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Economic valuation and conservation, restoration & management strategies of Saint Martin's coral island, Bangladesh

Seema Rani [a,b,c], Md Kawser Ahmed [c], Xue Xiongzhi [a,*], Jiang Yuhuan [b], Chen Keliang [b,**], Md Mynul Islam [d]

[a] Coastal and Ocean Management Institute (COMI), Xiamen University, Xiamen, China
[b] Third Institute of Oceanography (TIO), Ministry of Natural Resources, Xiamen, China
[c] International Centre for Ocean Governance (ICOG), University of Dhaka, Dhaka, 1000, Bangladesh
[d] Institute of Statistical Research and Training (ISRT), University of Dhaka, Dhaka, 1000, Bangladesh

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ABSTRACT

Tropical coral reefs render a large number of ecosystem services, although without sustainable use practices and conservation measures over the last couple of decades many tropical coral reef ecosystems have been damaged because of excessive use of reef resources. This study provides an estimation of economic benefits from both direct and indirect use of Saint Martin's Coral Island resources, one of the ecologically critical areas (ECAs) of Bangladesh. The coral reef and the associated habitats of St. Martin's Island contributes 33.6 million USD/year to the local economy from fishing, tourism, shoreline protection, seaweed culture, and gathering of intertidal shellfish. Tourism and fisheries are the major economic sectors, generating annual direct use values of 19.4 million USD and 13 million USD/year respectively. The indirect use value of shoreline protection is estimated to be about 180,000 USD/year. Economic benefits of around 1 million USD, could also be generated from an entrance fee collected from tourists visiting the island. The net present value (NPV) of benefits from all of the resources of Saint Martin's Island over a 25-year time frame, with a 6.5% discount rate, is about 545 million USD. A coupled socio-ecological-political, restoration and management framework is recommended. The government should come forward with a conservation, restoration and management plan so that the framework could be used for the management and restoration of a degraded coral reef ecosystem.

1. Introduction

Coastal populations living near coral reefs rely on reefs for their sustenance and livelihood. More than 100 nations have coastlines fringed by coral reefs and almost half a billion people live near reefs (Bryant et al., 1998). Coral reefs provide opportunities for income and employment through fishing, recreation, and other extractive industries, such as live reef fish for the aquarium trade, and coral mining. Although coral reefs make up less than 1% of the global sea surface, they host an assortment of marine creatures and provide many ecosystem services, valuable to humans (Thur, 2003). A single reef may host around 200 species of coral, 300 species of fish and 10,000 to 100,000 invertebrate species (Cesar, 2000). Coral reefs provide ecosystem services such as aiding land formation, coastal protection and recreation. Coral reefs also have many important ecological functions, both within and between ecosystems. They provide spawning and breeding grounds and nurseries for many marine organisms, providing physical and biological support to other ecosystems such as mangroves, seagrass beds and the open ocean (Moberg and Folke, 1999).

Saint Martin's is the only place where coral grows in Bangladesh. In recent years the island has become one of the most popular tourist destinations in country (The Daily Star, 2019). Kamruzzaman and Uchinlayen (2018), found that factors like natural beauty, service quality, adventure and relaxation opportunities are the attractions that draw tourists to Saint Martin over other destinations. The island annually attracts hundreds of thousands of tourists due to its spectacular land and seascapes, as well as coral colonies in crystal clear water (Thompson and Islam, 2010). The rocky sub-tidal habitat from the seaward margin to about 1000 m offshore, supports a diverse coral community represented by approximately 66 scleractinian coral species, of which 19 are

* Corresponding author.
** Corresponding author.
E-mail address: xzxue@xmu.edu.cn (X. Xiongzhi).

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fossils, 36 are living and 11 are soft corals (Tomascik, 1997). A total of 234 species of fish has been recorded from the coastal water of the island of which 16 are fresh water species 89 coral associated of which damsels, parrots, surgeons, groupers, snappers, emperors and butterfly fish are the most abundant. 186 species of molluscs and seven species of crab are reported. There are five species of marine mammals in the sea surrounding the St. Martin's Island which are globally threatened according to the IUCN Red data book. The island is an important nesting ground for olive ridley turtles one of the three globally endangered marine turtle species. 29 reptilian species have been recorded of which 11 are locally threatened (The Daily Star, 2016). 112 species of birds, belonging to 36 families in 15 orders are listed. Of these, 37 (33%) were passerine and 75 (67%) non-passerine. 80 species (71.43%), were found to be rare (Sultana et al., 2018). Pacific Reef Egret, is occasionally recorded on dead coral in Chera Dwip, the southern tip of the Island (The Daily Star, 2016). The grey heron can only be found on the southern part of this island, where there are live coral colonies.

Many studies show that the coral reef health is declining globally, which has created serious problems for humankind and the environment (Jones et al., 2004; Bryant et al., 1998; Hodgson, 1999; Wilkinson, 1999; Souter and Lindén, 2000). Consequently, an increased number of coral reef restoration projects have been developed globally (Rinkevich, 2005). The rate of decline of corals in MPAs, even those that are actively managed, is slower than in nearby areas that are not managed at all (Jones et al., 2004; Bruno and Valdivia, 2016). However, a review of thirty reef conservation projects around the globe, revealed that only half of them had achieved a significant benefit and success while others showed limited or no success (Baine, 2001). Concerns over the health of the world's coral reefs has translated into protection and conservation actions at local, national, and international levels. There are some international level agreements and initiatives, such as: The International Coral Reef Initiative (ICRI), Global Coral Reef Monitoring Network (GCRMN), the Convention on Biological Diversity (CBD), and the Convention of International Trade in Endangered Species of Wild Flora and Fauna (CITES) (Bryant et al., 1998). Improving our knowledge on coral reefs, is one of the most important actions needed to protect them (Souter and Lindén, 2000). According to Fahrudin (2003), many countries with coral reefs have adopted coral reef protection legislation into their Environment Protection Acts or Fisheries Laws.

