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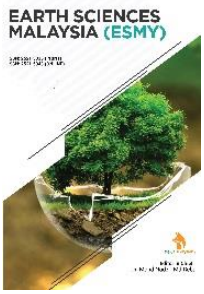

RESEARCH ARTICLE

AN EXPLORATION OF LAND ZONING OF CORAL ISLAND OF BANGLADESH FOR REDUCING THE VULNERABILITY OF CLIMATE CHANGE

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ABSTRACT

Saint Martin is an only tropical island of Bangladesh having coral and adjacent rich biodiversity which is built of organic material derived from associate organism of coral ecosystem. Present study was conducted to developed the exclusive zoning plan that based on the specific goal of managing natural resources of St.Martin's island. . The authors mentioedn that it is important to recognize that the current zoning plan is based on the assumption that conservation and sustainable use of natural resources are the primary objectives. This is found that climate Change is now affecting the biodiversity of ST. Martin island and coral reef diversity hampering due to vulnerability of environmental degradation and climate change. The authors mentioned that, participation and involvement of island inhabitants should required to prime concern for successful implementation of the effective zoning management plan. Desired level of usage can be achieved through interventions, but only in consultation and active cooperation and participation with local communities, with a clear recognition that additional environmental, biological, socioeconomic and sociopolitical data are required for an effective management and conservation of corals and other marine biodiversity of St. Martin's island through proper implementation of zoning and Marine Protected Area.

KEYWORDS

St. Martin island, Coral reef, Island inhabitants, Climate change, Zoning plan, Marine protected area.

1. INTRODUCTION

Zoning is an important component of Marine Protected Area (MPA) management plans, since it defines the purposes for which a protected area may be used . Zoning is considered an integral part of future management plans for St. Martin's. Island, Bay of Bengal, Bangladesh .Since it is an effective management tool enabling the physical separation of conflicting uses and the establishment of varying levels of protection of natural resources (OECD, 2016; Islam et al., 2017; Ninawe, 2017; Sarker et al., 2018; Sarker et al., 2019)

Bangladesh belongs to the one of the largest coasts (710 km long) in South Asia, including Cox's Bazar beach and St. Martin's Island in the locality of the Bay of Bengal. The livelihoods of the communities of these areas are based on the coastal resources, especially marine fish. Nevertheless, the inhabitants is deprived compared to the in land dwellers in terms of education, employment and medical advances. They are deprived of proper economic growth due to increased population, loss of employment and income from only specific period of time, tourism season; this problem often worsens due to climate change induced natural hazards that left the inhabitants with nearly no definite alternative source of income, and the locals also suggested for secondary livelihood with the present forms are essential for the coastal communities. What to do to improve their economy needs to be sought out and socio-economic assessments are required to ensure sustainable development and improvement of the community (Chowdhury et al., 2011; BOBLME, 2015; Shamsuzzaman et al., 2016; Barua et al., 2017; Mohammad et al., 2017; Islam and Shamsuddoha, 2018)

St Martin's Island a small island in the northeast of the Bay of Bengal, about 9 km south of the Cox's Bazar-Teknaf peninsular tip and forming the southernmost part of Bangladesh. It is about 8 km west of the northwest coast of Myanmar at the mouth of the river Naf. The island lies between 92°18′ and 92°21′E longitudes and 20°34′ and 20°39′N latitudes. The local people call it '*Narikel Jinjira*'. It is almost flat and is 3.6m above the mean sea level. The 9.66 km wide channel between the mainland and the island is much shallower than the open sea southwest of the island. There are reefs from 10-15 km to the west-northwest.

Coral reefs are the most miscellaneous of all marine ecosystems. They are loaded with life, with perhaps one-quarter of all marine species depending on reefs for food and shelter. This is an extraordinary statistic when you

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consider that reefs cover just a tiny portion (less than one percent) of the earth's surface and less than two percent of the sea bottom. Because they are so diverse, coral reefs are often called the rainforests of the sea. Coral reefs are also very important to people. The value of coral reefs has been estimated at thirty billion dollars and almost as much as 172 billion U.S. dollars annually, providing food, protection of shorelines, jobs based on tourism, and even medicines (Dr. Nancy Knowlton, 2018).

Coral communities extend to about 200 m offshore of Saint Martin's Island. Corals are found around most of the Island, but their abundance and cover is generally low. Based on limited quantitative data from quadrate surveys of the south-east around Cheradip, where corals are more abundant than in other areas, the density estimate of corals is 1.3 colonies/m2. In this area, corals cover 7.6% of the rocky substrate (Paul M. Thompson P. M., 2010). The variety of the coral community on Saint Martin's Island can be classified as low with low species supremacy, meaning that no species dominates. The most recent data on the corals of Saint Martin's Island is from a 1997 survey, which estimated that 30,000 coral colonies are removed annually, representing 24% of the existing population then (Thomascik, 1997). Removal of coral was persistent since so we can easily assume that the current condition of coral at the site is very reduced.

Marine Protected Area (MPA) status for *Narikel Jinjira* has a potential to make a significant contribution to the conservation of coral and other marine resources and to meet a range of other community objectives. The need to establish a MPA on *Narikel Jinjira* was recommended in a draft document produced by the National Conservation Strategy (NCS) Secretariat (under the auspices of the Ministry of Environment and Forests, Government of the Peoples Republic of Bangladesh) with assistance from NORAD and IUCN during Phase II (1986-1992) (Shamsuzzaman and Islam, 2018; Hossain et al., 2015; BOBLME, 2015; Javed and Chakraborty, 2017; Islam, 2011; Sharifuzzaman, 2014).

First 1997, Tomascik conducted a survey to make an assessment on the status of marine biodiversity including coral resources in Narikel Jinjira and to identify major environmental (natural and anthropogenic) threats to the future sustainable use of these resources. Though there was a zoning proposal, considering the different areas with its habitat, significance etc. in a govt. project described by Tomasik(1998) but unfortunately no implementation of that zoning were done for protection & conservation of flora & fauna of this important island. Similarly no conservation strategy were taken for St. Martin's-the only coral belonging island in Bangladesh, though it has been declared as "Ecologically Critical Area (ECA)" by the Bangladesh Government in 1997 (Nafi, and Ahmed, 2017; Javed and Chakraborty, 2017; BOBLME, 2015; Islam et al., 2012).

