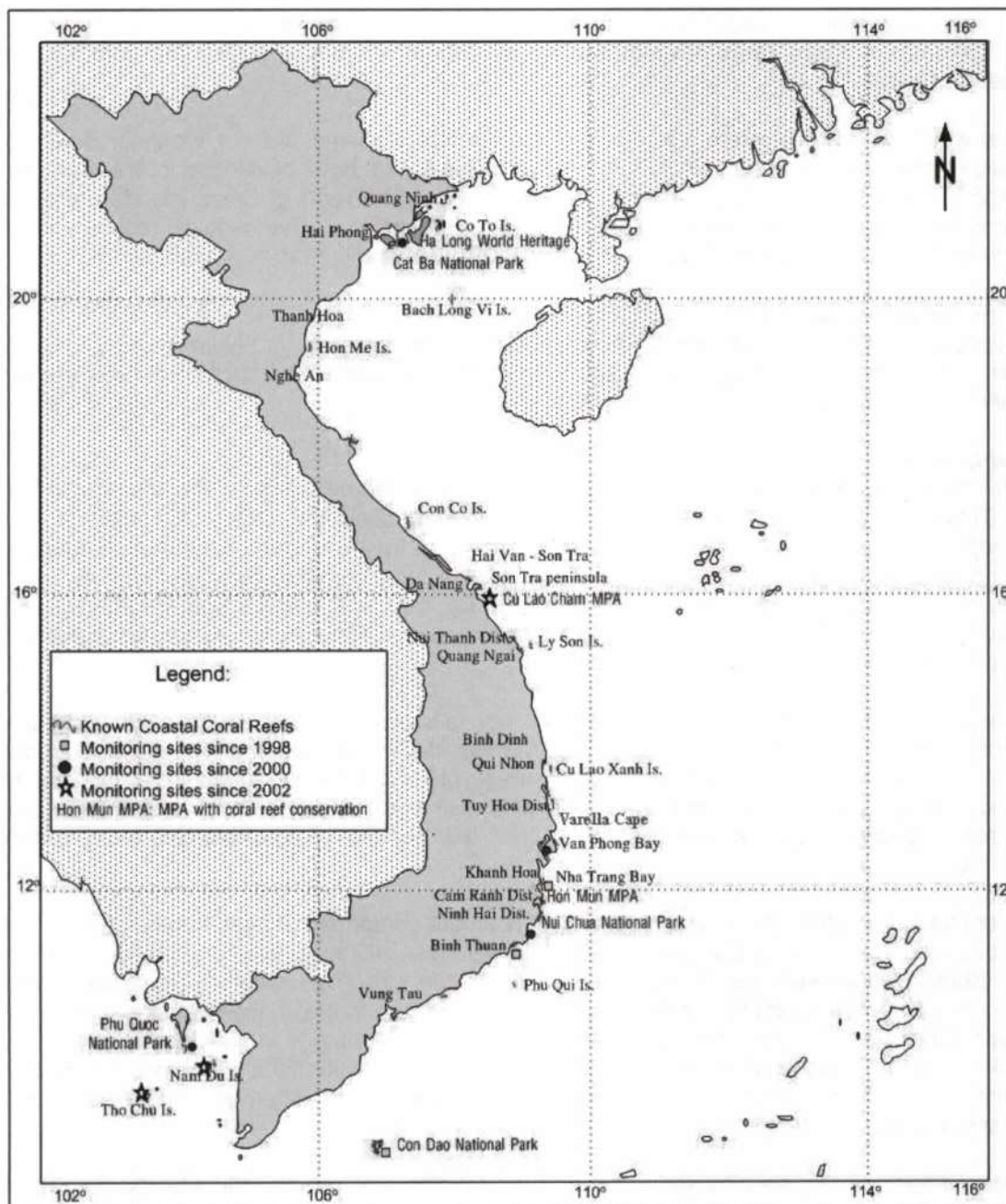


Figure 1 Locations of Known Coral Reefs in the Coastal Waters of Viet Nam. (including monitoring sites and Marine Protected Areas)

In terms of the environmental conditions suitable for the growth of reef-building coral species, the coastal areas of western Tonkin Gulf are less favorable for reef development. This is largely due to low water temperatures during the winter months, and large contributions of freshwater and sediments to this part of the Gulf from adjacent river systems. Corals are mainly observed in areas of Ha Long Bay, Bai Tu Long, the Co To Archipelago, and Long Chau Islands, which are mostly surrounded by shallow and muddy bottoms. The coral reefs that have developed in the western Tonkin Gulf are typically narrow and extend to a depth of only 5-7m. Coral reefs have developed at depths of 10m in areas adjacent to Bach Long Vi Island.

Conditions for coral reef development are favourable in the coastal waters of the south-central region, as well as adjacent to the islands offshore southeastern region. Water temperatures in these areas are normally higher than 20°C, with predominantly offshore influences. The coastline in these areas is comprised of a diverse range of small bays and islands, which contributes significantly to the diversity of coral reef areas in these regions. Coral reefs are a dominant coastal habitat around

islands such as Cu Lao Cham to Con Dao, and extend along the coastline from Danang to Binh Thuan Province. Fringing coral reefs are very diverse in their morphology and range in width from 50 to 800 metres. Many reefs have developed on submersed banks, which are common on the continental shelf.

Coastal waters of southwestern Viet Nam in the Gulf of Thailand are not ideal for coral growth because of muddy bottoms and highly turbid waters. Coral reefs have developed in areas adjacent to the offshore islands of Phu Quoc, Nam Du, and Tho Chu. The reefs of these islands are relatively similar in terms of morphology as there are minimal fluctuations in the hydrological regime and hydrodynamics of the area. These reefs are normally 50-100m wide and spread to a depth of 10-13m.

Coral reef morphologic types

Two types of coral reefs are located in the continental shelf waters of Viet Nam, namely fringing and platform reefs. Coral assemblages are also observed in some areas. Offshore coral reefs are usually atoll and platform reefs.

Fringing reefs

Coastal fringing reefs have developed in coastal water areas from Quang Tri Province to Ca Na Bay (Binh Thuan Province). This reef type is not observed along the coast of Tonkin Gulf or in southeastern and southwestern waters, mainly due to large freshwater and sediment contributions to these areas as noted above. Island fringing reefs are the most common coral reef type in Viet Nam. Islands on the continental shelf such as Ha Long, Cat Ba, Cu Lao Cham, Ly Son, Phu Quy, Con Dao, Phu Quoc, Tho Chu, Nam Du, and small islands in Khanh Hoa Province are known as highly diverse coral reef areas.

In terms of morphology, fringing reef generally belongs to two different types: typical fringing reefs and untypical fringing reefs. Typical fringing reefs are characterised by a completed stage of coral reef establishment process. Such reefs are usually made up of a fringing lagoon, reef flat, and slope. Fringing lagoons are observed at some reefs with channels running along the shoreline. Lagoon substrate is typically sand and dead corals, with a low number of coral species thinly distributed across the lagoon floor.

Most reef flats on the typical fringing reefs of Viet Nam are comprised of dead corals, and are subject to exposure during low tides. Live coral coverage is very low, with most live coral found in submerged caves. Boulder corals such as *Goniastrea* and *Porites* can form "micro atolls". These are formed by such corals growing outward rather than up, largely in response to the shallow water environments on reef flats. Often the core of the boulder corals sinks and dies, leading to the development of the micro atoll like structure. These structures are present on reefs of Ninh Thuan Province and along the northern coast of Binh Thuan Province in Viet Nam. Live coral coverage and species diversity increases with reef flat depth.

In some areas, single species grow extensively to create mono-specific stands on reef flats. *Montipora aequituberculata* dominates areas subjected to low wave energy to the west of Cu Lao Cau Island. *Panova decussata* dominates the low wave energy reef flats of An Thoi at Phu Quoc Island, whilst *Acropora hyacinthus* dominates strong wave energy reef flats at Cu Lao Cham and Con Dao Islands. The staghorn coral *Motipora digitata* dominates strong wave energy reef flats at My Hoa (Ninh Hai) of Ninh Thuan Province. Steeply sloping reef slopes characterise most fringing reefs systems, extending from the reef flat in a seaward direction. The composition of coral species is more highly diverse on reef slopes, and are characterised by large numbers of hard and soft coral species. Most reef slopes of typical fringing reefs in Viet Nam end at depths between 5-8m.

Seagrass and mangrove communities are common at the edges and landward sides of typical fringing reefs. The effects of typical fringing reefs in reducing the effects of wave action on the coastline, creates an environment suitable for seagrass and mangrove community development. Bay Canh Island, Ben Dam Bay at Con Dao is characterised by a large mangrove forest on the landward side of the fringing reefs in the area. A similar mix of coral reefs and seagrass beds can be observed at the Southeastern Bay of Con Dao Island, in Binh Thuan Province along the Vinh Hao coast, and along the Ninh Hai coast in the Ninh Thuan Province.

Unotypical fringing reefs are characterised by an incomplete stage of coral reef development (Sudara and Thamrongnawasawat, 1991). They are called coral gardens by Vo and Hodgson (1997). Such reefs are usually divided into three zones from the shore to deeper water areas. The zone closest to the shore is typically characterised by poorly developed coral communities and sometimes no coral. The next zone, described as the “continuous zone”, is a partially developed reef flat with high coral coverage (occasionally reaching 100%). The third zone, or “the slope” is characterised by a gentler slope than a typical fringing reef and low coral coverage and diversity.

Detailed investigations conducted at the Nam Du Islands (Latypov, 1986) indicated that such reefs are normally those less affected by wind and waves. Small colonies of staghorn corals *Acropora* and massive corals *Porites*, *Goniastrea*, and *Platygyra* are observed in nearshore zones. On the partially developed reef flats, staghorn corals *Acropora* dominate, often with mono-specific stands several hundreds metres wide. Reef slope are typified by massive corals *Favia*, *Cyphastrea* and *Physogira*, cup-sharp *Turbinaria* (southern Tho Chu Island), or foliate corals *Pachyseris* (southern Bay Canh Island of the Con Dao Island group). The morphological structure of unotypical fringing reefs is highly influenced coastal hydrodynamics.

Closed reefs are observed in the near-shore bays of Viet Nam. Low wave energy conditions enable the development of corals to depths of 5-7 metres. Reefs may extend up to a width of 150m, but are usually characterised by a low number of species of mostly massive corals and thin staghorns. Big staghorn *Porites* dominates such reefs in Dam Bay (Nha Trang Bay) and in other areas such as Co Co Canal (Van Phong – Ben Goi Bay). Because there is typically no reef flat to prevent sedimentation on the reefs, very few coral species are adapted to survive under such conditions (Grigg and Dollar, 1990).