The Government of Bangladesh, represented by the Department of Environment, and the Ministry of Environment, Forest and climate declared the island as an Ecologically Critical Area in 1995, to protect its distinct ecosystems (Rajasuriya et al., 2003; Thompson and Islam, 2010). The environment of St Martin's Island can hardly cope with the pressure of 900 tourists a day, but nearly 6000 people go for overnight visits every day during peak season. The island's biodiversity is being destroyed by the overwhelming number of tourists. Sea turtles used to lay their eggs where jetties have now been constructed, so turtles no longer exist (Bangi News, 2015). Dying corals, fewer birds and an increasing population of house crows are signs of a loss of biodiversity (The Daily Star, 2018). High population density, huge illegal infrastructure built in an unplanned manner, destruction of mangrove plants and bushes, collection of sea shells and stones, unplanned development of tourist facilities and dumping of garbage are threatening the island (The Daily Star, 2015). Apart from natural and anthropogenic impacts, global climate change poses a high risk to the biodiversity of coral reefs of St. Martin's (The Daily Star, 2009). The government is considering an online registration system for tourists wanting to travel to Saint Martin's Island in an effort to conserve the biodiversity of this unique island (The Daily Star, 2019). If significant and effective efforts are not made to conserve, restore and manage the coral reef ecosystem of Saint Martin's Island the ecosystem services will decrease dramatically (Thompson and Islam, 2010).

Environmental resources provide valuable flows of services to people (Champ et al., 2003). In the context of a coral reef environment these services include fisheries, formation and protection of coastal land, tourism and recreational activities. Environmental resources are considered public goods, consequently such resources have often been undervalued and, at worst, have been treated as free goods, leading to their overuse. Individuals in a given situation, will tend to make choices that give them the highest level of utility. The value of a reef ecosystem, can be estimated by what it is worth to the people who use it or at least value its existence. Studies have been conducted to value global reef resources in other regions, such as the Caribbean, Indonesia and Philippines (Dixon et al., 1993; Costanza et al., 1997; Fahrudin, 2003; Thur, 2003; Cruz-Trinidad et al., 2011). Economic analysis of recreational benefits from coral reefs in Thailand, Vietnam, Malaysia, Philippines, and Zanzibar are presented in book chapters edited by Ahmed et al. (2005).

Coral reef ecosystems around the world are endangered (Andersson and Gledhill, 2013; Hughes et al., 2016; Pandolfi et al., 2003; Grimsditch and Salm, 2006; Parmesan, 2006). Under traditional conservation management coral reefs are not fully protected. Consequently they are in constant danger of further degradation (Wilkinson, 2008; Bruno et al., 2007; Shafir and Rinkevich, 2009). In order to save the coral reefs restoration is necessary and it is significant that reef habitats and ecosystem services can be repaired by restoration activities (Young, 2000). Restoration ecology of coral reefs has shown that traditional conservation methods are not suitable for coral reef management (Hobbs and Harris, 2001). A decade ago, reef restoration started with lots of hope (e.g. Shafir et al., 2006a, b; Shafir and Rinkevich, 2008). The coral nursery and coral gardening concept was adopted in many parts of the world *e.g.* Red Sea, Phuket, Singapore, the Philippines, Tanzania and Jamaica (Rinkevich, 2008). Coral reefs continue to degrade for many different reasons despite using the best management tools. Improved reef management helps to reduce the degradation to some extent. Coral can be grown in underwater nurseries, and then later transplanted into damaged areas of the coral colonies. However, extensively degraded coral reefs need large-scale underwater nurseries and transplantation of corals into degraded habitats, together with conventional management tools (Rinkevich, 2008).

The majority of residents of St. Martin's island, the tourism industry, artisanal fishermen from the island and also the Teknaf area are highly dependent on the coral reefs, so the health and sustainable use of the reef is important for the island and nearby areas. Although reefs are a highly valuable economic resource, there has been no research in Bangladesh regarding the value of coral reef resources and there is no research that compares such values with the cost of implementing and/or strengthening resource management policies. The present study is the first of its kind in Bangladesh. Relevant information could enable the government to make better policies regarding resource use and conservation and also enable the government to encourage resource users to behave responsibly through education and raising awareness. This research will benefit protection and management policies for conserving the island and contributing to the country's overall protection of coral reefs.

Management and restoration activities of coral reefs around the globe, are usually focused on recovering the bio-physical characteristics of the coral reef ecosystem, but rarely think of how to recover the socio-ecological and ecosystem services. Current research, proposes a conceptual coupled framework; which can lead to better societal outcomes from restoration activities, while restoring bio-physical-chemical, social and ecosystem service of coral reefs systems.

The objectives of the study were: i) to calculate the values attributed to both the direct and indirect utilization of ecosystem services provided, and ii) to develop a conservation, restoration and management plan and strategies for Saint Martin's Island.