Coral reefs are very vulnerable for ecosystems.'(Pratchett et al. 2009) suggests In no other ecosystem does the major habitat-forming organism function so close to their upper thermal limit.' 'Burke (2011) found that 'by 2011, 19% of reefs had been lost and 75% were threatened.'Coralsunder water in Saint Martin's island are being damaged and destroyed by global warming, unplanned tourism and over exploitation. For last 12 years due to indiscriminate human interference, destructive development, pollution and tourism etc, there were huge degradation of the natural quality of the St. Martin's Island, its rice marine flora and fauna, which include corals, coral associate fishes, shells, mollusks , turtles, algae, seaweed and other valuable resource. So, the above activities have an adverse impact on the flora and fauna of St. Martin's Island and that views also supported by different authors on their reports, news and publication on the destruction of St. Martin's Island and its coral resources. Different recent report also alarming that if not proper conservation strategy taken for St. Martin's Island immediately, this island may not be a "Coral Island" in near future (Bhuyan et al., 2019; Nafi, S.M. and T. Ahmed, 2017; BOBLME, 2015 ; Islam et al., 2012; Islam and Thomson, 2010) . Realizing the importance and significance of St. Martin's Island and its rich biodiversity and the urgency for the conservation of this resources, the present study conducted for zoning plan is proposed as a key tool for the management of *Narikel Jinjira* as a marine protected area. This plan identifies a range of purposes for the protected area designation, and provides a clear rational for thezoning of different area and resources based on the present study. The purpose of zoning is to protect the St. Martin's Island "MPA" from the so called unplanned development activities and pressure from over exploitation of the natural resources. It is very important part of the conservation plan of St. Martin's Island to conserve and restore biodiversity of the entire MPA.

2. Materials and Method

2.1 Location of the Study Area

The St. Martin's Island is roughly dumbbell shaped, approximately 7 km long and 500 m wide at its broadest point. It is almost flat and is 3.6 m above the mean sea level. Total Island area is about 600 hectors or 6 miles. The north side of the Island is mainland of Bangladesh; to the North-south cost is Myanmar and Open Sea in the west. Though St. Martin's Island until recently been considered by the scientific and conservation community as the only "coral Island" of the county, however recent studies have revealed that the island itself is a sedimentary Island, consisting of continental base rocks, where coral communities have colonized due to favorable ecological conditions (DoE, 1999). It is locally known as "*Narikel Jinjira dwip*". According to the geologist, this Island was formed due to an up thrust of ocean floor along with the upliftment of the overlying shale and sand stones during the period of the formation of the hills of Arakan and Chittagong region about 125 million years ago. Tomascik (1997) believes that there is a submerged reef on the south and southeast of St. Martin's Island and presumed that this reef is the western extension of the Malaysian sea coast. Beaches of this small island fringed with coconut palms and bountiful marine life. Large areas of sand dune, some mangrove formations, *Pandanus* vegetation and scattered boulder, dead corals are the major characteristics of this island (Figure 1).

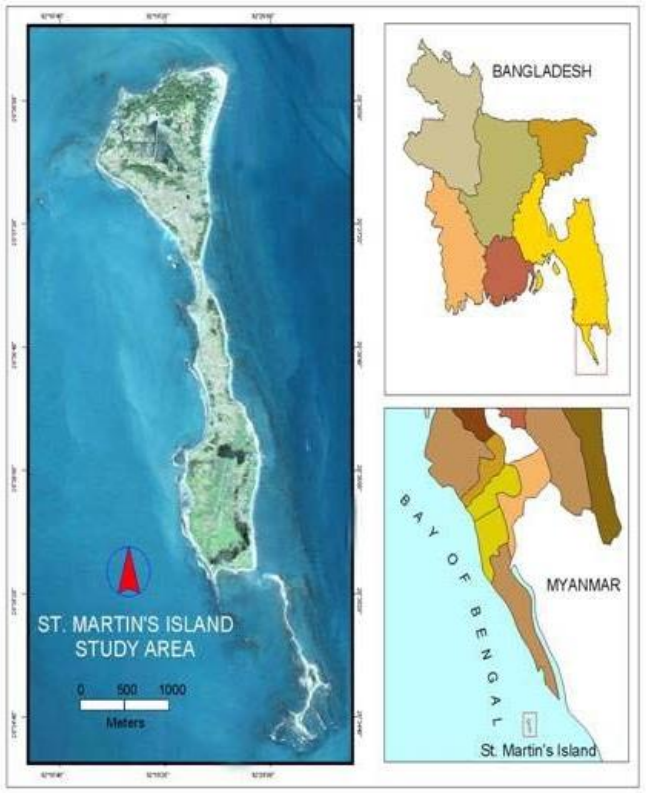

Figure 1: Shows the geographic locations of the St. Martin's Island

2.2 Geomorphology of St. Martin's Island

A cluster of smaller islands encircled the St. Martin's Island. The island is mainly divided into six parts:-1) *Uttarpara* or Northern part, 2) *Dakhinpara* or Southern part, .3) *Maddhyapara* or Middle Part, 4) *Purbapara* or Northern Part, 5) *Paschimpara* or West Part and 6) *Siradia*. The northern part is called *Purbapara* or Northern Part and is 2,134m long and 1,402m wide. The southern part is known as *Dakhinpara*, which is 1,929m long, with a narrow tail of 1,890m towards the southeast and a maximum width of 975m. *Dakhinpara* is about 7ft above sea level. A narrow central belt or *Maddhyapara* or Middle Part connects the two parts. The length and width of this belt are about 1,524m and 518m respectively. *Maddhyapara* is about 1.2km long and about 350m wide. The total area of the *Purbapara* or Northern Part is 2.5km. It is 1.5km wide. Western part of the St Martin area is 2km. It is 1.5 km wide. In addition to the main island there are a number of tiny islets ranging from 100 to 500 sq m, which are locally known as Chheradia or *Siradia*, which means separated island. *Siradia* is about 400m long and 90m wide during high

tides and it separated from the northern islet during low tides, narrow sandy bridges connect these. The size of the *Siradia* island is now much reduced and its shape has been changed.

2.3 Zoning Mapping Analysis

The authors applied following methodology for developed the zoning mapping of St. Martin's Island during the present investigation:

(a) Recognizing the primary objectives of the proposed protected area on *Narikel Jinjira*.

(b) Assessment of activities requiring separation into different zones.

(c) Selecting specific criteria to evaluate different areas of N*arikel Jinjira* for different activities.

(d) Based on above criteria, survey of proposed area:

(i) Natural resource base

(ii) Socio-economic

(iii) Assessment of threats to coastal and marine ecosystems and the natural resource base.

(iv) Identification of protected area sites using selected criteria(v) Quantitative analysis: Scuba was used to obtain a quantitative assessment of coral communities on the south-east part of the island. Two standard techniques were used (i.e.; the Liner Intercept Method and the Quadrate Method) to obtain information on coral community structure. The seaward boundary of the rocky (boulder) intertidal along the east and south part of the island was determined by using GPS.

(v) Mapping: It is important to recognize that the current zoning plan is based on the assumption that conservation and sustainable use of natural resources.