Exposed reef exist in areas of high wave energy. Drains normally divide seafloor terrain in such areas, and the substrate is normally rock and some sands, and dead corals in the channels of deep drains. Reef-building corals may distribute down to 15m deep but account for a small proportion of overall coverage. Zone division at such sites is not obvious, but are typically dominated by *Acropora*, *Pocillopora*, or soft corals. Staghorn corals are normally observed at the ends of such reefs.

Semi-enclosed reefs represent those reefs that are partly enclosed by edges, islands, or submerged rocks. Such sites are usually characterised by well-developed formations of large reef-building corals. They can also be highly diverse in terms of both species composition and colony morphology. Overall coral reef coverage on these reefs is high, and is normally comprised of foliate coral *Montipora* and staghorn corals *Acropora* in the shallow water areas, to massive corals *Porites* and *Diploastrea*, foliate corals *Pachyseris* and *Echinopora*, and cup-sharp *Turbinaria* in deeper waters.

The above-analyzed results showed that the unotypical fringing reef had much more complicated morphology to compare with typical fringing reef. In qualitative, unotypical reef had higher ratio in most of the study areas (table 1). Typical fringing reef just had relatively high number in Con Dao, Ninh Thuan and northern Binh Thuan province.

Table 1 Percentage of Typical and Unotypical Fringing Reefs at the Study Sites.

Study Areas	No. of Studied Reefs	Typical Ringing Reef (%)	Unotypical Fringing Reef (%)
Quang Nam – Da Nang	16	19.8	81.2
Khanh Hoa	13	0	100
Ninh Thuan	7	57.1	42.9
Northern Binh Thuan	12	50	50
Con Dao	17	58.8	41.2
Kien Giang	11	0	100

Platform reefs

Platform or patch reef is that which develops on submerged banks or hills (Stoddard, 1978; Veron, 1986). Bathymetric maps highlight many submerged banks and hills in the coastal waters of Viet Nam, although these areas have been understudied and there is currently a paucity of information relating to this reef type in Viet Nam. Coral specimens collected from several banks provide some insight into platform reef morphology in some areas.

The Grand Bank of Nha Trang Bay is based on macmatic rocks formed during the Tertiary Period (Pham Van Thom, unpublished). The area of the bank is approximately 10km² and rises to depths of 20m. Reef-building corals grow mainly on the northeastern side of the bank and account for a significantly large proportion of coral coverage in the area. Coral species composition consists mainly of *Seriatopira histrix*, *Porites lutea*, *P. rus*, *Galaxea fascicularis*, *Lobophyllia corymbosa*, and *Acropora valida*. The top of the bank is characterised by lower diversity of coral species, with coral cover being made up of colonies of small size *Acropora* and some massive coral species (*Favia*, *Favites*, and *Goniastrea*). The seaweed *Sargassum* is also abundant in this area, reaching lengths of 3-4m.

The Thuy Trieu Bank on seaward side of Cam Ranh Bay is two times larger than the Grand Bank, and extends in a northwest-southeast direction. It rises from a depth of 40m to a water depth of 3m. It is comprised predominantly of carbonate sedimentation stones from the Tertiary Period (Pham Van Thom, 1992). On the seaward side of the bank, the substrate is mostly boulder rocks and pebbles at the depth of 25-40m and hard rock base at the depth of 10-25m. Coral coverage on this bank is very poor, and is comprised of few species like *Scolymia vitiensis* which attach to rocky boulders and dead corals. Dead corals were observed on the top of the bank flat, along with several live soft and hard coral colonies of small-sized *Acropora* and *Favites*.

There are many shallow areas with depths less than 20m in the waters of Northern Binh Thuan. The Breda Bank is the largest with a size of 22km² and rises to depths ranging between 4-10m. The bank is comprised of carbonate-enriched sedimentation rocks from the Tertiary Period, as well as bioclastic sediments and some phosphated rocks on the surface (Pham Van Thom, 1980; 1985). This site is mainly composed of soft corals *Sarcophyton* and the massive corals *Goniastrea*, *Porites*, and *Platygyra*. *Sargassum* is also present in shallower areas. Generally, corals are observed to develop poorly on submersed banks in Vietnamese waters.

Coral assemblages

In addition to fringing and platform reefs there are additional areas in Viet Nam where corals are observed without reef formation. Such areas are referred to as coral assemblages, and such areas are understudied in Viet Nam. Preliminary observations suggest that such areas can be classified into two types of coral assemblages.

In some shallow and low wave energy areas, coral assemblages are composed of one or two species, including *Acropora* (thin branch colonies) or *Porites* (massive colonies). Such coral assemblages are present in Ben Goi Bay (Khanh Hoa Province) and on the northeast coast of Phu Quoc islands (Kien Giang Province). Sandy and mud substrates were observed to be disadvantageous for coral assemblage development in the areas investigated to date.

The second type of coral assemblage occurs on rocky bottoms in areas exposed to high wave energy conditions. Such assemblages can be observed at the Son Tra Peninsular (Da Nang City) and north of Hon Tre Island in Nha Trang Bay. Massive or encrusting corals (*Goniastrea*, *Merulina*, and *Porites*) and branch corals *Acropora* and *Pocillopora* are small in size and attached directly to the rocky substrate in a scattered distribution.

BIODIVERSITY

Composition of hard corals and hermatypic corals

Based on the taxonomic system of Veron and Stafford-Smith (2000), and after amending the results of Vietnamese coral taxonomy of many authors up to date, a list more than 400 hard coral species belonging to 79 genera was established. As such, Viet Nam's coral fauna can be compared with the most diverse coral areas of the world. From the 400 known species, 380 are hermatypic species and the remainder are ahermatypic species. From the 79 identified hard coral genera, 72 genera⁵ belonged to hermatypic corals (Table 2).

⁵ Following an inventory from all taxonomic publications, 74 hermatypic genera are listed by Vo Si Tuan et al. (2005). Off that list, two genera namely *Australogyra* and *Wellsophyllia* published by Latypov (1995) were not re-recorded by the extensive surveys during 2002-2004. These two genera were removed from this list, indicating a total of 72 genera of hermatypic corals.

Five main distinct coral reef regions in Viet Nam are include: (1) the Western Tonkin Gulf (from the Northern border with China to Con Co Island); (2) central Viet Nam (from Con Co Island to Varella Cape); (3) South central Viet Nam (from Varella Cape to Phu Quy Island); (4) South eastern Viet Nam (Con Dao Islands); and (5) South western Viet Nam (Tho Chu, Nam Du, and Phu Quoc Islands).

- * *Tonkin Gulf*: Corals are mainly distributed around islands on the seaward of the Gulf toward Ha Long and Bai Tu Long Bays, Co To Islands, the north-eastern part of Cat Ba Islands, Long Chau Islands, Bach Long Vi, Hon Me, Hon Son Duong, and Con Co Islands. Nearly 200 species belonging to 56 genera of hard corals (186 species of 53 genera of hermatypic corals) have been recorded from the region.
- * *Central Viet Nam*: This region is characterised by a sinuous shoreline, few large rivers, and a predominantly oceanic environment. Corals are not only located adjacent to the region's many islands (Cu Lao Cham and Ly Son), but also along the shoreline. Approximately 250 species of hard corals belonging to 64 genera have been observed in this region, and about 230 of them belong to 61 genera of hermatypic species.
- * *South-Central Viet Nam*: This is a highly diverse area in terms of both coral reef types and environmental conditions suitable for coral growth. As such, this region contains the highest recorded number of coral species in Viet Nam. Approximately 400 species belonging to 77 genera can be observed in the region, of which 350 species belong to 71 genera hermatypic reef species.
- * *Southeastern Viet Nam*: The Con Dao Island group is not a large area, which is a limiting factor in the size of fringing reefs at the islands. Despite this, 350 species belonging to 63 genera of hard corals have been recorded with more than 300 species from 61 genera being of the hermatypic type. The many submersed banks in the region have not yet been surveyed and the numbers of species presented here likely under-estimates.
- * *Southwestern Viet Nam*: Nearly all corals in this region occur adjacent to islands that are located sufficiently far from the coastline to enable coral development in the more turbid waters of the Gulf of Thailand. Large reef areas have developed at Tho Chu, Nam Du, and Phu Quoc Islands. Nearly 270 species belonging to 64 genera of hard corals have been recorded at these sites from the limited survey work conducted to date. More than 250 of the species of 61 genera recorded are of the hermatypic type.

Biodiversity zoning based on hermatypic corals

The total of 72 hermatypic coral genera recorded at the site indicate that the coastal waters of Viet Nam are characterised by a highly diverse coral fauna. This is most likely due to geographical location of Viet Nam, which is in close proximity to the coral dispersal centre in the Philippines and Indonesia. There is also significant inter-regional variations in the types of coral reefs and associated communities which have developed along Viet Nam's coast. This is due to Viet Nam's coastline crossing many latitudes and the related gradients in physical and chemical environments. These are main factors affecting the biodiversity of corals (Veron, 1998).

Surveys of coral fauna characteristics (see Vo Si Tuan, 1998) showed a clear differentiation in generic richness of hermatypic corals in the coastal waters of Viet Nam. Supplementary analysis improved this hypothesis with some minor changes. South central waters might be assumed as the most diverse area in the number of recorded genera (71) and also species number with nearly 350 in Nha Trang bay (Vo Si Tuan *et al.*, 2004), more than 300 in Ninh Hai reefs (DeVantier, unpublished). The number of recorded genera at southeastern and middle central waters is relatively diverse (61 genera). Detailed surveys at Con Dao Islands showed a high species richness of hermatypic corals with more than 300 species recorded (DeVantier, unpublished). Records of 60 hermatypic genera in southwestern waters indicate that coral fauna there is more diverse than that at the Tonkin Gulf (53 hermatypic genera recorded).

Table 2 List of hard coral genera and their distribution in Viet Nam.