2. Materials and methods

2.1. Study area

Saint Martin's Island, located between 20°34′ and 20°39′N latitudes

and 92°18′ and 92°21′E longitudes is a small and isolated island in the northeast Bay of Bengal, 12 km south off the Cox's Bazaar-Teknaf peninsular tip of Bangladesh. The total area of the island is about 12 km^2, 9 km long and width ranges from 60 m to 1.8 km. The island comprises three major parts: i) Central Island, ii) Middle Island, and iii) Chera Dwip Island the southern-most part of the island. During high tides, a narrow channel 94 m wide and 2 m deep separates Chera Dwip Island from Central Island, which creates the impression of two different islands (Fig. 1).

2.2. Economic valuation framework

The MEA ecosystem service framework, is overlaid with the concept of Total Economic Value (TEV). Over the last two decades, TEV has become the most widely-applied framework for identifying and categorizing ecosystem values. This ecosystem valuation toolbox, is now commonly-accepted and widely-used in conservation and development planning including in marine and coastal environments (see, for example, van Beukering et al., 2007b; UNEP-WCMC, 2011; Wattage, 2011).

This study, determined the economic valuation of resources of Saint Martin's Island based on the total economic value framework shown in Fig. 2. This analysis focused on major ecosystem services, important for the coral reef communities of Bangladesh. Using value estimates the consumptive value (direct use values or goods) of tangible natural resources such as fish and shellfish, as well as non-consumptive (indirect use values or services) environmental and leisure uses. Direct use values associated with major economic sectors, were estimated using the equation:

$$\text{NPV} = \left(\sum_{t=0}^{t} Bi - \sum_{t=0}^{t} Ci\right) \Big/ (1+r)^{t} \quad (1)$$

Where NPV = net present value, B = benefits of each sector, C = costs of each sector, i = sector, t is the year, and r is the social discount rate. Local values were converted to US dollar using 1 USD = 78.00 BDT (2017).

A variety of valuation techniques are available to determine the value of environmental resources. Material resource uses can often be valued by direct market prices but for non-market goods such as environmental resources, non-market valuation (NMV) techniques have to be applied. For example, the monetary value of uses such as fishing can usually be obtained directly and relatively easily from market prices, for fish and the inputs needed to harvest them. In contrast, it is not easy to assign dollar values to public environmental goods such as visit experiences, for which there are no market prices. Cesar (2000) identifies three methods for estimating the value of goods and services, provided by coral reefs: i) directly obtaining values or expenditures, ii) using market statistics to gain information indirectly about values and expenses (revealed preference), and iii) survey-based approaches that use theoretical markets and scenarios (stated preference). The latter two categories given above are the main approaches for NMV. The revealed preferred methods are based on assessing the real behavior of individuals. In contrast, stated preferred methods are based on valuation reports that individuals make in reply to survey inquiries regarding proposed environmental policies. The stated preference method was used in this study.

Fig. 2, gives a categorization of goods and services of reefs in the context of Total Economic Valuation (TEV) for Saint Martin's Island.

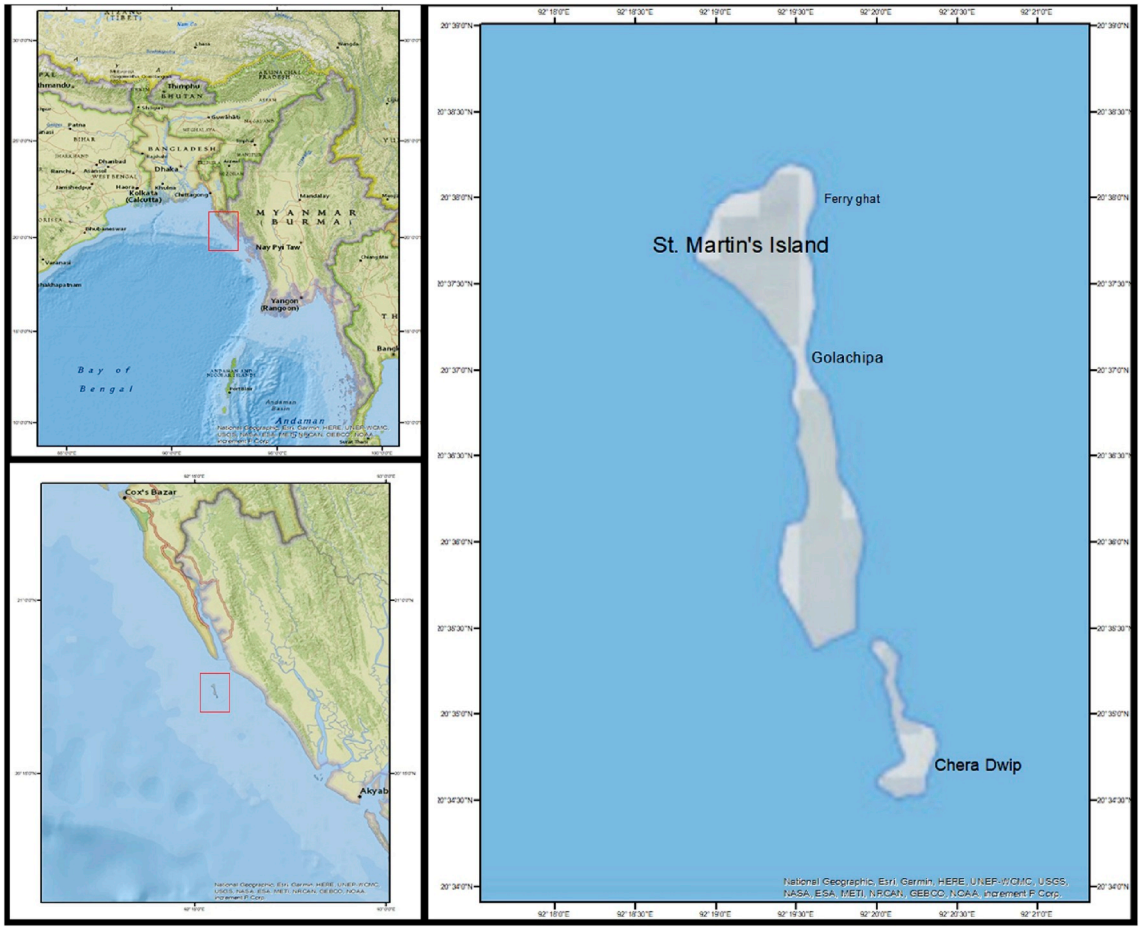

Fig. 1. Map of Saint Martin's island.