(vi) Proposed zoning plan : On the basis of present study (2015), a zoning plan is proposed as a key tool for the management of St. Martin's Island as a marine protected area. The zoning system consists of: 1) General use zones, 2) Buffer zones, 3) Coral appreciation area, 4) Coral reserve, 5) Turtle nesting reserve and 6) Coral sanctuary

3. Results and Discussion

There are five zones identified which are; (a) General use zone, (b) Eastern buffer zone, (c) Western buffer zone, (d) Turtle nesting zone (e) Coral sanctuary. In 1997 a study on "Management Plan for Resources of N*arikel Jinjira* (St. Martin's Island)" was done by Tomascik, where he reported four identified zones which were; (a)General use zone, (b) Buffer zone, (c) Coral application zone and (d) Coral sanctuary. But in that report no restricted or separate nesting zone was shown for endangered marine turtle. Similarly there are no detail study was done on zoning for showing the sensitive floral and faunal abundance, habitat and significance of those zones.

In the recent years, there is a huge change in the natural resources of the St. Martin's Island due to the indiscriminate human interference, destructive development, tourism and pollution. For this reason the present survey (2015) indicate different zoning proposal than the zoning proposed by Tomacsik (1997). In this present zoning plan (2008), it describes about the delineation, description, justification, function and restriction of all particular zones which are very important for the proper conservation and sustainable uses of the natural resources of this island. Tomacsik zoning map (1997) and the changes occurs during the following years can be seen below in the proposed zoning map of St. Martin's Island based on the present study(2015) (Figure 2 and 3).

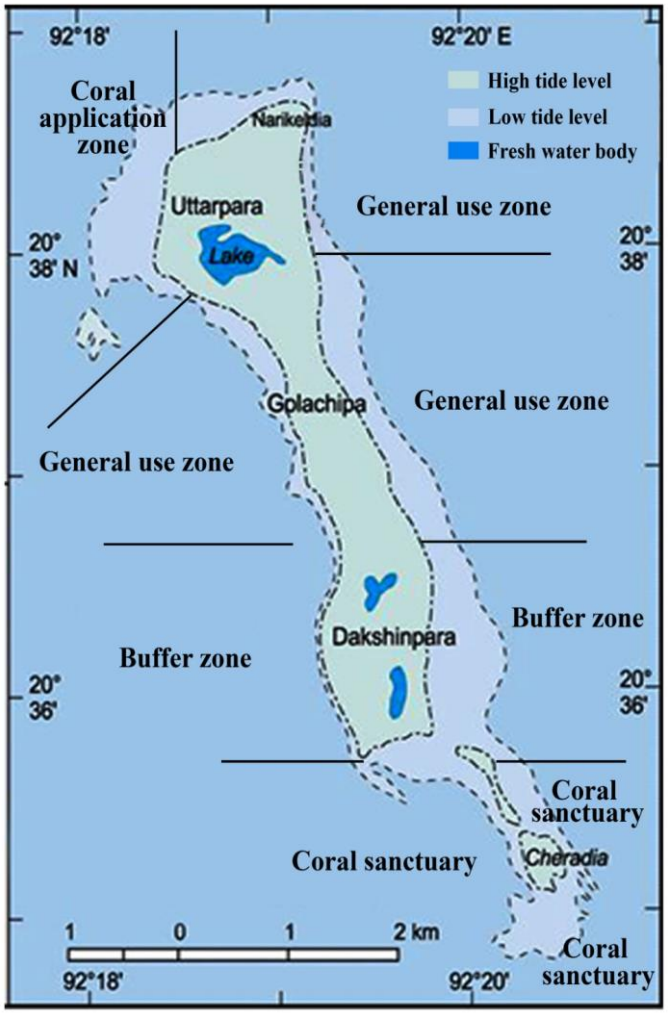

Figure 2: Zonation of the St. Martin's Island proposed by Tomacsik (1998)

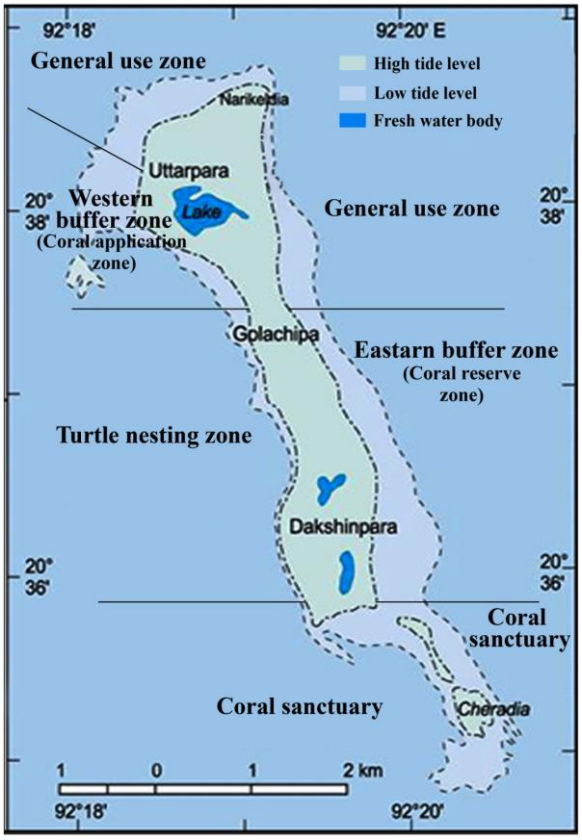

Figure 3: Zonation of St. Marin's Island proposed by the Present Study (2015)

All proposed zone's delineation, description, justification, function and restriction are described below based on present study (2015):

3.1 General Use Zone

All coastal areas outside the designated protected areas fall into the General Use Zone (GUZ) category. The primary function of GUZ is to allow traditional uses to continue without restrictions being placed, other than illegal activities such as fishing with SBN net or use of poisons. Considering the relatively low abundance of large boulder reef fish predators (e.g., groupers),and in view of future tourism development, it is strongly recommended to legislate prohibition of commercial fishing and fishing through use of band current net (SBN) within 1 km of *Narikel Jinjira* coastline. Northern section of island including all areas of northern zones. Corresponds exactly to Tomscik's north general use zone including the mangrove patch at the south western corner at the mainland and weed meadow off the south eastern coast of the mainland, mostly to Tomascik's eastern general zone (Figure 4).