No.	Genera	West Tonkin Gulf	Midle central	South central	South-eastern	South-western	Offshore reefs
1	<i>Stylocoeniella</i>	+	-	+	+	-	+
2	<i>Pocillopora</i>	+	+	+	+	+	+
3	<i>Seriatopora</i>	-	+	+	+	+	+
4	<i>Stylophora</i>	+	+	+	+	+	+
5	<i>Palauastrea</i>	-	-	-	-	-	+
6	<i>Madracis</i>	+	+	+	+	+	+
7	<i>Montipora</i>	+	+	+	+	+	+
8	<i>Anacropora</i>	-	+	+	+	-	+
9	<i>Acropora</i>	+	+	+	+	+	+
10	<i>Astreopora</i>	+	+	+	+	+	+
11	<i>Porites</i>	+	+	+	+	+	+
12	<i>Goniopora</i>	+	+	+	+	+	+
13	<i>Alveopora</i>	+	+	+	+	+	+
14	<i>Pseudosiderastrea</i>	+	+	+	+	+	+
15	<i>Psammocora</i>	+	+	+	+	+	+
16	<i>Coscinarea</i>	+	+	+	+	+	+
17	<i>Pavona</i>	+	+	+	+	+	+
18	<i>Leptoceris</i>	+	+	+	+	+	+
19	<i>Gardineroseris</i>	-	+	+	+	+	+
20	<i>Coeloseris</i>	-	+	+	-	+	+
21	<i>Pachyseris</i>	+	+	+	+	+	+
22	<i>Cycloseris</i>	-	+	+	+	+	+
23	<i>Diaseris</i>	-	+	+	+	+	+
24	<i>Cantharellus</i>	-	-	+	+	+	-
25	<i>Heliofungia</i>	-	-	+	-	-	+
26	<i>Fungia</i>	+	+	+	+	+	+
27	<i>Ctenactis</i>	-	+	+	+	+	+
28	<i>Herpolitha</i>	+	+	+	+	+	+
29	<i>Polyphyllia</i>	+	+	+	+	+	+
30	<i>Halomitra</i>	+	-	+	+	-	+
31	<i>Sandalolitha</i>	+	+	+	+	+	+
32	<i>Lithophyllon</i>	+	+	+	+	+	+
33	<i>Podobacia</i>	+	+	+	+	+	+
34	<i>Galaxea</i>	+	+	+	+	+	+
35	<i>Acrhelia</i>						+
36	<i>Echinophyllia</i>	+	+	+	+	+	+
37	<i>Oxypora</i>	+	+	+	+	-	+
38	<i>Mycedium</i>	+	+	+	+	+	+
39	<i>Pectinia</i>	+	+	+	+	+	+
40	<i>Blastomussa</i>	-	-	+	-	-	+
41	<i>Micromussa</i>			+			-
42	<i>Cynarina</i>	+	+	+	-	-	-
43	<i>Scolymia</i>	-	+	+	+	+	-
44	<i>Australomussa</i>	-	-	+	-	-	+
45	<i>Acanthastrea</i>	-	+	+	+	+	+
46	<i>Lobophyllia</i>	+	+	+	+	+	+
47	<i>Symphyllia</i>	+	+	+	+	+	+
48	<i>Hydnophora</i>	+	+	+	+	+	+
49	<i>Merulina</i>	+	+	+	+	+	+
50	<i>Caulastrea</i>	-	+	+	+	+	+
51	<i>Favia</i>	+	+	+	+	+	+
52	<i>Barabatoia</i>	+	+	+	+	+	+
53	<i>Favites</i>	+	+	+	+	+	+
54	<i>Goniastrea</i>	+	+	+	+	+	+
55	<i>Platygyra</i>	+	+	+	+	+	+
56	<i>Leptoria</i>	+	+	+	+	+	+
57	<i>Oulophyllia</i>	+	+	+	+	+	+

Table 2cont. List of hard coral genera and their distribution in Viet Nam.

No.	Genera	West Tonkin Gulf	Midle central	South central	South-eastern	South-western	Offshore reefs
58	<i>Oulastrea</i>	+	+	+	+	+	+
59	<i>Montastrea</i>	+	+	+	+	+	+
60	<i>Plesiastrea</i>	+	+	+	+	+	+
61	<i>Diploastrea</i>	-	+	+	+	+	+
62	<i>Leptastrea</i>	+	+	+	+	+	+
63	<i>Cyphastrea</i>	+	+	+	+	+	+
64	<i>Echinopora</i>	+	+	+	+	+	+
65	<i>Moseleya</i>	-	-	-	-	+	-
66	<i>Trachyphyllia</i>	+	+	+	+	+	-
67	<i>Euphyllia</i>	+	+	+	+	+	+
68	<i>Catalaphyllia</i>	-	-	+	-	-	-
69	<i>Plerogyra</i>	+	+	+	+	+	+
70	<i>Physogyra</i>	+	-	+	+	-	-
71	<i>Heterocyathus</i> *	-	+	+	-	+	-
72	<i>Turbinaria</i>	+	+	+	+	+	+
73	<i>Duncanopsammia</i>	-	-	+	-	+	-
74	<i>Heteropsammia</i>	+	-	+	+	+	-
75	<i>Dendrophyllia</i> *	+	+	+	+	+	-
76	<i>Tubastrea</i> *	+	+	+	+	+	-
77	<i>Balanophyllia</i> *	+	-	+	-	+	-
78	<i>Culicia</i> *	-	-	+	-	-	-
79	<i>Flabellum</i> *	-	-	+	-	-	-

Note: - *: *Ahermatypic corals*.

Water temperature is a key factor limiting coral growth and the formation of reefs. The number of coral species observed on reefs usually increases from high to low latitudes (Veron, 1998). This suggests that Viet Nam's coastal waters may have greater coral diversity than countries which coastlines extend across few degrees of latitude. However, according to the documents of Krempf (1930) and Vo Van Lanh (unpublished), Viet Nam's coastal waters can be classified into three temperature regimes. There is a clear decline in surface temperatures of Tonkin Gulf and middle central waters in winter. This decline in temperature is not prevalent in South central and Southeastern waters. The intersection point of these two zones is Varella Cape according to Krempf (1930) or 13°N according to La Van Bai (1991). The Gulf of Thailand is isolated by Ca Mau Cape and has a cooler temperature in the summer and warmer temperature in the winter when compared with Tonkin Gulf (La Van Bai, 1991). The clear differences between the three temperature zones results in significantly diverse coral communities at the demarcation fronts.

Water currents of the South China Sea and the Gulf of Thailand play an important role in the dispersal of larvae from areas of the Philippines and Indonesia. The interactions of the highly diverse coral hot spots in the Philippines and Indonesia with the Western Pacific Ocean and Kalimantan channel are also significant. Water is exchanged with the Western Pacific during the winter and via the Kalimantan channel during the summer. These exchanges are critical for the exchange of coral larvae between coral biodiversity center with Central and Southeastern waters of Viet Nam.

Another important factor influencing the biodiversity of coral reefs in Viet Nam is sea level change. Geological surveys highlighted an old coastline at depth of approximately 100m in the South China Sea at 18 000 years ago (Saurin, 1962). At that period, coastal line in the North of the Philippine, in the East of Indonesia and in the North of Papua New Guinea was as similar as that nowadays. These were shelters for coral communities to be existing even affected by disasters of seawater surface changes. Days by days, the seawater level has been increasing and submerging the areas in the western, northern and southern parts of those areas became new home for corals (Well, 1988). In accordance to this logicity, reef-building corals in the Viet Nam central part has longer development history and more advantage to receive coral seedlings dispersed from coral biodiversity center in the Pacific-Indian waters thanks to a little changeable shores. Other waters all (such as Tonkin Gulf, Southwestern and Southwestern) were mainland in the period of 18,000 years ago, so had shorter duration of coral dispersion.

Moreover, another less significant and more localised factor to be considered is the influence of the sedimentation regime on coral biodiversity via substrate characteristics, sediment accumulation, and illumination (Veron, 1998). In this respect, South Central waters contain more highly biodiverse coral reefs than other areas.

A synthesis of the effects of all the aforementioned factors on the reef-building biodiversity (Table 3) shows that South central waters has the most suitable condition and Tonkin Gulf is the worst area on coral biodiversity.

Table 3 Effect of main factors on hermatypic coral biodiversity. (- disadvantage, + advantage)

Area	Temperature	Dispersal level	Coastal line change	Sedimentation regime
Tonkin Gulf	-	-	-	-
Middle central	-	+	+	-
South central	+	+	+	+
Southeastern	+	+	-	-
Southwestern	+	-	-	-

Based on the studies and analysis of natural conditions influencing reef-building coral distribution, it can be assumed to separate four zones of reef-building coral distribution.

South central and Southeastern waters have similar biomes due to being locating in areas with similar temperature regimes and relative proximity to areas of coral dispersal in the Philippines and Indonesia. Information and data on environmental conditions and the distribution of coral genera in Vietnamese waters enabled the adjustment of the isopangeneric contours of reef-building corals established by Veron (1993) for the South China Sea (Figure 2).

The isopangeneric contour of 60 genera originates from Con Co Island (17° North). The Tonkin Gulf area is characterised by less than 60 genera of hermatypic corals. Waters of middle central Viet Nam are located to the south of this where the number of genera ranges from 60-70. The isopangeneric contour of 70 genera originates from Varella Cape (approximately 13° North), encompassing the Paracel and Spratly archipelagos. Studies of population inter-dependence in the South China Sea, based on the genetic structure of fish *Dascyllus trimaculatus* (Ablan *et al.*, 2002), support the establishment of a boundary at Varella Cape. Areas having more than 70 genera include South central waters, Paracel and Spratly. Although only 61 genera of hermatypic corals have been observed at Con Dao Island, it has been proposed that Con Dao be included within the 70+ genera isopangeneric contour.

Southwestern waters of Viet Nam belong to the distribution zone with less than 70 genera. The isopangeneric contour of 70 genera covers all the Gulf of Thailand, although does not seem to be compatible with findings of small-scale studies, which indicate that there are fewer genera in this area. Surveys conducted at Phu Quoc Island in Viet Nam (WWF-IOC team, 1994) and at Mu Koh Chang in Thailand (Thamasak, unpublsh) identified only 34 and 44 genera of hermatypic corals, respectively. It is necessary to undertake additional surveys to enable a better understanding of coral reef fauna in the Gulf of Thailand.

Species level analysis suggested establishing contours of 300 species overlapping the 70 genera contour and 200 species overlapping the 60 genera line. Nha Trang Bay, the Ninh Hai coastal reefs, and Con Dao Islands are characterised by a high level of coral species diversity, with more than 300 species recorded. They are perhaps amongst some of the most species rich coral reef areas in the world.

Coral reef associated organisms

Surveys of coral reef associated organisms conducted from 1993 to present identified nearly 1,000 species of invertebrates (Table 4). Molluscs were the most diverse, with nearly 500 species recorded, and were followed by the crustaceans with more than 250 species. Approximately 175 species of polychaetes and species of 100 species echinoderms were recorded. The littoral fauna was comprised of more than 200 species, whilst the rest belonged to sub-littoral organisms. The areas of Con Dao Islands and the coastal waters of Khanh Hoa Province have been studied more intensively, and more than 400 and 300 species of coral reef associated organisms were observed in these areas respectively.

Table 4 Coral reef invertebrates in the coastal waters of Viet Nam.