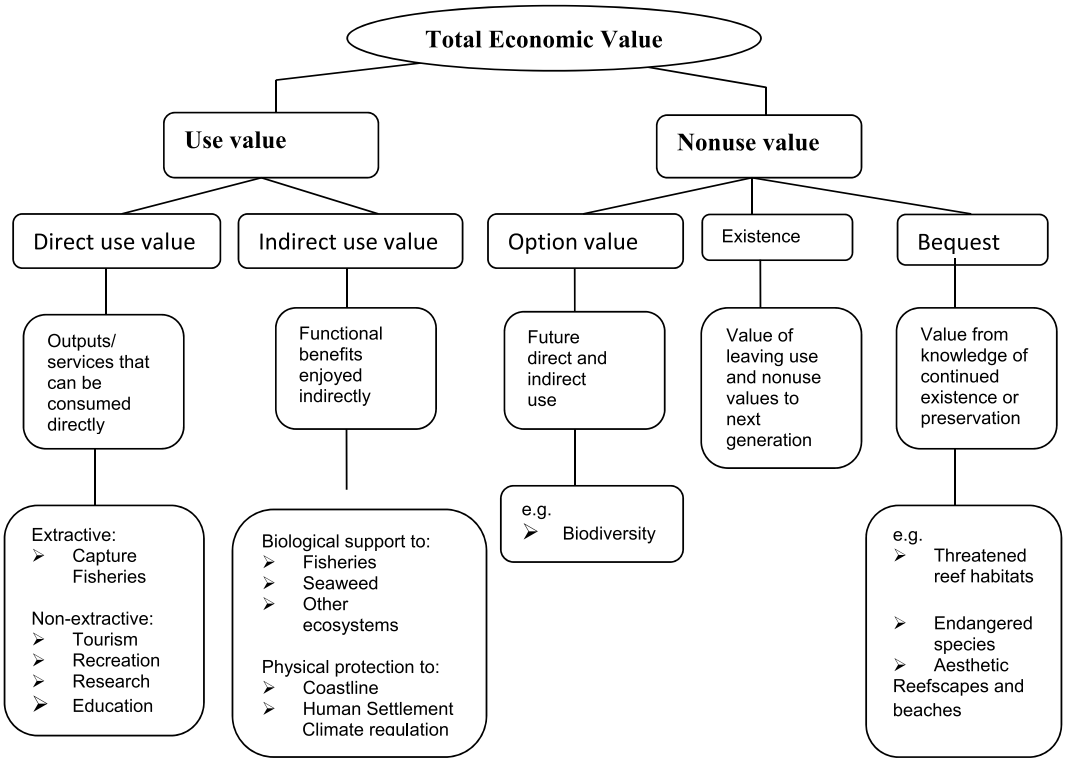

Fig. 2. Total economic value of Saint Martin's island.

Both market and non-market values were measured. Table 1, lists goods and services that typically dominate the overall valuation of an island habitat, and shows the valuation method applied. All costs were calculated from empirical data collected using survey instruments. Annual revenues were calculated by multiplying the average monthly revenues during peak and lean months with the average peak and lean months respectively. The results were a static estimate of ecosystem values at the time data were collected, and projections of future values over a 25-year time horizon. The valuation estimates reflect, at the minimum, the magnitude of potential losses due to improper management of coastal and marine resources.

Table 1
Techniques use to value environmental goods.

Valuation Technique		Description
Revealed Preference	Production Function	Assess the direct and indirect relationship between the loss of an (unpriced) environmental resource and associated changes in (priced) economic output
	Replacement/ Relocation Cost	The cost of replacing or relocating a habitat is assumed to be equal to the value of the habitat
	Aversion/ Preventative Cost	The value of the habitat is assumed to be the cost of the measures needed to prevent damage to the habitat
	Travel Cost	The travelling time and cost to a site are analysed to determine a recreational value for the site
	Hedonic Pricing	This technique analyses the environmental attributes and its effect on the overall market price
Stated Preference	Contingent Valuation	A questionnaire-based survey technique, asking a sample of individuals their willingness to pay for a specific change in environmental policy

Source: Cesar (2000) and Champ et al. (2003)