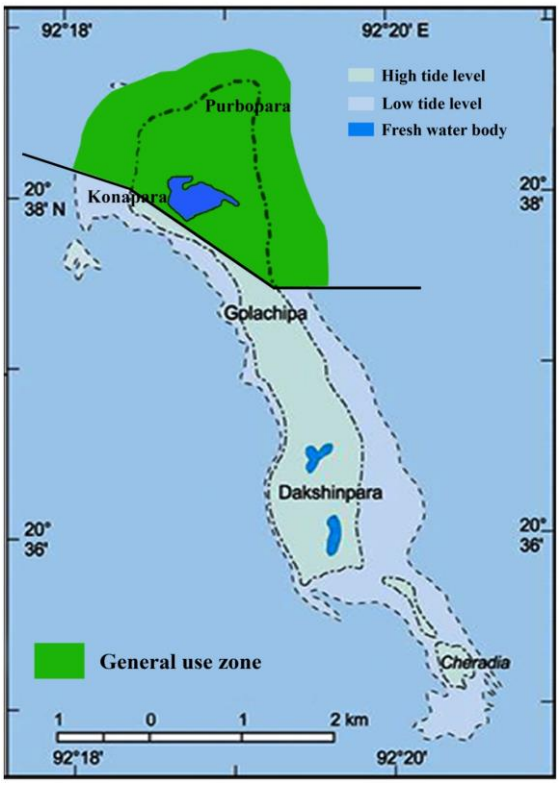

Figure 4: Proposed General Use Zone based on the present survey(2015)

3.2 Buffer Zones

The buffer zone offers continuation of traditional or established uses and activities as long as they are not damaging to the environment and incompatible with management objectives. The buffer zone provides protection to the core areas (coral and turtle sanctuaries), by limiting access and implementing strict controls through regulation of all destructive uses to protect the core zones. The two proposed buffer zone extend along the east and west coastlines. There are (a) Eastern Buffer Zone (b) Western Buffer Zone

3.3 Eastern Buffer Zone (Coral Reserve Zone)

The "Coral Reserve" is the primary target area for the initiation of ecotourism on the island. Training and financial assistance to those interested in setting up ecotourism oriented businesses should be provided. Micro-credit or other financial facilities should be established on the island and not in Teknaf or Cox's Bazar. Human resource development will be essential. Retraining program for current coral and shell collectors in the area should be conducted through the assistance of the local NGO. Retraining should focus on snorkeling guides and glass bottom boat operators. SCUBA diving in the area is feasible due to it's sheltered location and relatively good visibility (Figure 5).

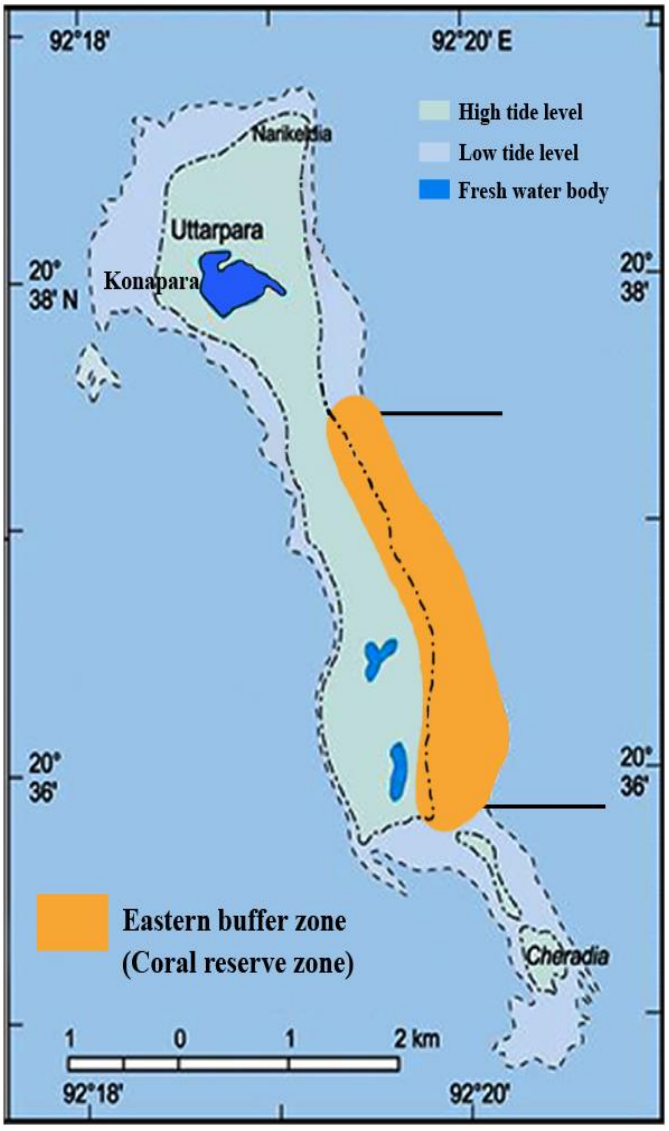

Figure 5: Proposed Eastern Buffer Zone (Coral Reserve Zone) based on the present study (2015)

It should also be fully recognized that while ecotourism potential of *Narikel Jinjira* is relatively good, development of *Narikel Jinjira* as an international SCUBA diving destination should be subordinate to national needs. Even though *Narikel Jinjir*a coral communities are relatively unique, they and the general environment of *Narikel Jinjira*, cannot compete with well developed world-class diving destinations such as the Maldives. Some of the main criteria used to assess areas as potential SCUBA diving destinations are: 1) Presence of coral reefs; 2) presence of unique underwater features (e.g., caves); 3) presence of unique biota; 4) clear water; and 4) accessibility. None of these important criteria are met by *Narikel Jinjira*.

3.4 Western Buffer Zone (Coral Appreciation Area)

Located within this relatively large area is a lagoon of significant conservation and ecotourism value. It is recommended that this lagoon should receive a higher degree of protection than the "Coral Appreciation Area". Attractive activities such as collection of corals, shells and fish should be excluded from this zone to allow public to view corals and coral associated fish relatively undisturbed by human activities. Collection of inter-tidal mollusks may be allowed under strict regulation (Figure 6).