Taxon	No. Family	No. Genera	No. Species
Echinoderm	30	63	96
Crustacean	44	144	251
Polychaeta	38	110	176
Molluscs	78	177	446
Total	190	494	969

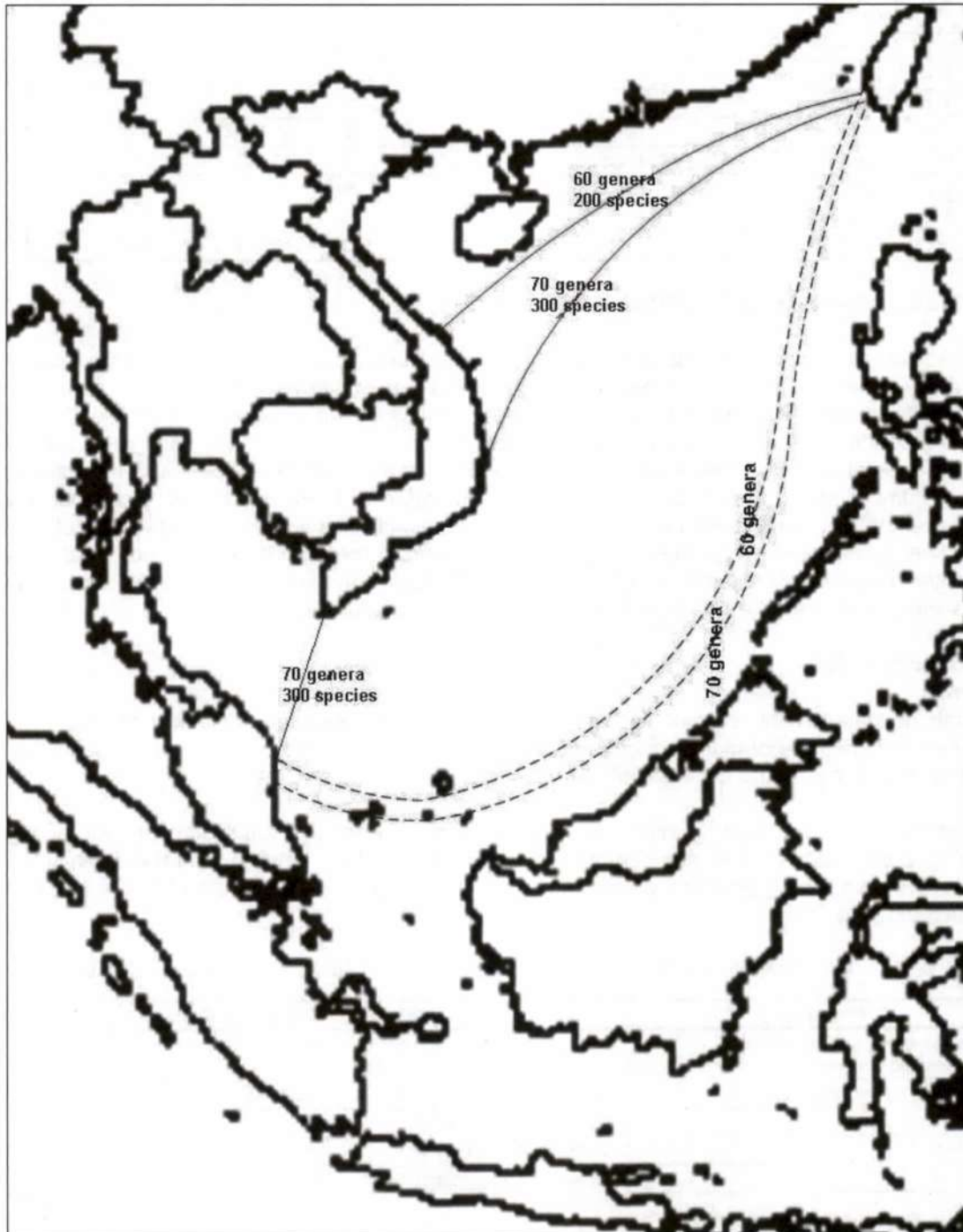


Figure 2 Isopangeneric and isopanspecies contours of hermatypic corals showing high biodiversity of hermatypic corals in Vietnamese waters. (dashed line – following Veron, 1993; solid line – modified from Vo Si Tuan, 1998)

In total, some 411 species of coral reef fish, from 139 genera in 44 families, have been recorded as being present in the coastal waters of Viet Nam (Table 5). Of these, the families Pomacentridae (66 species) and Labridae (61 species) were both well represented, as was the Chaetodontidae (32 species). Locations in south-central Viet Nam, including Nha Trang Bay and Ca Na Bay, are more diverse in coral reef fish, with 222 and 211 species having been recorded at the sites, respectively. These areas may be more diverse in coral reef fish than other coastal water areas of Viet Nam.

Table 5 Composition of coral reef fish in some major locations in coastal waters of Viet Nam.

No.	Location	Family	Genera	Species
1	Co To	16	27	34
2	Cat Ba	16	25	31
3	Cu Lao Cham	33	76	178
4	Nha Trang	38	102	222
5	Ninh Hai	32	81	147
6	Ca Na	37	87	211
7	Con Dao	33	84	202
8	Phu Quoc	27	60	135
Total		44	139	411

SOCIO-ECONOMIC BENEFITS FROM CORAL REEFS

Coral reefs are an important coastal habitat type in Viet Nam, playing a critical role as a reservoir of biodiversity. They are also important for fisheries and tourism development in the coastal zone. Traditionally, millions of people from different communities in the coastal zone of Viet Nam have directly depended on coral reefs for food and other benefits. In recent years, coral reefs have been used for coastal tourism development, especially when the economy is open and the interests of public communities on the marine environment are improved. Being one of the most visually impressive habitats, coral reefs are utilised for recreational activities such as snorkelling, scuba diving, and recreational fishing. Coral reefs have also contributed to the formation of islands, and protect a substantial portion of Viet Nam’s coastline from the effects of wave action and the impacts of storms. They are also considered a “live laboratory” for research and education.

Economic benefits

Fisheries

Although no data on the current harvests of reef fishes and invertebrates exist for most coastal provinces, fisheries are of high economic significance in Viet Nam. Many commercial species of fish, molluscs, crustaceans, and echinoderms live and take shelter on coral reefs.

Coral reef fisheries are typically multi-species, multi-gear fisheries and small-scale in nature. Hookah air diving, purse seine and gill net, light fishing, drift nets, long line, trawling, and the gleaning of tidal flats are common fishing gear and practices used to target coral reef associated fish on and adjacent to coral reef areas (Table 6).

Table 6 Main fishing activities and marine resources collected from coral reefs in Viet Nam.

Fishing activity	Main Marine Organisms Fished
Hookah air diving with or without dynamites and poisons	Groupers, sweetlips, top shells, triton shells, giant clams, lobsters, ornamental fish and live corals
Net (gill net, purse seine, drift net)	Sweetlips, snappers, cardinalfish, coral breams, anchovies
Light fishing	Anchovies and cuttlefish
Long line	Cuttlefish and fish
Fixed net	Mackerel, tuna, snapper, jacks
Trap net	Cuttlefish and fish
Gleaning on tidal flat	Seaweeds, gastropods and fish

Many commercial reef fish such as groupers, snappers, sweetlips, emperors, parrotfish and triggerfish are being caught. Live groupers *Epinephelus* spp., *Plectropomus* spp. and *Cephalopholis* spp. have become the favoured targets and are harvested from reefs because of their high prices. Other reef fish such as grunts *Plectorhynchus* spp., snappers *Lutjanus* spp. and emperors *Lethrinus* spp.,

mackerel *Scomberomorus sp.*, tuna *Auxis sp.* and anchovies are also being caught. Annual catch of grouper *Epinephelus sp.* from coral reefs in Ninh Thuan Province occupied some 10% of a total catch of demersal fish in the whole province, with annual landings ranging from 0.6 (1995) to 1.0 tonnes (2002) (Data from Ninh Thuan Department of Fisheries, 2001). Mackerel (*Scomberomorus sp.*) and tuna (*Auxis sp.*) are the main contributors to the total fisheries production landed in Ninh Hai District, Ninh Thuan Province. These fishes are usually concentrated in front of Vinh Hy Bay where coral reefs are commonly found. In Phu Quoc, a total of mackerels and anchovies landed in 2001 was about 3,500 and 12,500 tons respectively (Data from Phu Quoc Department of Agriculture, Forestry and Fisheries). Anchovies were harvested on or close to coral reefs from April to September around the year with a total catch reaching up 5-7 tonnes per boat per day.

Cuttlefish (*Sepia spp.*), squid (*Sepioteuthis spp.*) and (*Loligo spp.*) are fished on a commercial basis. Lobsters (*Panulirus spp.*) have also become an important species due to high market prices. Collecting edible sea cucumbers, gastropods and bivalves for food or for sale in souvenir shops has commonly appeared in most of the coastal provinces. Among them, abalones (*Haliotis spp.*), top shells (*Trochus niloticus* and *T. maculatus*), giant clam (*Tridacna spp.*) are considered as commercially important food and materials for souvenirs. A total production of giant clams collected around Con Dao islands reached 10 tonnes during April-July of 1994. Information collected from one of the three local sellers at My Hoa Village, Ninh Thuan Province in 2001 confirmed that there were some 4 tonnes gastropod and bivalve shells being exported to Nha Trang and Da Lat Cities during 2000-2001. Edible sea cucumbers are also collected from coral reefs in the area. According to data collected by Phu Quoc Department of Agriculture, Forestry and Fisheries in 2001, as much as 3,879 tonnes of squid and cuttlefish were caught for both local uses and international export. Pearl oysters (*Pinctada mertensi* and *P. maxima*), abalone (*Haliotis ovina*) and scallops (*Chlamys nobilis* and *C. Irregularis*) were exploited for food and jewellery. Information collected from local fishermen indicates that the number of *Pinctada maxima* caught at the depth of 20 - 40m by four hookah divers reached 10-15kg per day.

The annual catch of adult lobsters harvested from the coral reefs of Ninh Thuan waters ranged between 30-50 tonnes (Data from Ninh Thuan Department of Fisheries, 2001) with the price ranging from 200,000 – 300,000 VND per kg. During the past five years, hookah divers from My Tan, My Hiep villages - Nhon Hai Commune, Ninh Thuan province collected ornate lobster (*Panulirus ornatus*) on the coral reefs for lobster cultured-cages. Recently, the cage culture of lobsters has developed quickly in Khanh Hoa and Ninh Thuan Provinces. There are some 15,000 cages for lobster culture with the amount of juveniles collected from the wild totalling around a million per year in Khanh Hoa Province. Annual ornate lobster harvested from coral reefs in Ninh Thuan waters was 200,000-300,000 individuals (Data from Ninh Thuan Department of Fisheries 2001). Information from local fishermen indicates that 250-500 juvenile of ornate lobster have been collected from the coral reefs of Nhon Hai Commune in Ninh Thuan Province during the settlement season (from November-April), and this may sometimes reach up to 2,000-5,000 individuals per day during the peak season (from January to February). The price of one lobster seed was 30,000-60,000VND depending on the season.