2.3. Data collection

Data were collected for qualitative and quantitative information on all goods and services, derived from marine ecosystems of Saint Martin's, including existing socio-economic profiles of the local communities and users of coastal and marine resources. Field data were gathered from October 2017 through to March 2018. The socioeconomic survey instrument was a structured questionnaire that included the number of coastal and marine resource users, age, gender, household income, major occupation, fish landings and value, catch per unit effort, and fishing costs per trip. This survey was administered to 468 randomly selected tourists and 234 participants from different stakeholders on the Island. For the key informant interviews, business owners and employees were selected as key informants for their expertise and experience about tourism, and their ability to provide detailed information about Saint Martin's challenges and opportunities that may arise for expanding tourism to Saint Martin's, and potential tourism-related business support to marine conservation efforts. Written field notes were also taken during interviews to note reactions, gestures, main conversational points, and important information that may not be expressed in the voice recording. Group discussions (with 12–20 participants per group) were used to obtain information that only specific resource users or stakeholders are knowledgeable about, and to help to validate information from the field survey. The participants in each focus group discussion varied, based on the resource concern being discussed:

a) Focus group discussion on tourism: participants were mainly local shop operators, discussing local trends in their business during lean and peak months, and the potential benefits to their livelihood if the conservation and restoration measures are taken;
b) Focus group discussion on the destruction of corals and the ecological environment: participants were mainly government officers, tourists, school children, hotel and resort owners, and religious

leaders; who discussed their views on establishing Saint Martin's Island as a marine conservation area;

c) Focus group discussions on the fishery sector—participants were mainly fishers, discussing trends in their fishing activities in the past five years and potential benefits to this sector if the conservation and restoration measures are taken.

Data were also collected to assess whether environmental user fees may be collected to help fund management and conservation of the island. The contingent valuation method employed a hypothetical question to respondents (tourists) about their maximum willingness to pay for island entrance. The contingent valuation survey was distributed to 330 local and foreign tourists during the months of October 2017 to February 2018. Respondents were asked to state their maximum willingness to pay for the amenity to be valued (*i.e.* if they are travelling to Saint Martin's), and what is the maximum amount they would be willing to pay as a daily entrance fee to the island. The mean willingness to pay was calculated directly from the surveyed local and foreign respondents. The total value was obtained by multiplying the mean willingness to pay by the annual number of visits.

2.4. Statistical analysis

The distribution of a variable qualitative in nature is shown by a frequency distribution. A frequency distribution displays the frequency of occurrence of the values of the random variables. The association between two variables, is checked through the Pearson chi-square test. The Chi-Square Test of Independence, is designed to determine whether there is an association between qualitative variables which is described as a non-parametric test. This test creates a contingency table to determine the degree of association between two qualitative variables. A contingency table is an arrangement in which data are classified according to two qualitative variables. The categories for one variable appear in the rows and the categories for the other in columns. Each variable must have two or more categories. Each cell reflects the total count of cases, for a specific pair of categories. The expected count considering the independence of two variables for each cell of the contingency table is then calculated. The test is a function of the observed count and expected count, and the test statistics follows a chi square distribution. If the p-value is less than the level of significance, then the null hypothesis of independence is rejected, and it is inferred that two qualitative variables have a significant statistical association.

2.5. Coupled socio-ecological-political-restoration-management framework

2.5.1. Socio-ecological-political framework

Since we don't know much about the complex relationship of human dimensions with the structure and function of coral reef ecosystem, it is very important to know how social change and the structure of social systems bring about ecological outcomes and how social system traits and Institution/governance (I/G) system indirectly shape social-ecological interactions for effective conservation and ecosystem management of coral reefs.

We have proposed a socio-ecological-political framework using Ostrom's (2007) basic structure of nested, multitier framework and human dimensions framework with 'Human Well-Being' and the 'Human Impact' components of Kittinger et al. (2012). Both Ostrom and Kittinger proposed four sub-systems for their socio-ecological systems (SES's) framework but we propose five sub-systems for our socio-ecological-political (SEPS's) framework.

Kittinger place 'governance system' as one of the 'social system traits' sub-system but we place 'governance system' which we call 'institution/governance (I/G)' as separate political sub-system from the 'social system traits' sub-system in order to make the socio-ecological-political framework simpler and understandable. The institution/governance (IG) subsystem has regulatory interactions among the other subsystems and components. For instance I/G subsystem has regulatory interactions with ecosystem service, human impact, social system traits and also reef communities.

All subsystems contribute a certain input that is than transformed into outcomes and feeds back on five different subsystems. The impacts that the stakeholders and the coastal communities impart on the coral reef ecosystems are intervened by institutions and governance (I/G) subsystems in our framework. There are two feedbacks between social and ecological systems, the first one starts from coral reef ecosystem to institutions and governance (I/G) sub-systems in response to anthropogenic activities and the other feedback starts from institutions and governance (I/G) systems where actions, response, policies taken in response to social stimuli.

2.5.2. Restoration Framework

In St. Martin's Island about 50% coral reef has been destroyed during the last 40 years (Mousumi, 2018). Restoration of the coral reef is necessary so as to compensate the destruction of coral reef. Restoration Framework establishes the main steps to restore the ecological features of a Coral Reef. Restoration Framework includes the basic social and ecological aspects for developing coral reef SEPS's analysis and restoration. We focus on the coral gardening which is one of the proven methods of coral reef restoration around the globe. The coral reef restoration framework consists of six stages of the adaptive management cycle which was constructed basically from the stakeholders' findings from FGD in St. Martin's Island, and successfully implemented restoration framework examples from other parts of the world, as well as from Uribe-Castañeda et al. (2018).

Institution and governance (I/G) subsystem of SEPS's starts the initiation from assess stage of restoration framework. Social system traits and stakeholder's involvement is necessary in planning and design stage of the framework.