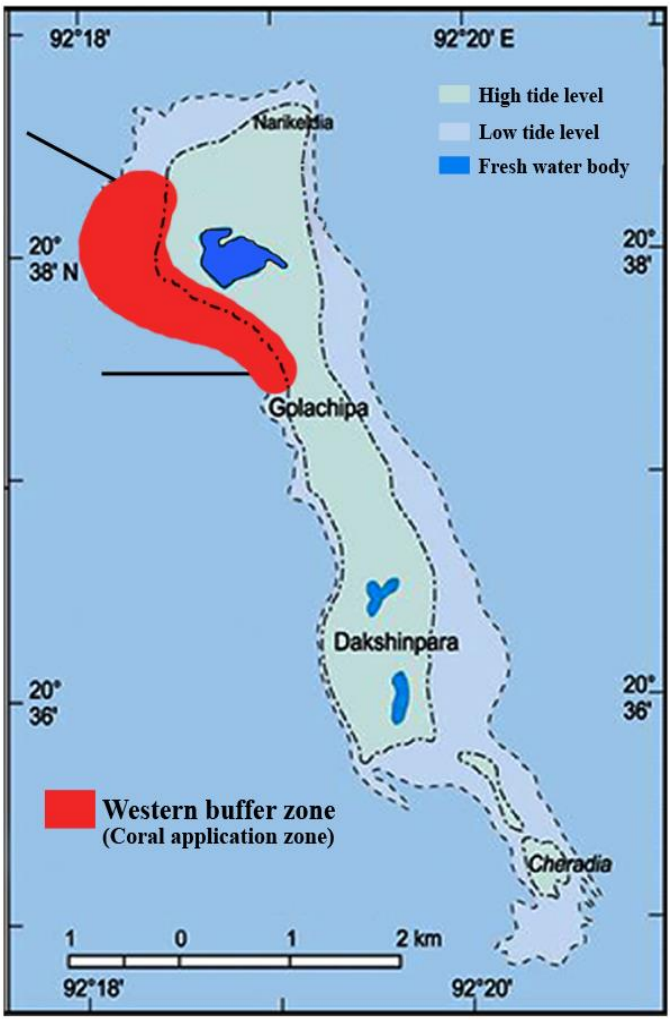

Figure 6: Proposed Western Buffer Zone (Coral Appreciation Area) based on the present survey (2015)

The lagoon is well protected from the weather during the dry season which will allow for safe snorkeling, SCUBA diving and the use of glass-bottom boats. The area of the "Coral Appreciation Zone" that surrounds the "Coral Reserve" will serve as a buffer zone. The desired level of use can be achieved through:

1. Use of license or permits to restrict the number of people entitled to operate in the area;

2. Enforcing closure during parts of the year critical to the life histories of Economically important species;

3. Setting size limits for economically important species;

4. Setting maximum permissible limits on catches of all economically important species;

3.5 Turtle Nesting Zone

Located within the western buffer zone is an important turtle nesting beach. This area should have a special status since it supports the only turtle nesting beach which is still being used by the Olive Ridley turtles. Due to it's scientific value as well as to the presence on endangered species (i.e., *Lepidochelys olivacea*) it is recommended to designate this area as the "Turtle Nesting Reserve". All interference with nesting turtles and collection of eggs, or killing of turtles, should be legally banned. The proposed Turtle Nesting Reserve corresponds to IUCN Habitat/Species Management Area, which is a protected area managed mainly for conservation through management intervention. The objective of the Turtle Nesting Reserve on *Narikel Jinjira* is to secure and maintain turtle nesting habitat conditions necessary to protect marine turtles and the beach/dune ecosystem by human interventions for optimum management. The Turtle Nesting Reserve will also facilitate scientific research, and offer opportunities for limited ecotourism development. The proposed Turtle Nesting Reserve includes the bay on the west coast of *Dakhinpara* where most of the Olive Ridley turtles are nesting. The area is judged to have high scientific and ecotourism value. Management plan for the reserve needs to be developed with strong community participation. Egg collection will be prohibited. Limited access to small guided tours will be allowed to generate funding for the self maintenance of the area. Local people should be trained and used as guides and guards with the assistance from the local NGO group. No fishing or other attractive activities will be allowed in the offshore waters within 500 m of the lower inter-tidal (Figure 7).

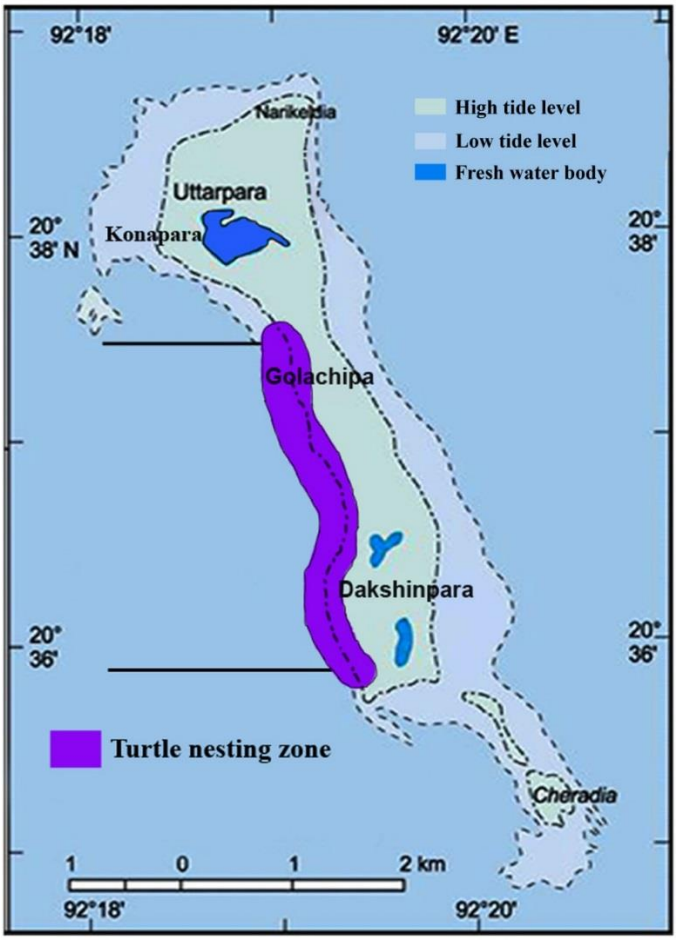

Figure 7: Proposed Turtle Nesting Zone based on the present survey (2015)

3.6 Coral Sanctuary

The areas of highest conservation value are usually designated as "sanctuaries", or the "core zones" in zoning plans. Sanctuaries, more or less, correspond to IUCN Strict Nature Reserve/Wildlife Area (i.e., Category I), which are protected areas managed mainly for wilderness protection and scientific research (Figure 8).