The gleaning or harvesting of organisms from reefs by hand is still commonly conducted to collect certain species on the reef flats. Collecting seaweeds and reef-associated organisms such as molluscs, crustaceans, sea cucumbers, sea urchins and fish on the reef flats during the low tide period is an important income generating activity for a many coastal communities of Viet Nam. In Ninh Hai waters, Ninh Thuan Province, some 15-25 tonnes of seaweeds are harvested annually from coral reefs. Of which, *Gracilaria eucheumoides*, *G. salicornia*, *Gelidiella acerosa* and *Betaphycus gelatinae* are mainly harvested for food. *Sargassum*, *Acanthophora*, *Hypnea*, *Gracilari*, and *Ulva*. occur with a very high biomass on many reefs and are harvested for producing fertilisers for agriculture cultivation. A wet kilo of seaweed from Ninh Hai district, Ninh Thuan Province was valued at almost 2,000 VND in 2002.

The collection of ornamental fishes from coral reefs has occurred in some coastal provinces for domestic uses and international export. In the recent past, ornamental fish such as butterflyfish, angelfish, wrasse, and scorpions fish were being caught for local aquaria and the international aquarium trade. The number of ornamental fish collected from Nha Trang Bay annually for transportation to aquaria in Ho Chi Minh City was around 1,000 fish (Chu Anh Khanh, per. comm.).

Tourism

Coral reefs are a major draw for snorkellers, scuba divers, recreational fishers and those seeking a vacation in the sun. Nha Trang City is considered as a major center of marine tourism development in Viet Nam, and the coral reefs surrounding nearby islands are very diverse and abundant. The number of visitors to Nha Trang has recently increased, with an approximate value in excess of more than 300 billion VND (equivalent US\$20 millions) being recorded in 2003. The annual number of visitors to the islands of Nha Trang Bay was estimated at 30,000 people in 1995 to more than 400,000 people in 2003. About ten percent of them joined diving and snorkling on the reefs of Hon Mun MPA. These services brought benefit about US\$400,000 occupied approximate 2% of total income of tourist sector in Khanh Hoa province. There was a further dramatic increase in numbers and diversification of operations. A tourism survey conducted by IUCN in 2000 revealed that many tourists would be willing to pay round US\$1-2 each to visit Hon Mun Marine Protected Area.

Tourism can be expected to play an increasingly important role in the development strategies of Phu Quoc district, Kien Giang province for the next ten years. Number of tourists (mostly domestic tourists) visited the islands has been increased dramatically during the last 7 years, from 4,543 people in 1995 to 74,997 people in 2001. The total international tourists visit Phu Quoc in 1995 were 1,106 people, increasing to 42,748 people in 2001. The duration of international visitors spent at the islands averaged 3-4 days per vocation per person while this increased to 3-5 days to domestic tourists. The total benefits of the district collected from tourism have also increased from 1.5 billions in 1995 to 11 billions VND in 2001. At present, tourism in Phu Quoc has been mainly focused on land while marine environment was not well attractive to visitors. Tourists spent their time to visit the Nature Forest Reserve in the norther part of Phu Quoc island and to swim at some beautiful beaches such as Bai Sao and Bai Vong beaches. The islands group in the southern part of Phu Quoc (An Thoi) with pristine coral reefs have been considered by tourist organizers during the last three years and that were emphasized as diving, snorkelling, fishing area for marine eco-tourism in the Tourism Development Plan of the district. At present, only one hotel (Sai Gon – Phu Quoc Resort) has operated diving service. It charges 20-110 USD/person including resort pleasure boat, guidance, mineral water, snack, insurance, life buoy and fishing equipments.

Tousit development based on coral reefs has also been considered in Con Dao islands and Cu Lao Cham Marine Protected Area (Quang Nam province).

Social Benefits

With the importance of fisheries and tourism, coral reefs have ben playing an important role in the development of economy, providing jobs and benefits for society. Fishing is a major activity with about 15,000 fishermen from different communities around Nha Trang Bay depended on. Population of Phu Quoc district recorded in 2001 was 74,000, of which some 11,130 fishermen are engaged in capture fisheries in the sea while most of the rest work in fisheries processing and other related occupation on these islands. Many primary processing factories of marine products have provided many kinds of sea products. Fish sauce "nuoc mam", a famous sea product, was produced in Phu Quoc and exported to many different countries on the world. This is a traditional industry of turning low-valued fish into a profitable product through long period of fermentation and processing with salt and water.

Tourism has provided significant employment for population of Nha Trang City. More than 80 hotels, 60 tourism boats and a range of associated services have provided thousands of jobs for local communities. At present, Phu Quoc has 8 large hotels to be built on the main island, mostly concentrated in the west coast of Phu Quoc island and that will be increased in the near future. The development of marine tourism at the area will be generated jobs and benefits for local communities.

Uses of coral reefs as a resource for education and aesthetic have been considered in Nha Trang bay and Con Dao National Park. There has been number of students from different universities coming for enhancing awareness and knowledge on marine ecology and conservation. The photos contest on natural beauty was organized in 2004 with number of photos of coral reefs of Nha Trang and Van Phong bays.

STATUS AND THREATS

With more than 200 coral sites along the Viet Nam coast have been surveyed for recent years shows that the coral coverage in the reefs is not in the good status. Based on the scale of English *et al* (1997), only 1% of coral reefs is in excellent coverage (higher than 75% coral coverage), while there is more than 31% of coral reefs in bad coverage (less than 25%). The coral reefs with fair and good coverage are about 41% and 26%, respectively. The specific inventory data of coral reef areas stated that most of coral reefs have coverage at average level from 25 to 50% (table 7). Only coral reefs located at offshore or far from the communities may maintain relatively good status (Vo Si Tuan, 2000).

Table 7 Coverage of some reef areas in the coastal waters of Viet Nam.

No	Study areas	No. sites	Coverage rank (%)	Average cover (%)	Time
1	Hà Long – Cat Ba	21	12 - 65	40.6 ± 15.2	1998
2	Bạch Long Vi	5	2.7 - 47.6	21.7 ± 19.0	1995
3	Hai Van – Sơn Trà	7	35 - 62.7	50.5 ± 15.7	1996
4	Cu Lao Cham	5	18.4 - 53.7	33.9 ± 12.4	2002
5	Nha Trang bay	8	5.6 - 44.4	26.4 ± 15.9	2002
6	Ninh Hai	6	16.3 - 55.9	36.9 ± 13.5	2002
6	Ca Na bay	6	18.4 - 68.4	40.5 ± 24.1	1996
7	Con Đảo	8	1.6 - 50.3	23.3 ± 18.2	2002
8	Phu Quoc	6	28.7 - 52.5	42.2 ± 8.60	2002
9	Nam Du	4	37.8 - 62.8	47.4 ± 11.7	2002
10	Thô Chu	4	4.6 - 15.9	11.3 ± 4.80	2002

The coverage of live corals on the reefs at some major distribution areas of Viet Nam waters has been decreasing by time. The coral coverage declined down to 30% at some areas (Table 8). It implies that coral reefs have been damaged and towards bad degradation.

The coral reef status has also been reflected via data of coral reef community. Some studies on coral fish of Nguyen Huu Phung and Nguyen Van Long (1997); Nguyen Van Long and Nguyen Huu Phung (1997) proved that coral reefs in Southern part of Central Viet Nam is relatively diverse in species composition. However, coral fish density is just remarkable in the further islands such as Con Dao, Phu Quoc, Nam Du, Tho Chu...ect. The inventory data of dominant species as standard of Reef Check (1998) presented serious poor of coral organisms, who have used for food or/and souvenir material values. Some families have food value such as Emperor (*Lethrinidae*), Snapper (*Lutjanidae*), grouper (*Serranidae*), Sweetlips (*Haemulidae*) remain rarely in the reefs and most of them are shorter than 20 cm long. The continuously studied data for several years in coral reefs at Cu Lao Cham, Nha Trang Bay, Con Dao, Phu Quoc also showed that the number of fish species with edible or/and ornamental value has been decreased by time and some species would be probably locally extinct (Nguyen Van Long, *in press*). Some benthic species having high value on the reefs such as lobster, Sea Cucumber, Trumpet triton *Charonia tritonis* and Giant Clam *Tridacna* spp. is remaining very few and even extinct in some reefs.

Table 8 Decline of coral coverage in some areas.

STT	Study areas	No. site	Decline of coral cover (%)	Period
1	Ha Long–Cat Ba	-	-7.1	1993 - 1998
2	Cu Lao Cham	5	-1.9	1994 - 2002
3	Nha Trang bay	8	-21.2	1994 - 2002
4	Con Dao	8	-32.3	1994 - 2002
5	Phu Quoc	5	-3.3	1994 - 2002

Burke *et al.* (2002) indicated that most coral reefs in the coastal waters of Viet Nam were under threats with 50% of the reefs ranked at higg level and 17% at very high level. Destructive fishing was assessed as popular and serious with 85% coral reefs at medium and high levels. Over fishing was indicated a serious threat to a half of coral reefs. The other threats have been concerned as lesser like potential sedimentation (47% coral reefs), coastal development (40% coral reefs) and pollutions

(7%). The mitigation of threats based on affective management is not remarkable in Viet Nam. In fact, only three areas consisting of Cat Ba, Con Dao and Ha Long Bay were ranked as rather effective management following the standard criteria of Reef at Risk in South East Asia. In comparison with other coral reef status in the region, based on the model, Viet Nam was ranked in the group of high rate of threatened coral reefs (together with the Philippines, China, Taiwan and Indonesia). The direct survey data clearly addressed multiple and rather serious threats at most of coral reefs in Viet Nam.

Over fishing

Surveys at 29 coastal communities of ADB project (5712-REG) (phase 2) showed that fresh seafood importing need of China and Hong Kong markets is creating a high pressure on coral reef resources of Viet Nam. In fact, those activities have not been controlled and checked even in some national parks like Con Dao. It leads to over fishing all the marine specialties such as sand fish, lobster, mollusks ect... The most important compositions to build up the coral reefs are hard corals, staghorn corals, and soft corals, which are extensively exploiting and trading. In addition to making souvenir, "live rock" have been annually exporting to Europe and US for marine pest needs. Ornamental fish are also exploiting for exporting to marine pest culture markets.

The data obtained during 2002- 2003 by coral reef monitoring reflect the poorness of ReefCheck indicators. The commercially valuable groups of large groupers Serranidae (e.g., *Plectropomus*, *Epinephelus*, *Cephalopholis* spp.) and Lutjanidae (*Lutjanus* spp.) are both highly depauperated and low relative abundance and sizes, reflecting the intensive fishing pressure. Only few of them were recorded at few sites in Cu Lao Cham, Con Dao islands, Nha Trang bay. Other notable absentees from almost areas include the labrid Humphead Maori Wrasse *Chelinus undulatus* and serranid Barramundi Cod *Cromileptes altivelis*, once common components of many Indo-west Pacific reef fish assemblages. These species are among the most favour target fishes for the Asian live fish trade, and are now locally extinct in many areas of East Asia. They were observed at only one site of Con Dao islands.