2.5.3. Management and Conservation Framework

The management and conservation framework was developed from the findings of FGD with various stakeholders on St. Martin's Island. Apart from restoration, management of the coral reef is necessary so that the remaining coral reef is out of the danger of being destroyed further. We propose management and conservation framework for the St. Martin's Island which includes the basic social and ecological aspects for developing coral reef SEPS's analysis. Management and Conservation Framework has 7 stages with a holistic approach to address social and ecological objectives to analyze, design, implement and monitor reef conservation and management programs. Apart from the coral reef restoration, in St. Martin's Island, we propose there should be a management and conservation framework so that the policy/decision makers have a better plan on turtle conservation, birds conservation and reef fish and lobster conservation programme with few management programmes like clean water, clean beach, prohibition from anchoring, sediment pollution etc.

2.5.4. Coupled framework

We propose that three frameworks should be coupled together. The Coupled Framework includes the basic social, ecological and political framework linked with management and conservation framework & restoration framework to develop conservation, restoration and management programmes for the St. Martin's Island. Institution and governance subsystem of socio-ecological-political framework has the response, actions, planning/policy linkages with restoration and management/conservation framework. Stakeholder's involvement, reef communities and social system traits couples the three framework together.

Our framework will provide guidance to stakeholders e.g. communities, researchers, managers and decision makers to analyze how coral reef restoration, conservation and management can be implemented in a

way that addresses both social, ecological and political objectives.

This framework was basically developed for St. Martin's Island. We have tested the framework for the first time in St. Martin's Island but it is replicable and adaptable in other parts of the world, especially as a very useful guide for South Asian countries. Further application will prove its validity and usefulness in different spatial and diverse regional contexts.

3. Results

For the economic valuation of the ecosystem services provided by Saint Martin's Island, the identification of relevant stakeholders was critical. Throughout this valuation, stakeholders were involved in order to identify the main relevant services and assess their values. The local stakeholders referred to here were persons or groups concerned with the way the coral island ecosystem services are used, enjoyed and managed. These stakeholders included the coastal communities of the Island who are mostly local fishers, farmers, hotel/resorts, restaurant and ship/boat owners, tourist operators, and gleaners. These stakeholder groups, directly benefit from the Island and its associated ecosystems.

3.1. Fishing

Fishing is one of largest professional activities of the 8500 residents of the Island. The local communities use the coastal resources for traditional fishing. Fishers depend on reefs and adjacent marine waters for subsistence fish harvesting and commercial purpose. The majority of the fishers use the coral reefs while others use nearby marine areas to catch fish in comparatively deeper waters.

Fishers mainly use nets (79.2%) of various lengths and mesh sizes; 20.8% of fisherman use hooks to catch bigger, medium and small fish (Table 2b). Only 3% of the fish caught is used for family consumption while 97% is sold. Fishers sell the different kinds and sizes for prices ranging from 100 to 1000 Tk/kg. The fish species caught include *Lates calcarifer (Sea Bass), Pampus chinensis (Silver pomfret), Harpodon nehereus (Bombay Duck), Tenualosa ilisha, Scomberomorus guttatus (Indian Mackerel), Liza parsia* (Mullet), *Pomadasys hasta* (Silver Bream), Indian salmon, and Ribbon fish.

The average fish catch ranged from 4 to 60 kg per boat/day during lean months increasing to 20–200 kg/per boat/day during peak months (Table 2). November through to April are considered as peak fishing months and lean months are from May to October. The total annual benefit, from the fishing sector is 1,513, 231,200 BDT or 19,400,400 USD (Table 2a). Apart from fishes, three species of lobsters found on this island are caught by traps and hooks.

Table 2a
Net benefits from fishing.

	Daily Catch (Kg per boat)	Average Catch (Kg per boat)	Revenue per boat (BDT)
Peak-month minimum (April–Nov.)	20	Daily: 110 Monthly: 3300 Peak month	14,256,000 BDT
Peak-month maximum (April–Nov.)	200	total: 3380*8 = 26,400 Average price per Kg: 540 Tk	
Lean-month minimum (Dec.–March)	4	Daily: 32 Monthly: 960 Lean-month	2,073,600 BDT
Lean-month maximum (Dec.–March)	60	total: 960*4 = 3840 Average price per Kg 540 Tk	
Total (12 months)	Peak month + lean month = 12 months		16,329,600 BDT
Expenses			
Monthly expenses (Fuel + labour)	Fuel: 49,500 Tk Labour: 75,000 Tk Total: 124,500 Tk		
Annual expenses	1,494,000 Tk		
Income from 1 boat	(Total annual fishing - annual expenses) 16,329,600 BDT – 1,494,000 BDT		14,835,600 BDT
Total Boat - 102	14,835,600*102		1,513,231,200 BDT
Total benefit from fishing			**1,513,231,200 BDT (19,400,400 USD)**

3.2. Gleaning

Gleaning, is an activity carried out during part of the year on Saint Martin's reef ecosystem. Residents of the island, including men and women, teen-aged boys and girls, gather shellfish and invertebrates on a daily basis from the shoreline to of the low-tide level. Most were, females aged between 12 and 19, 5th grade students of elementary school.

While gleaning is usually done by hand (most of the time from the beach), gleaners also use tools such as knives and plastic containers to extract large molluscs (gastropods and bivalves); from mud and sand in intertidal areas, for sale at local markets. Earnings from 120 gleaners was estimated to be 144 USD per day during peak months, or 17,308 USD annually (Table 3).