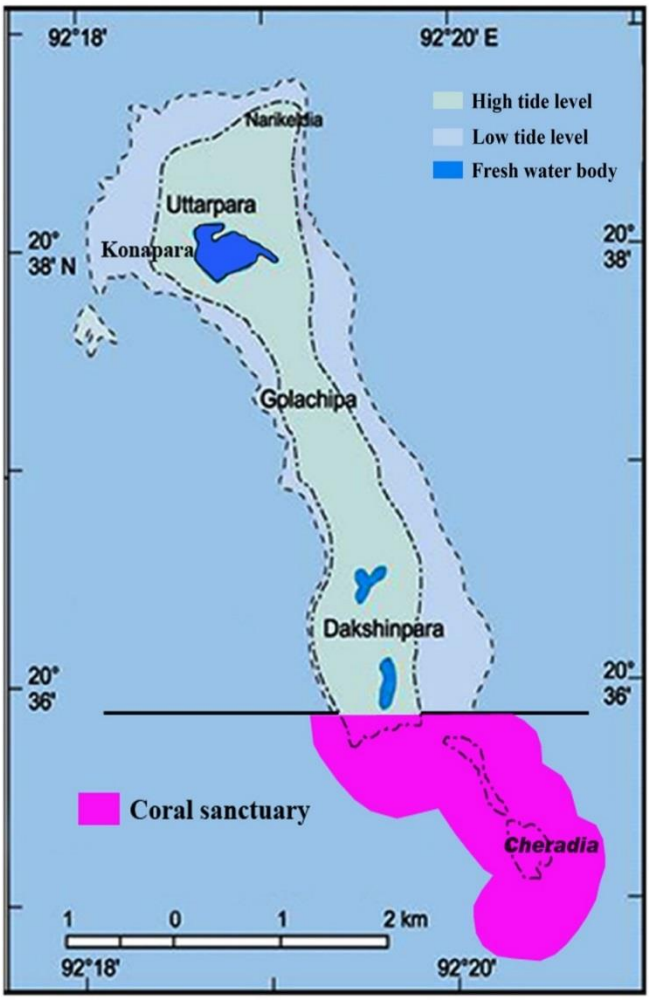

Figure 8: Proposed Coral sanctuary based on the present survey(2015)

1) Conservation of critical spawning stock biomass, population stability of exploited populations, intra-specific genetic diversity, natural population age structure, and examples of areas in natural equilibrium and ecosystem balance.The following benefits including core zones in the Marine Park management zoning plans that are relevant to *Narikel Jinjira* are:

2) Provision for research opportunities relating to unexploited or natural populations, areas in natural equilibrium and ecosystem balance, special fishery research areas, minimally disturbed sites, and differences between exploited or otherwise impacted areas and areas no so affected.

3) Provision of stable reference or control sites which if properly designed can be used to evaluate impacts or effects of various management regimes, activities, or threats.

4) Insurance of sustainable harvest by preventing recruitment failure and stock collapse via protection of spawning stock biomass, and maintenance of population age structure and intraspecific genetic diversity.

5) Enhancement of non-consumptive economic activities.

According to Tomacsik(1997), the primary management objectives of core zones are:

• to preserve habitats, ecosystems and species in an undisturbed state as possible;

• to maintain genetic resources in a dynamic and evolutionary state;

• to maintain established ecological processes;

• to safeguard structural landscape features or rock exposures;

• to secure examples of the natural environment for scientific studies, environmental monitoring and education;

• to limit public access.

The following criteria were used to determine the areas on Narikel Jinjira would meet the above management objectives:

1. The area should have the highest relative diversity of habitats, ecosystems and species in the proposed MPA;
2. The area should be large enough to ensure functional integrity of its ecosystems;
3. The area should be significantly free of direct human intervention and capable of remaining so;
4. The conservation of the area should be achievable through protection and not require substantial active management or habitat manipulation.

To include all sub-tidal habitats, the area will extending 1 km offshore from the seaward margin of the lower inter-tidal. Based on the current survey, the area contains highest abundance and cover by corals, as well as the highest diversity of fish. Due to it's remote location, attractive uses are limited. However, due to over-exploitation of corals in the northern parts of the island, coral collectors are now also operating in this area. The area is to be fully protected (i.e., no extraction of any living or non-living objects). Non-destructive scientific research will be allowed.

3.7 Land Use Change

3.7.1 Past land use

Tomascik (1997) describes the past land use of the site. When the Island was first settled in the 1880s it was covered with what has been described as rainforest with an abundance of teak. The community was dependent on the extraction of teak timber, with the first wave of deforestation of the original forest occurring in the 1920s for sale to Burma for house construction and boat building. Later, fishing and agriculture became common professions. A further wave of deforestation began in the 1940s for conversion of land to paddy, including the gradual conversion of the Island's Uttar Para lagoon to paddy fields. Another wave of deforestation of the original forest occurred in the 1980s. The large scale deforestation over the past 150 years eliminated most of the original wildlife and probably significantly affected the shallow -water benthic communities, including the coral.

3.7.2 Present land use

Deforestation : The use of wood for cooking and timber for constructing houses contributes most to the ongoing deforestation of the Island. The daily requirement of fuel wood for a large population (POUSH, 2006a) is large – while many purchase wood imported from Teknaf, poorer families cannot afford to do so. In most cases small bushy plants are used (MoEF, 2001). Another major cause of recent deforestation is the clearing of vegetation including mangrove to make claims on land. Deforestation has led to increased water turbidity and sedimentation, both of which affect coral development.

Agriculture: Agriculture accounts for 116 ha of land use on the Island and homestead gardens for a further 7.4 ha, representing 37% of land use in total (POUSH, 2006a). Farming mainly occurs in the north of the Island (Uttar Para) with the main crops being chilli and watermelon. An indigenous smallbulbed onion variety is also cultivated and a small amount of maize is intercropped with chilli. A small amount of transplanted Aman rice is cultivated in the rainy season. Planted trees, particularly coconut, have replaced the original vegetation. Homestead coconut gardening is an important source of income. Some timber yielding species are also found. Livestock are also raised – 360 cows and 329 goats were recorded in 1996 (Tomascik, 1997), while only 182 cows and buffalos and 219 goats were recorded in 2000 (Islam, 2001). In 2005, 33% of households were reported to own livestock (POUSH, 2006b). Agriculture is causing the ongoing destruction of habitat, especially the clearing of rocky land for cultivation and the filling in of lagoons. Additional problems are the cultivation of exotic and hybrid species and the use of chemical pesticides and fertilisers. The impact of agricultural runoff on the coral resources during the rainy season as a result of increased water turbidity and sedimentation may be considerable (Tomascik, 1997).

Tourism: Thousands of visitors come to the Island, mainly during the good weather season between December and March, and number more than the carrying capacity of the site given the current level of management . Infrastructure facilities are being developed for tourism but in an unplanned way and without any EIA. A major problem resulting from tourism is uncontrolled and inadequate waste management. Untreated sewage is piped directly into the sea, or stored in open ponds, adversely affecting marine and ground water quality. Tourists purchase or collect large quantities of coral and shells, which has resulted in the severe depletion of these species.

Water extraction: Deforestation and large scale expansion of agriculture has impacted on the ground water lens of the Island (Tomascik, 1997). During Tomascik's 1996 survey, one well went dry and some became saline. Freshwater on the Island is available at shallow depths (10 feet) (Islam, 2001) but the needs of the local population and the large annual influx of tourists corresponding with the dry season has created a great demand for freshwater, leading to a drop in the water table. This demand is only going to increase in the near future. Motorised pumps are now used during the peak tourist season to cope with the demand, further reducing the water table level to the extent that the local community have trouble accessing water via tube wells (Islam, 2001).