Benthic indicators for commercial species were not recorded at number of sites. The Giant Clam *Tridacna squamosa* is observed commonly only in Cu Lao Cham. The Giant Triton *Charonia tritonis* is not seen in any of sites monitored. Notable absentees in almost areas are the commercially important sea cucumber species. The same situation occurs for lobsters, which were recorded at few sites of Cu Lao Cham, Nha Trang and Ca Na bays. The Top Shell *Trochus nilotichus* presents only in Con Dao islands and Cu Lao Cham with low density. Amount of dead corals exploited for limestone and making dykes of aquaculture ponds has not been reported.

Destructive fishing

This threat is performed via using destructive fishing method such as dynamite, poison, small mesh size fishing nets, trawling net, electrical fishing. According to the survey of project ADB 5712-REG in 1999, destructive fishing methods are implementing in 21/29 coastal provinces/cities. In there, the destructive fishing methods have been commonly using at Quang Ninh, Nghe An, Quang Binh, Thua Thien – Hue, Quang Nam, Quang Ngai, Khanh Hoa, Ninh Thuan province. Recently, dynamite fishing has been decreased, but cyanide fishing has been become more popular for increased demand of living fish trade. The effectiveness of those destructive fishing methods is very dangerous and badly impact on whole ecosystem.

There are few statistic data concerning with destructive fishing. Some interviews with local fishermen show existence of dynamite fishing in some reef areas. The survey in Nha Trang bay (Vo Si Tuan et al, 2002) showed that ca. 10% of manta-tows had evidence of blast fishing in the form of "craters" and/or other obvious physical damage to reef areas. The monitoring practices did not record any traces on the transects and the index values are maximum. Hookah diving using poison has brought to high benefit for a lot of coastal fishermen in Cu Lao Cham, Nha Trang and Ca Na bays, Phu Quoc islands... According to above-mentioned survey, evidence of poison fishing was found at a lot of reefs in Nha Trang bay. Overall ca. 5% of manta-tow sites were affected. Abandoned poison "squirt bottles" were also observed on one reefs. Actually, a lot of "hookah" divers use poisons to capture fish, both for food and to supply the lucrative aquarium trade and cyanide is thought to be used regularly. However, and evidence is not always obvious.

Tourism

One of the biggest impacts of tourism is the increase of souvenir need and does leading to wild animal exploitation. Marine turtle (Hawks' bill turtle, green turtle...) has been exploiting at any time and anywhere and free trade in big tourism center such as Nha Trang, Vung Tau. Other species can be used for making souvenir things for example: pearl oyster, snail, sea urchin...becoming rare animals in the reefs and being in danger of local extinction. Tourism also creates physical impacts like anchoring on coral reefs, careless jumping down of tourists... can break corals.

Coastal development and sedimentation

The development of coastal cities has been affected to coral reefs. The infrastructure construction such as port and dike building, has directly or/and indirectly damaged coral reefs. Some evidences presented that recent increase of sediment concentration in the water has a connection with coastal development, dredging, soil exploitation, forest cut and other unplanned agricultural activities.

Ha Long – Cat Ba coastal areas are examples, which demonstrate a strong impact of sedimentation on coral reefs. The previous studies showed that the suspended sediment concentration in the water at those areas is rather high. Coral reefs of the Cat Ba National Park were damaged by high sediment concentration discharged from mining activities of Quang Ninh province. The coastal areas in the central Viet Nam have been known as less impact of waterways system. However, studies also showed that the coral reefs at those areas are in danger of sedimentation from the rivers in the rainy season. It is highly concerned that high water turbidity has not only locally occurred, but also expanded to a large area, where corals are currently distributing.

Pollution

Industrial zones and manufactures' development nearby the coast is creating potentially negative impacts. New building, harbor enlargement and more frequent operation of boats have been speeded up the coastal pollution process. Increasing of seawater nutrient is another threat and it may generate a eutrophicating phenomenon. Surveys recorded over growth of seaweed at some areas in the North of Nha Trang Bay and South of Van Phong Bay. (Pham Van Thom & Vo Si Tuan, 1997). Aquaculture is dramatically developing at shallow coastal areas near by the coral reefs created negative influence on coastal coral reefs. Data collected from recent studies showed that blooming tendency of harmful algae at aquaculture areas will be a potential threat to coral reefs in those areas (Pham Van Thom, unpublished).

Coral exploitation

Dead coral exploitation using for construction material and making dykes of aquaculture ponds has been popularly happened at some places such as Phu Yen, Khanh Hoa, Ninh Thuan...coral exploitation at littoral areas decreased distribution areas of corals, created hydraulic unbalance of coral reefs as well as increased sedimentation caused by erosion, aggradations and exploitation. The most certainly important composition of coral reefs is hard corals, horny corals and soft corals, which are currently exploiting and trading at the big scale. Nowadays, coral trading is an increasing commerce around the world including dead corals, souvenir material corals and alive corals for ornamental culture. Viet Nam exporters have been licensed from the government agencies. The difference in coral trade between Viet Nam and other export countries is weak control in species, exploitation yield, and transparency in the coral trade. Even though Viet Nam doesn't have any inventory data on exported corals but other import countries knew it very well. The table 9 presents the data on the yield of corals exploited in 1998. It probably needs further discussion on this commercial activity in Viet Nam. According to some studies (Vo and Truong, 1997; Dang Ngoc Thanh & Vo Si Tuan, 1998) coral reefs in Viet Nam are seriously being damaged in most of waters. Living resources have been over exploited and become extremely poor. Many problems like ecological balance of the coral reef ecosystem are still being uncovered. Ecosystem conservation is quite simple even in the proposed marine protected areas. Management capacity of functional agencies is still not required enough. Those are some issues should be discussed when approved coral export campaign in the future.

Table 9 A figure on coral export in Viet Nam and some countries.

Export country	Living corals (piece)	For souvenirs (kg)
Viet Nam	19,327	103,157
Tonga	10,754	232
Solomon	25,856	50,403
Indonesia	517,841	
Fiji	71,353	155,527

(source: CITES, 1998).

Anchor and Others Kind of Damage

The damage caused by anchoring was recorded mainly in tourist sites such as Nha Trang Bay. As showing in the habitat survey (Vo Si Tuan *et al.* 2002), anchor damage is apparent in < 10% of survey sites focusing in areas with the most intensive tourism activities. Other sites with noticeable damage were in the vicinity of the villages and where fishing boats anchor. Overall data of the monitoring sites do not show anchor damage on the transects and showed maximum values of the index. Meanwhile, some other damage causing coral breakage, rubbish (non-fishing and fishing related) were recorded in most areas and presented via low values of the indexes. This means that rubbish is discharged directly into the sea by local communities and fishermen.

During recent years a number of fishing ports have been constructed in a lot of the islands with coral reefs such as Cu Lao Cham, Bach Long Vi, Phu Qui, Con Dao. Port building and dredging nearby Ha Long bay are considered a reason for sediment loading on coral reefs. These have directly or/and indirectly damaged coral reefs but no detailed surveys on the impacts done.

Storms

Storms can physically damage and break corals at shallow waters, especially Staghorn corals. Many corals were completely broken, alive corals' coverage declined and population structure rather changed after the storms threw. Coral surveys conducted from 1986-1989 reported large areas of broken staghorn corals accumulated on the seabed and nearby the South-Eastern coasts of Cat Ba, Dau Be and Long Chau. Those were consequences of Joe storm passed the areas by 23rd July 1980.

Some storms seriously affected to coral reefs of the coastal waters in South Viet Nam. In 1997, impacts of Linda storm on coral reefs in Con Dao were a clear proof for this phenomenon. The survey results before the storm (1994-1995) stated that 70% of coral reefs were ranked at high or very high coverage levels. After the Linda storm, most coral reefs were damaged and coral coverage of some reefs was nearly down to more or less zero. If possible, those coral reefs need to spend more than ten years to recover as previous status.

Coral bleaching

In 1998, coral bleaching seriously affected on many coral reefs in Viet Nam. Coral reefs in Con Dao were considered as a clearest evidence for this impact style. After the Linda storm, many newly recovered coral reefs in Con Dao were damaged by bleaching in 1998. Data collected from more than 11 coral reef sites demonstrated that the frequency of damaged coral colonies was very high and fluctuated from 0 to 74.2%, average value was about 37% depending upon different sites. Periodical survey data conducted from 1998 to 2002 showed that Con Dao coral reefs recovered very slowly after two serious damages of Linda storm and coral bleaching phenomenon (Vo Si Tuan, 2000).

Outbreaking of some species

Crown of Thorn Starfish (COTS) *Acanthaster planci* becomes a danger of coral reefs around world. They eat corals faster than recovery rate of corals when obtained high enough density. This will impact on the coverage of live corals on the reefs and create ecological unbalance of reefs. Human activities have been considered as indirect reasons relating to this outbreak.

COTS has been a considered problem causing degradation of the reefs in some coastal central areas in Viet Nam. Actually, its outbreak occurring for recent years would be a serious damage to a lot of reefs, especially in central coastal waters from Quang Nam province to Khanh Hoa province. Reef monitoring activities during 2002-2003 showed the abundance of Crown of Thorn Starfish (COTS) and *Diadema* sea urchin for benthos (Table 10). The records of high density of COTS on the reefs of central coastal waters (Cu Lao Cham islands with the average density of 50ind/ha), Van Phong

- > 150ind/ha and Nha Trang bays - > 60ind/ha) suggest further surveys to explain the reasons. The outbreak of COTS in Nha Trang bay started in 2001 (Vo Si Tuan, 2002) and continues a problem for reef conservation. Sea urchin *Diadema setosum* reach rather high abundance around the coastal islands of Gulf of Thailand (Phu Quoc and Nam Du). The comparison of *Diadema* density in 2000-2001 (Vo Si Tuan 2002) with that during 2002-2003 recognised the increasing trend at almost areas, except at Ninh Thuan coastal waters (Table 10).

Recently, expansion of Sponges has been recorded only in several sites in Ha Long Bay and Cat Ba islands. Sponges have expanded in many reefs, squeezing out and eroding coral colonies. Several large sized boulder corals can be broken even by a slight touch.

Table 10 Summary for density of Crown of Thorn Starfish and sea urchin.

Reef areas	Crown Of Thorns Starfish (2002-2003)	<i>Diadema setosum</i>	
		2000-2001	2002-2003
Cu Lao Cham	2.50 ± 3.50		26.61 ± 32.65
Van Phong bay	7.74 ± 12.52	28.5	43.92 ± 48.16
Nha Trang bay	3.34 ± 3.45	4.6	63.13 ± 85.05
Ninh Hai	0.00	7.1	4.17 ± 3.24
Ca Na bay	0.24 ± 0.34		125.76 ± 163.71
Con Dao	0.13 ± 0.35	4.9	20.38 ± 56.03
Phu Quoc	0.08 ± 0.20	124.3	434.09 ± 173.20
Nam Du	0.00		460.88 ± 189.11
Tho Chu	1.13 ± 1.34		89.77 ± 132.55

MANAGEMENT

National legislation related to marine resources and coral reef management

The **Law on Environmental Protection** was passed by the National Assembly in 1993. It is broad and includes strategic direction for environmental protection. In 1994, it was followed by Decree No. 175/CP, which provides guidance for its implementation. The law contains a broad mandate for environmental impact assessment, and it establishes environmental quality standards specifying the provisional environmental quality criteria that are to be used for monitoring and inspections of projects and activities. The law has been effectively implemented, making great strides in environment protection, especially enhancing the people's awareness on the environment and ecology.