3.3. Seaweed

In Saint Martin's Island, about 100 people, mostly fishermen but also children and women, collect seaweeds, particularly *Hypnea* spp., by hand or using push nets during low tide. About 40–80 kg of seaweeds can be collected per day per person, depending on the abundance at the collection location. The seaweeds are dried in the sun on the open sandy beach and take 3–4 days to dry. The price of seaweeds from seaweed collectors to wholesalers, is reported to be BDT 80–100 (1–1.2 USD), and wholesalers receive BDT 400–500 (5–6 USD) selling to trawlers from neighboring countries like Myanmar. People also collect seaweed from Saint Martin's and sell it at Cox's Bazaar. A previous study (Sarker, 1992) showed that about 1500 metric tons of seaweed can be harvested from the island. Sarkar et al. (2016) reported that there are 400 seaweed collectors, who collect seaweed from natural sources and that their average annual harvests is about 6–9 metric tons. We found that there are only two farms engaged in seaweed culture Island and there are very few seaweed collectors in St. Martin's Island. Annual benefits from seaweed culture is 165,700 BDT (2051 USD) (Table 4).

Seaweed farms are mostly located in Cox's Bazaar, but farmers collect the seeds of the cultured species from Saint Martin's Island. Seaweed culture is still not popular in the island because coastal residents in this area consider seaweed farming as a minor source of income and Bangladeshi people usually don't consume seaweed, although the Mog and Rakhyine tribal communities do consume seaweed (Majumder, 2010). 200 metric tons of dried seaweeds were exported to Myanmar, from Saint Martin's Island in 2013 (COAST Trust, 2013).

Most seaweed farms use an off-bottom farming method, which consists of approximately 20 single lines. For each culture cycle of 20–25 days, 80–160 kg (wet weight) can be harvested per line. Seaweed is mostly sold after it is dried (7:1 fresh-dry ratio). Peak months for seaweed farming are from January to March (Table 4a). Farmers usually culture only *Hypnea* sp. using a rope substratum but many other species are available in the study area, which could be potential species for culture. All the seaweeds are thalloid type, and there are no filamentous cultural species. Distribution is sub-tidal or intertidal, mostly epilithic and epizoic while a few are epiphytic (Table 4b).

3.4. Tourism

Marine leisure and recreation are considered mainly to be a direct-use (non-consumptive) value; where the benefit is received from either a direct or indirect interaction with the resource (Beaumont et al., 2006). Tourism contributes to the local economy of many coastal

Table 2b

Gender	%	Age	%	Fish	%	Boat	%	Education	%	Income/day	%
Male	100	18–30	6	Big fish	15	Rented	16	No edu	14	10000	
		31–40	12	Medium	4	Own	8	Primary	6	11000–20000	
		41–50	2	Small	5			High School	4	21000–30000	
		51–60	2							31000–40000	
		61–70	2							41000–50000	

Table 3
Net benefits from gleaning.

Total people involved:	120 person
Peak-month minimum	50 Tk
Peak-month maximum	100 Tk
Lean-month minimum	0 Tk
Lean-month maximum	0 Tk
Daily expenses	Collect manually No maintenance cost
Average Income per day per person	75 Tk
Per month per person	75*30 = 2250 Tk
Per year (5 months) per person	2250*5 = 11,250 Tk (144 USD)
Total annual benefits	**11250 Tk.*120 = 1,350,000 Tk (17,308 USD)**

Table 4a
Net benefits from seaweed farming.

Number of respondents	2
Personal consumption (%)	0
Selling (%)	100
Number of crops	2
1st crop (February)	
Max	Average 400–550 Kg (dry weight)
2nd crop (March)	
Max	Average 400-550 Kg (dry weight)
Total harvest	1050 kg. (dry weight)
Total farms	2 farms
Selling Price (per Kg)	80 Tk (dry weight)
Total gross income	1050 Kg x 2 farm x 80Tk = Tk. 168,000Tk.
Expenses	
Costs (per crop) for rope, net, seedlings, bamboo pole, float	1150 Tk
Costs per 2 crops	2300 Tk.
Gross income - costs	168,000 Tk. – 2300 Tk
Net annual income	**165,700 Tk (2051 USD)**

Table 4b
Commercially important seaweed species found in St. Martin's Island.

Seaweeds name	Family name	Forms	Habitat	Distribution
Chlorophyceae (Green Seaweed)				
Caulerpa racemosa	Chlorophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Caulerpa sertularioides	Chlorophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Codium fragile	Chlorophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Enteromorpha intestinalis	Chlorophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Enteromorpha moniligera	Chlorophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Rhodophyceae (Red Seaweed)				
Gelidiella tenuissima	Rhodophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Gelidium amansii	Rhodophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Gelidium pusillum	Rhodophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Halymenia discoidea	Rhodophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Hypnea musciformis	Rhodophyceae	Thalloid	epiphytic	Intertidal/ subtidal
Hypnea pannosa	Rhodophyceae	Thalloid	epiphytic	Intertidal/ subtidal
Hypnea valentiae	Rhodophyceae	Thalloid	epiphytic	Intertidal/ subtidal
Porphyra spp.	Rhodophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Phaeophyceae (Brown Seaweed)				
Hydroclathrus clathratus	Phaeophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Sargassum coriifolium	Phaeophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Sargassum oligocystum	Phaeophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal
Padina tetrastromatica	Phaeophyceae	Thalloid	Epilithic/ epizoic	Intertidal/ subtidal

communities in the coastal areas of Bangladesh, including Saint Martin's Island. The Island has become a well-known tourist destination. Tourist activities are mainly surfing, swimming, beach walking, cycling, boating and sun bathing.. With the variety of recreational activities in the Saint Martin's reef area, there is potential for further tourism development. Foreign tourists comprise less than 1% of the total visitors. Tourism revenues include direct revenues (*e.g.*, ship fees) and indirect (private sector) revenues (e.g., lodging and resort accommodation, and restaurants). While this situation has proven to be lucrative for the islanders, it is causing the island's natural beauty to deteriorate.