Marine invertebrate collection: The large scale removal of keystone species from intertidal and subtidal habitats, including mollusk and sea cucumbers is a problem. Shells are extracted from the beach and lower intertidal zone for sale as curios. Of 332 family heads engaged in natural resource exploitation in 2000, almost one fifth were shell collectors (Islam, 2001). Earlier only larger shells were collected but now small shell species are also collected. As the shell resource has become overexploited, live molluscs are now being collected. Sea cucumber is also heavily exploited.

Seaweed harvesting: One species of seaweed is reported to be harvested in large quantities by the local community and traded to Myanmar. Seaweed is normally collected from the beach between February and April and is traded in its dry form, measured by weight. Of 332 family heads engaged in natural resource exploitation in 2000, 32 (10%) were engaged in seaweed collection, and in 2001, 20 boatloads of 2-3 metric tons each were traded (Islam, 2001). Seaweed is important for initiating the formation of sand dunes.

Coral extraction : Commercial coral collection began in the 1960s and is now the professional activity of a few families. Of 332 family heads engaged in natural resource exploitation in 2000, almost one –fifth were coral collectors (Islam, 2001). Coral is collected between October and April when the sea is calm, water is clear and the tides are favorable. The NCSIP-1 survey between 1995-1997 found that at least 11 small non-mechanized boats were being used up to depths of 5 metres, while others that did not have boats walked out up to depths of about 2 meters. A hammer and chisel is used to break the coral. Acropora, Favia and Goniastra spp. were the main types collected with Acropora spp. the most highly sought after. The estimated weight of coral harvested ranged from 40- 100kg/day/boat or about 20-40 kg/day/person. Tomascik (1997, in MoEF, 2001b) estimated that 24% of the existing coral population is removed annually. Most is smuggled to Cox's Bazar to supply the curio businesses there.

Fishing/fish drying: Fishing has a long history at the Island and is the main activity of the inhabitants, with about 600 professional fishermen and 170 fishing boats recorded on the Island in 2000-01 (Islam, 2001). The main fishing season is September to April, during which each boat averages a total catch of about 11 metric tons (MoEF, 2001b). The main fishing gears are drifting, fixed and plain gill nets and the seine net. The fish are caught offshore as well as from coral beds. Fishing in inshore waters over boulder reefs is done with rock-weighted gill nets which has an adverse impact on coral. Most of the fish are sun-dried locally at both the five large fish drying farms existing on the Island and at individual households, and then supplied to merchants in Cox's Bazar and Chittagong. The type and amount of chemicals used during fish processing and the impact of their use on the beach habitat is yet to be determined. Shrimp fry collection is also undertaken at the Island and the fry supplied to the Cox's Bazar shrimp farms' shrimp fry suppliers. Of 332 family heads engaged in natural resource exploitation in 2000, almost 50% were shrimp fry collectors (Islam, 2001). Shrimp fry collection causes the large-scale loss of many other aquatic organisms.

4. Climate Change Vulnerability in St. Martin Island

Global climate change poses a high risk to the biodiversity of coral reefs of St. Martin's. The major threats to the coral reefs are high levels of sedimentation, cyclones, storm surges and beach erosion. Global warming is a matter of major concern for coral reefs of this island as elsewhere.St. Martin is a tiny island in the Bay of Bengal approximately 9 km south of the Cox's Bazar-Teknaf peninsula. It is the the southernmost part of Bangladesh and is locally known as Narikel Jinjira (Coconut Island). St. Martin's Island is a stock of extraterrestrial, marine and land resources. Depending on tidal level the surface area is about 8 kilometres and the beach length is about 14 kilometres. This is the most attractive tourist spot of Bangladesh.

The biodiversity of St. Martin's island is characterised by mangrove forests, seaweeds, corals, turtles, crabs, fish, seabirds, coconut trees and Pandanus vegetation. The island is a unique example of co-occurrence of different ecosystems. Mangroves are home to corals, crabs, sea weeds and sea birds, and provide excellent nurseries for marine fishes. It also protects the inhabitants from the storm surges, cyclones and tidal waves, and prevents the island from erosion.

Screw pine (Pandanus) is one of the iconic tree species of this island. It grows on exposed mainland and along beaches, and has thick 'prop roots' to anchor itself in the loose sand. The island is a congenial habitat of a diverse coral community represented by approximately 66 Scleractinian coral species, of which 19 are fossil corals, 36 are living corals and 11 are soft corals (Tomascik 1997). About 14% area of this island is visited by 3 species of marine nesting turtles including Olive Ridly. All of them are considered as globally endangered by IUCN.

This is also a suitable habitat for different species of multi- colour ornamental fishes. During the year 1997, 240 fish species were recorded from the catch landed on this island and 86 of them are coral associated (Tomascik 1997). The abundant coral associated fishes are Damsel, Parrot, Surgeon, Groupers, Snappers, Emperors and Butterfly fish (Haider 2008). 186 species of mollusc and oyster, 7 species of crab, 9 species of echinoderms, 4 species of sea urchin, 1 specie of sea cucumber, some brittle stars, 5 species of marine mammals, a number of colourful nudibranch and bryozoans, 14 species of algae, 29 reptilian species and 120 species of birds (out of them 53 species are migratory) were recorded at the St. Martin's Island.

4.1 Impact on biodiversity

Coconut trees: Reproductive development of coconut tree is highly sensitive to high temperature and water stress. The fruit set is adversely affected, mainly due to a reduction in pollen viability. The nut development is affected mainly resulting in small number of nuts, empty nuts or elongated nuts.

Mangrove forests: Sea level rise will cause a major threat to mangrove ecosystems through sediment erosion, inundation stress and increased salinity at landward zones. These problems will be exacerbated for mangrove stands of this island due to 'coastal squeeze' (landward migration is restricted by smaller size and human settlements). High rainfall and silts being washed down can also affect mangrove growth weakening its resilience.

Screw pine (Pandanus): Increasing salinity will cause high mortality of Pandanus trees. The removal of Pandanus trees will enhance beach and dune erosion.

Seaweed: Ozone layer depletion will allow a greater amount of ultraviolet rays that can be harmful for seaweeds. UV rays decrease photosynthesis and productivity of seaweeds and directly affect bio-molecules.

Sea-algae : 40% algae population may die due to climate change by the end of this century (Muller 2008).