Law of Fisheries was adopted on 26th December 2003 by the National Assembly of Socialist Republic of Viet Nam. This Law came into force from 1st July 2004. The Law stated that Fisheries resources shall be subject to the ownership of the people and under the integrated management of the State. Organisations and individuals shall have rights to exploit the fisheries resources as provided for by legislation. Following the law, fisheries activities shall ensure the economic effectiveness in accordance with the protection, rehabilitation and development of fisheries resources and biodiversity; shall protect environment and natural landscape. The development of fisheries activities in all aspects shall be done in accordance with the development master plan and plans of fisheries sector nationwide and in specific provinces. The articles related to coral reefs included contents on sustainable fisheries development; prohibited activities in fisheries activities; habitat protection, conservation, protection, rehabilitation and development of fisheries resources, and Planning and management of protected areas and marine parks.

The **Ordinance on the Protection and Development of Fisheries Resource** was approved by the Government of Viet Nam on 25 April 1989. It contains 29 article stipulating national fishery resource protection and development in inland water bodies, territorial waters, transitional areas, EEZs and national continental shelf areas. Article 3 states in details that the fishery resources protection and development must be integrated with their living environment protection. Article 8 also stipulates to strictly ban any harmful acts to damage fishery resources, to pollute living environments of aquatic organisms by uses of dynamites, toxic substances, electric pulse, waste discharge and destruction of coastal habitats, etc.. Although no specific provision is provided for marine conservation palling by the Ordinance, it has become an important legal instrument for supporting fishery resources management for both inland and marine resources.

Directive No. 125 – CT dated 28 April 1988 on development of aquaculture issued by the Chairman of the Council of Ministers (Now called Prime Minister). The document considered aquaculture activities, especially shrimp culture for export in coastal provinces and Mekong delta and other coastal area, which were developing very strongly, contributing to the economic growth, increased people's income and improved well-being. However, environmental protection, balanced and scientific planning were not paid due attention. This Directive has provisions on initial planning of land with water surface for aquaculture, on the integration between aquaculture farming and protection of resources, protection of land especially agriculture land, the protection of environment and natural ecosystem. However, this document still mainly focuses on economic development.

There are some other legal documents supporting to enforce above-mentioned laws, including: **Decree No. 195/HDBT**, dated 2/6/1990 issued by Minister Council on executing Ordinance on the fishery protection and development; **Decree No. 48/CP**, dated 12/8/1996 issued by Government on stipulation of administrative violation on the protection of fishery resources; **Directive No.1/1998/CT – TTg** dated 2/1/1998 issued by the Prime Minister on banning of using explosive, striking – electricity, poison for fishery exploitation. **Decree No. 26/CP**, dated 12/8/1996 issued by Government on stipulation of administrative violation on environment protection; **Decree No. 68/CP** dated 01/11/1996 and **Decree No. 76/2000/ND** – dated 15/12/2000 issues by Government on detail stipulation of enforcement Mineral Law.

Legislations on tourism have considered concerns on impacts of tourist activities to resources and environment in general and to coral reefs in particular. On 22/6/1993, the government has enacted **Resolution 45/CP** on management reform and development of the tourist sector. In the Resolution, the government has confirmed that Viet Nam has large potential to develop tourism activities, is endowed with natural beauty, places of interest, historical, religious and architecture relics.

In order to codify regulation on tourism, the National Assembly Standing Committee (2000) has approved the **Ordinance on Tourism**. The Ordinance stipulates that: 'the State ensures tourism development toward cultural tourism and ecological tourism' (Article 2), "Organization, individuals operating tourism business are responsible for protecting, reasonably and effectively exploiting and utilising tourist resources and protecting the environment in tourism areas, routes, and sites" (Article 14), "The state invests in basic surveys on tourist resources; placing priority on projects that protect and restore tourism resources, utilisation and development of tourist resources" (Article 16). If tourism is managed in this direction, coral reefs in tourist sites will be reasonably exploited and conserved.

Decree on Viet Nam's Marine Police was approved by the Permanent Committee for the 10th National Assembly and promulgated in 28 March 1998. All 4 clauses that regulate tasks of the Viet Nam's Marine Police (Clause 6, 7) also mention the task of marine environment protection "Guarding against environmental pollution in the territorial seam sea border, Viet Nam's economic privilege territory and shelf of ocean bed".

National policies/plans for environment protection and nature conservation

The 1991-2000 National Plan of Environment and Sustainable Development is a framework plan that outlines inter sectoral key priorities on environment protection, and it also exhibits Viet Nam's environmental commitment to international community. Chapter 11, par 3.4 of the Plan emphasized on integrated coastal zone management and planning, and the details are to:

- Protect estuaries and coral reefs;
- Protect and reforest mangrove forest
- Carry out investigations of sea weeds and grass;
- Manage coastal lagoons in Central Viet Nam; and
- Protect the coast from erosion and undertake technical solutions for coastal protection.

Biodiversity Action Plan for Viet Nam (BAP) was approved by the Prime Minister of the Government by his Decision 548/TTg dated December 22, 1995. The objectives of BAP are: Planning of significant coastal wetland protected area establishment: Ca Mau, Red river delta, Tram Chim, Tam Giang Lagoon, etc; Establishment of select priority MPAs with highest level biodiversity values; Implementation integrated coastal zone management in line with the sustainable development principle. BAP was adopted in due time and its adoption has exhibited an important effort to fulfill the country's commitment to the Convention of Biological Diversity (CBD) that Viet Nam ratified in 1994.

National Strategy on Management of Protected Area System was approved by the Prime Minister of the Government by his Decision 192/2003/QĐ – TTg dated 17 September 2003 adopted the strategy to develop Protected Area System of Viet Nam to 2010.

Institutional Framework

National institutions/ executive bodies

Decree 43/2003/ND-CP of Viet Nam government dated on 2nd May 2003 authorized Ministry of Fishery to declare list of species needed to be protected, restored and giving solutions for protection aquatic ecosystems, genetic diversity, aquatic biodiversity. Ministry of Fishery were also authorized to give regulations on notak-zones, catching limited areas and list of non-imported and non – exported species, and manage domestic aquatic reserves, marine protected areas.

Decision 08/2003/QĐ-BTS of Minister of Fisheries signed on 5th August 2003 authorized the National Directorate of Aquatic Resources Exploitation and Protection (NADAREP) to oversee and monitor implementation of regulation on species needed to be protected, non-imported, non-exported species (except aquaculture seed), seed conservation and manage domestic aquatic reserves, marine protected areas.

Although that MOFI now has overall management responsibility for the MPAs system but that sites with a terrestrial as well as a marine component will be managed by MARD together with MOFI. This situation is likely to continue for the foreseeable future. Management regulations for MPAs are also under discussion but these are likely to be broad and flexible, in order to allow management regulations to be tailored to specific geographical areas and management requirements.

Legislation at the provincial level

There are 27 coastal provinces, cities in Viet Nam, among which over 10 provinces and cities having coral reef distribution with varied coverage and diversity. Due to the practice of protection activities of corals and other aquicultural and natural resources, the provinces has issued a number of different legislative documents, including decisions and directions. These documents focus mostly on the implementation of the Government's policies, legislative documents regarding the protection of aquicultural resources and corals. In addition, provincial authorities are the major actor to organise the implementation of enforcing the rule of law not only in the area of protecting corals and aquicultural resources. As a result, the provincial authorities have issued related regulations, directions such as exploiting corals; purchasing and transporting corals, destroying corals to plant aquicultural products, building projects regarding the issues of waste treatment. Some localities have established, at different levels, zones of marine protection with the focus of protecting coral ecology. Further, more importantly some local communities with the assistance of the international organisations for natural preservation and central offices of sciences have committed and organized to protect coral reef effectively.

In general, the documents issued by the local authorities are characterised as: to solve a typical and serious case of legal violation at localities such as destroying and exploiting corals in a large scale. With an aim to organizing forces, collaborating different branches and authorities at levels to enforce the effective implementation of the rule of law regarding the protection of coral reefs. Issuing general regulations for a zone of protecting natural resources including coral reefs might be major or minor element, and to serve sustainable development (tourism, aquicultural resources) for communities. Having regulations to arrange and plan zones of different functions for territorial water including a number of islands and coastal areas, and different subjects of protection.

Besides, local legal documents show the active initiatives to solve the problems at hand without waiting for guidance from the central government: To harmonise the issues of protecting coral reefs and protecting aquicultural resources, and protecting environment. To solve the relations between protecting corals and exploiting minerals, planting aquicultural resources, developing communities. To unify the instructions, collaborate protecting forces within the provincial areas. Some policies and issues approach the view of integrated management, linking the protection of corals and economic development, and issues in mainland. Some regulations have supplemented the management gap existing at central level, in accordance with the overall policies of the Party and Government.

Provincial/local institutions

Sustainable management of Viet Nam's marine resources areas faces a number of institutional constraints. One of the most significant of these relates to the formal administrative jurisdiction for marine areas. There is a clear system of jurisdiction and administration for the terrestrial part of Viet Nam but no such comparable system exists for the country's marine areas. Coastal provincial jurisdiction is in practice assumed to end at the limit of the coastline (low water) and there are no provincial boundaries extending into the marine times area. Where Provincial governments are involved in marine management they do so on a purely sectoral basis (e.g., fisheries, marine transportation, etc). The result is that the marine zone of Viet Nam is treated as a completely open access with none of the control of the hierarchical system of government and administration that exist on the terrestrial side.

At provincial level, offices and branches such as the Department of Fisheries, the branch of Exploitation and Fishery Resource Protection, the Department of Natural Resource and Environment remain under the supervision of expertise by the offices at ministerial level. Thus, there are still confusing, overlapping issues or some areas lacking the management at central level. However, under the law provincial People's Committee is the authority to govern natural resources and environment within its provincial areas. Specialized offices are the authority to advise the implementation of tasks assigned by the provincial people's committee. As such, whenever there a need to collaborate to solve overlapping issues or lack of management recognised or to assign responsibility for a specific issue, the provincial people's committee can actively make decision.