Coral species: Global climate change poses a high risk to the biodiversity of coral reefs of St. Martin's. The major threats to the coral reefs are high levels of sedimentation, cyclones, storm surges and beach erosion. Global warming is a matter of major concern for coral reefs of this island as elsewhere. The most noticeable damage caused by high sea temperature is coral bleaching. Coral bleaching turns into colourless ugly coral. Coral reefs have already suffered major mortalities as a result of high-temperature events. It is also dependent on a species of algae that lives symbiotically in its body and produces additional food by photosynthesis. When the sea temperature rises above 28°C, the coral expels the algae and consequently it starves.

Turtle: Sea-level rise causes erosion of turtle nesting beaches. Higher sand temperature leads to changes in sex ratios or prevent eggs from hatching. Coral reefs are essential feeding habitats of turtles. Coral bleaching destroys the feeding sources of turtles. Huge rainfall can raise ground water tables, thereby flooding nests of turtles.

Mollusc: Sea acidification will decline the abundance of mollusc.

Crabs and shrimps: Due to sea level rise, the breeding place of crabs and shrimps will be destroyed.

Sea fish: Fishes will lose their habitats with coral bleaching and mangrove destruction.
Seabirds: High sea temperature will affect seabird foraging success, growth patterns and reproductive potentiality. Coral bleaching increases surface temperature, which decreases breeding and populations of seabirds.

4.2 How to mitigate the risk of Climate Change

- To strengthen monitoring of biological resources and impact of climate change for appropriate biodiversity management
- To develop alternative livelihoods for the people who are dependent on coral resources
- To establish an appropriate conservation strategy
- To emphasise the conservation program of coral ecosystem and protection of migratory birds
- To keep the turtle's habitat undisturbed
- To involve NGOs in the conservation program
- To establish an information system of biodiversity of this island
- To strengthen research work on the impact of climate change
- To emphasis ex-situ conservation of endangered species
- To measure the adverse effects of natural calamities, global warming and sea level rise
- To create public awareness by using different media
- To raise funds for conservation program
- To implement ecosystem approach and community based conservation program by involving local people
- To maintain and restore mangroves for reducing erosion
- To establish mechanisms to promote carbon uptake

5. Conclusions and Recommendations

Coral degradation is the talk of the tongue for the ecologists around the world. Many researches have been done on the corals of Saint Martin's and the Island's ecosystem. They have discussed the problems and proposed solutions for those. But implication of those steps are rarely seen. Though Bangladesh Government recently took a step for controlling tourism, it was withdrawn almost immediately.

St. Martin's Island is identified as one of the Environmentally Sensitive Areas in Bangladesh has suffered deforestation thrice in this century. On the other hand the extractable natural resources also depleting very quickly. Government of Bangladesh has passed a gazette notification saying that a marine park will be developed on the island. Based on the environmental data (i.e., surface seawater temperature, salinity and turbidity) collected, it is concluded that natural environmental conditions around Narikel Jinjira are marginal for the development and survival of coral communities, and sub-optimal for the development of coral reefs.

This study should be followed by a one year monitoring program to obtain a better picture of the environmental conditions during the full year cycle. The rainy season is a critical benchmark for environmental conditions and an appropriate environmental monitoring program should be implemented before any large scale development proceeds on Narikel Jinjira. It is, therefore, essential that all future development activities pay close attention to environmental management, and Environmental Impact Assessments (EIA) should be required for all major projects, including tourism development.

The management and conservation activities are not followed properly, where users of the island still haphazardly utilise the natural resources of coral reef. The destruction of habitat and over-exploitation of these resources have resulted in decaling the biodiversity as well as degradation of coastal and island ecosystems. There is lack of awareness among the resource users about the interaction of various coastal components and they do not have enough knowledge about the resource and its importance, utilization and conservation. Studies revealed that in addition to the declaration of ECA by Ministry of Environment, Bangladesh, new scientific studies should be planned for the Saint Martin's Island, since the unique and dynamic nature of the inter-tidal and sub-tidal rocky habitats offers excellent research opportunities for the national and international scientists as a global interest of coral reef biodiversity. At present, there is not much data or information on the present status of corals and associated flora and fauna in St. Martin's. No one is using currently available state of the art technology and no 'Coastal Zone Management Unit' exits in this island. So, proper implementation of the rules and regulations for 'Ecologically Critical Areas (ECA's)', declaration and implementation of 'Marine Protected Area (MPA)' as suggested by Tomasik (1997) and other experts in 'Eco-tourism -- St. Martin's Island', control of pollution, sustainable and controlled tourism, alternative livelihood for the local people, and further research should be immediately undertaken for sustainable utilisation and to save rich biodiversity of this only coral island of Bangladesh. Still there may be time to save the biodiversity and fish resources of this island; otherwise it may be too late. So, all the stakeholders including government policy makers should come forward to save the marine biodiversity of this important island and the livelihood of the local people.

Mass tourism, sewage and waste disposal in the island are the main human activities for coral bleaching. As coral bleaching is an issue that attracts strong interest from the public, the media and decision makers, therefore coral reef managers have to provide up to date information concerning coral bleaching event and its impacts. The main cause for coral bleaching in Saint Martin's island is elevated sea temperatures. Coral bleaching is due to warmer than normal temperatures causing zooxanthellae to become super-sensitive to light (photoinhibition). With the global temperatures rising due to climate change, coral bleaching events will occur more frequently. Coral reefs are also threarened by the changes in alkalinity of sea water by rising sea levels. The reefs of Saint Martin's island face a large amount of stress, making them less and less resilient to a coral bleaching event. The coral reef may be dysfunctional within the near future. Saint Martin's is very dependent on its reefs. Thismakes it important to be prepared for a bleaching event and to have a Coral Bleaching Response Plan.

For the conservation of biodiversity in the St. Martin's Island the following rules, regulations, policies and management strategies, the authors recommended following actions should be required by the relavant stakeholders:

- Strengthen socioeconomic monitoring of reef resources to provide information appropriate for coral reef management;
- Improve evaluation of reef fisheries and identify and develop viable alternative livelihoods for those dependent on threatened reef resources;
- Accelerate the establishment of the national network of nature conservation and reserved, protected areas that include a full range, type and level of biodiversity and which will have a reasonable distribution and appropriate area coverage;
- Strengthen infrastructure and capacity for resource management, primarily targeting marine protected areas;
- Strengthen the capacity to develop and implement regulations relating to resource extraction;
- Conservation of special habitats and eco-systems such as hill forests, wetlands, mangrove ecosystems, coral reef ecosystems as well as the protection of migratory animals and birds;
- Each person visiting the island brings in additional issues to be taken care of like drinking water, sewage, solid waste, food, accommodation, etc.
- Restrict tourists to go out and walk around the island after 2000 hrs since 2000-0200 hrs is the nesting period of sea turtles;
- Establish a national information system for the conservation of biodiversity. A national biodiversity database may be established which will include nature reserve database, an ecologically critical area database on rare and endangered plants and species;

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