Coral reef monitoring

The need for developing this coral reef monitoring is increasing days after days in line with pressure put by human beings in Viet Nam. On the world, a great number of rapid methods on monitoring of coral reefs are built. One objective of the new methods is to try to come up with main indicators reflecting the characteristics of the population/society and reflecting the impact of human beings on the coral reefs. One important matter to be considered is how to expand the monitoring scale, meanwhile simplifying the method in order to shorten the monitoring time under water and involve many stakeholders, including volunteers and coastal communities.

Reef Check method can be evaluated as the one to response well to some aforesaid requirements, which is proved through the fact that Reef Check is used with LIT in Global Coral Reef Monitoring Programme (GCRMN). The foundation of this method is to monitor the characteristic indicators of the basic proportions living on the bottom grounds of coral reefs (hard corals, soft corals, dead corals, seaweeds, etc and aegagous creatures), and quantify some organism playing an important role on reefs economically and in the sense of ecosystems.

Reef Check monitoring also leaves options for selecting more suitable indicators/ instructed species for different reef areas and can be changed in accordance to the capacity of the participants. For areas whose ecology progress is paid attention to like Con Dao, the indicators are increased including the varieties of coral species, bleaching situation against classified units, fish quantity against families. When establishing community-based monitoring station like the ones in Van Hung (Khanh Hoa), Ninh Hai (Ninh Thuan), local economically-valued species are added to the list of the instructed species. The selection of the addition is made by local fishermen with the consultation from scientists. Besides the monitoring meaning, this way should help with raising awareness of communities on conserving marine natural resources with the participation from the local people.

Coral reef monitoring in Viet Nam was officially carried out since 1998 in the proximity of different topics. During the initial period, selected sites depended on the implementation of the projects whose researching goals may not relate to reef monitoring. Later, monitoring orientation was, step by step, combined into contents of some projects oriented network system building and more areas set up. The selection carried out based on the idea of "network" consisting of ecological stereotype and management recommendations. Selected sites should be representatives for different marine waters, for areas with coral distribution and for biodiversity zoning.

As for management, some areas are protected in the proximity of some marine protected areas, some are open for free exploitation, even exploitation without management. Data collected from fixed monitoring sites in Nha Trang Bay, Con Dao since 1998 initially shown the changes in the structure of reef organism population under the natural impact and human impact. However, data collected from

the permanent monitoring sites are not periodic and continuous due to financial difficulties and human resources so the effectiveness are not so high. Coral Reef Monitoring with the participation of local communities is considered necessary and important requirements in order to raising research potentialities and managing coral reefs in Viet Nam in a near future.

Coral reef rehabilitation

First trials for coral rehabilitation were carried out in 2000 at Con Dao islands following strong impacts Lynda typhoon. Some other practices were done during 2002-2005 in Van Phong and Nha Trang bay as experiments with poor data on mortality and growth. More extensive rehabilitation was implemented by the National Project to restore and management of coral reefs in south Qui Nhon bay (Binh Dinh province) where coral reefs had suffered serious degradation due to coral mining, destructive fishing, providing systematic data from 2002-2004. Coral transplantation with collection of small part of coral colonies from good reefs was used as technique for rehabilitation with materials used for attachment of coral pieces including dead coral substratum, cement block, cement tubs, iron sticks.

The concurrent site management with strong supports from local government and communities has brought positive effectiveness of reef rehabilitation thank to not only coral transplantation but also natural recovery. Outputs of rehabilitation in Binh Dinh province indicate that:

- The species as *Acropora nobilis*, *A. yongei*, *A. microptalma* obtained quick growth. Meanwhile *Porites nigrescens* presented good adaptation to environment seasonal change.
- Foliose corals belonging to *Montipora*, *Echinopora*, *Pachyseris*, *Echinopora* and branch *Acropora*, *Porites* play an important role of natural rehabilitation.
- At one of experiment sites, all restored corals died in rainy season, meanwhile corals grewed well in summer, indicating a big change of fresh water flow and sedimentation which prevented coral restoration.

Restoration of reef resources was firstly considered by the Institute of Oceanography under the support by SUMA programme of Ministry of Fisheries during 2002-2004. Reproduction of Top shell *Trochus nilotichus* with wild broodstock was successfully practiced to provide spats for resource restoration with involvement of local community in Ninh Van village (Ninh Hoa, Khanh Hoa province). Top shell reserved in cages grewed well in natural conditions and become broodstock to produce more spats (F1) for further restoration in Khanh Hoa province in present time.

Establishment and management of marine protected areas (MPAs)

Viet Nam is now in a suitable period to develop the MPA system. On theory, a small part of marine resources and coastal resources of Viet Nam is protected in the existing MPA system. These MPAs are currently the focus to protect and conserve biodiversity in marine areas and coastal areas within the country. While the proportion of different ecosystems has not yet been enough mentioned in the MPAs system, the awareness of need in defining this proportion in the national MPA system has been increasing. This can be proved through the fact that Government agencies and the scientist submitted some national programs to develop MPAs and some proposed plans for each concrete MPA or to expand the areas of the existing MPAs.

The survey results on local communities in Viet Nam conducted by the project ADB 5712-REG have shown that coastal communities do not consider protected areas important. In fact, they are very important. This indicate that marine biodiversity are of high value, natural resources proliferate and bring economic benefits either directly or indirectly. Moreover, low priority is given to protected areas, meanwhile, high priorities are given to marine biodiversity and indicate that basic foundation to maintain, strengthen and expand protected areas in Vietnam is economically-based foundation, not only based on the value of biodiversity.

At the same time, tourism activities are quickly developing in coastal zone which included existing or proposed protected areas. Cat Ba, Nha Trang, Con Dao and Phu Quoc together with islands in Ha Long Bay which is approved as the World Heritage are important areas where tourism activities are being developed. Tourism can play an important role in developing coastal areas of Viet Nam.

However, complicated matters still remain. Natural resources restocking in marine waters and coastal waters of Viet Nam are not in good conditions and being threatened by many factors, including over-exploiting, changing land- use methods and by polluting. In the existing protected areas system, there are great faults, especially of wetland environment, marine and coastal environment. Except some protected areas, Viet Nam lack of a program for marine/coastal protected areas. National Parks such as Cat Ba and Con Dao recommended their marine areas be protected and be recognised as such recently. Even so, these recommended-protected marine areas should be expanded to cover important marine habitats. Now, on theory, only part of coastal/marine natural resources of Viet Nam are considered in the existing protected area system.

There is a close relation between Marine/ Coastal Protected Areas with the matter of economic development in coastal areas. The matters like difficulties/ constraints are also clear and need to be addressed as follows:

- Biological basis is not strong for the planning of protected area system
- Low financial investment for MPA system
- Low capacity of planning, establishing and managing protected areas
- Legal frame, policies for protected areas in Viet Nam need to be completed
- The matter of developing and improving livelihoods for communities
- Awareness of communities and of managers on conservation
- Existing capacity and managing situation at established Protected areas or to be established.
- The matter of maintain sustainable activities of protected areas.

The challenge is to maintain, manage and reform important habitats on biodiversity which play a key role to the local and national economy, especially important protected areas, both in conserving biodiversity and coastal communities whose welfare and sources of income relied upon marine environment. Investment in conserving biodiversity in Viet Nam can be and should be considered as important steps to ensure the economic stability at coastal areas and stimulants for better improvement activities of the environment quality, meanwhile, establishing a conserving community and a more well-informed people who in reverse support natural conservation activities.

The histories of the Protected areas in Viet Nam are deemed to start from 1986 when natural reserve areas with priority-given ecosystems (mangroves) were established in Ca Mau, Bac Lieu. Then, National Parks such as Cat Ba, Con Dao were established and, step by step, they include waters around islands. Together with WWF – Indochina, the Oceanographic Institute took the initiatives in the research of the potential of biodiversity in accordance to the guidelines to establish marine protected areas in some marine waters during 1993-1995. After that, with the investment of the National Centre of Science and Technology, the Oceanographic Institute continued to build up scientific basis for plans under current preparation. Some realistic activities in line with guidelines for marine conservation are being carried out at marine/ coastal protected areas like Con Dao, Phu Quoc, etc.

The project ADB 5712-REG (phase 2) recommend a national system consisting of 30 marine/coastal protected areas. The management of 6 of them need to be strengthened. Eight of them need expanding and management need to be increased. 6 of them are newly established. Nowadays, the Vietnamese Government consigned Ministry of Fisheries (MOFI) to make a plan to develop marine protected areas. The results of marine parts of the project ADB are incorporated into this plan. 15 areas are listed with the ecosystem given priority to such as coral reefs and seagrass beds. One area in Spratly is also brought into the plan. With the sponsor of Global Environment Fund, DANIDA and Vietnamese Government, the Hon Mun Pilot Project and Cu Lao Cham MPA have been operating in accordance to the strategy of marine conservation. At local levels, provinces and cities also started to prepare protection plan and managing their coral reefs. The model of coral reef management with various objectives is applied to coral reefs in Ninh Hai district, Ninh Thuan province in order to resolve the conflicts between economic stakeholders in using and conserving the local reefs. The plan to establish “no-take” zones or sanctuaries with small-scales is being made in Ninh Hai (NinhThuan) and in Van Phong Bay. However, they are only first-step pilot models in order to seek out effective measures in reaching integrated managing of coral reefs in particular and of marine protected areas in general in a sustainable way.

The next step towards developing more specific legislation for MPAs has been taken by MOFI through the development of Draft Regulation on Marine Conservation Area Management (2000/QD-TTg). This regulation stipulates the general provisions and regulation for MPA management and includes a short definition of three proposed categories for marine conservation areas (i.e., Marine National Park; Habitat/species protected areas and Marine Resources Management Areas). It also provides guidance for formation of MPA Management Board and identifies mechanism for State management MPA. The regulation provides also the basis for establishing a broader national legal framework for MPAs.

Following this draft regulation, the Ministry of Fisheries is responsible for the management of MPAs including: Development of legal documents and policies related to the establishment of MPAs (official approval is obtained through the National Assembly); Development of programs and project proposals to expand the system of MPAs; Establishment of management boards for MPAs under the direct management of MOFI; Publicity, training and professional development for marine conservation.

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The next step towards developing more specific legislation for MPAs has been taken by MOFI through the development of Draft Regulation on Marine Conservation Area Management (2000/QD-TTg). This regulation stipulates the general provisions and regulation for MPA management and includes a short definition of three proposed categories for marine conservation areas (i.e., Marine National Park; Habitat/species protected areas and Marine Resources Management Areas). It also provides guidance for formation of MPA Management Board and identifies mechanism for State management MPA. The regulation provides also the basis for establishing a broader national legal framework for MPAs.

Following this draft regulation, the Ministry of Fisheries is responsible for the management of MPAs including: Development of legal documents and policies related to the establishment of MPAs (official approval is obtained through the National Assembly); Development of programs and project proposals to expand the system of MPAs; Establishment of management boards for MPAs under the direct management of MOFI; Publicity, training and professional development for marine conservation.

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