The only way to reach Saint Martin's Island is by boat and larger vessels for tourists leaving from the Teknaf peninsula. In the past five years the number of visitors to Saint Martin's has increased dramatically. At least 4000 to 6000 tourists visited this island daily, and 60% of them stay for 1–4 days. There are five shipping companies that run daily trips to the island (Green Line, LCT Kutubdia, Eagle, LCT Kajol, and Keari-Sindbad), reaping a benefit of 382,320,000 BDT/4,901,538 USD (Table 5). In addition to travel by ferry, tourists also travel by country boat and speed boat. A country boat can accommodate 35 to 40 passengers, and a speed boat has the capacity to carry 15–20 people. Benefits from non-ferry boats is a BDT 40,806,000/523,154 USD annually (Table 6).

Peak months for tourism are October to March and lean months are from April to September. The average age of the surveyed tourist was 29 years old, travelling on average for 2 days with at least one companion. Annual benefits from hotels and resorts is 591,660,000 BDT equivalent to 75,853,845 USD (Table 5). Benefits from beach cycling and rickshaw van hiring is 11,850,000 Tk/151,923 USD (Table 6). Tourists visit the extreme southern part of the island (Chera Dwip) for picnicing, beach cycling, swimming, snorkeling or beach wading by hiring a boat, as there is no accommodations on Chera Dwip. Benefits from such boat travel are 31,230,000 BDT/400,385 USD (Table 6).

Tables 7–10 shows that the distribution characteristics of the respondents, bivariate association of degradation of coral reef, and conservation and management efforts with the demographic characteristics. Tourists who travel to St. Martin are mostly male (77%), in the 20 to 39 age group (86%), with 83% doing higher studies. Only about 4% of tourists are in the 50–69 age group, which means that aged people usually don't travel to St. Martin's Island. Among the travelers, 77% are employed and 22% are students. 74% of tourists visit the island once a year, surprisingly a little more than 15% and 11% of tourists visit the Island twice and thrice a year. Kamruzzaman and Uchinlayen (2018), has showed that the tourists prefer St. Martin to any other place in Bangladesh as a recreational destination for a holiday.

Table 5
Net benefits from tourism Ship to and from St. Martin's Island.

Ship visits every day	4 ships
Ticket price (per person)	500-1200 TK = average 850 Tk
Capacity of every ship	800
Maximum daily tourist arrivals	4500 1500 visit the island and leave before the end of the day 3000 have an overnight stay
Income from tourist ship	2800 visitors x 850 Tk per visitor = 2,380,000 Tk per day *30 = 71,400,000 Tk per month
Maintenance + fuel cost per month per ship	120,000 Tk maintenance per month +60,000 Tk fuel per day * 30 days = 1,920,000 Tk per ship per month 4 ships = 1,920,000*4 = 7,680,000 per month
Income -maintenance	71,400,000 Tk - 7,680,000 Tk
Net benefits from tourist ships per season	63720000Tk./month x 6 months
Total (Ship)	**382,320,000 TK (4,901,538 USD)**
Income from hotel (Total hotel-105) Peak season- (October to March) Lean- April–September	
Hotels – 25	**Small Resorts- 80**
Average number of rooms per hotel: 15	Average number of rooms per resort:7
Room price average: 2500 Tk per night	Room Price average: 600 Tk per night
Average number of tourists staying per night: 125	Average number of tourists staying per night: 10
Daily earnings from hotel per day: 37,500 Tk	Daily earnings from resort per day 4200 Tk
Daily average maintenance cost: 2500 Tk	Daily average maintenance cost: 600 Tk
Net daily earnings from hotel: 35,000 Tk	Net daily earnings from resort: 3600 Tk
Monthly earnings: 1,050,000 Tk	Monthly earnings: 108,000 Tk
Yearly earnings per hotel: 6,300,000 Tk	Yearly earnings per resort: 648,000 Tk
Total earnings from commercial hotels: 6,300,000 *25 = 157,500,000 Tk (2,019,231 USD)	income from resorts: 648,000*80 = 51,840,000 Tk (664,615 USD)
Total income (ship + hotel)	**591,660,000 Tk (75,853,845 USD)**

Table 6
Net benefits from transport and recreational activities.

Total boats – 30	Country Boats – 4
Trip per Day: 2	Trips per day: 2
Average number of passengers: 15	Average number of passengers: 35*2 trips = 70
Price per passenger: 250 Tk	Average Price per passenger: 190 Tk
Daily earnings per boat per day = 2*15*250 = 7500 Tk	Income per Day 190 Tk * 70 passengers = 13,300 Tk
Net Daily: 7500 Tk-560 Tk (expenses) = 6940 Tk	Monthly earnings per ship: 399,000 Tk
Monthly net income: 6940*30 = 208,200 Tk	Total Yearly (6 months): 2,394,000 Tk/ship
Total Yearly: 208,200 Tk * 5 months * 30 boats = 31,230,000 Tk	2,394,000 Tk. *4 ships = 9,576,000 Tk
Net benefit (Boat + Trawlers)	**40,806,000 Tk (523,154 USD)**
Rickshaw Van - 100	Cycle – 50
Daily average income/rickshaw van: 650 Tk Monthly average income 19,500 Earnings per day each cycle: 200 Tk Per day 50 × 200 = 10,000/day	Rent per hour/per cycle: 20 Tk
Yearly income: 19,500 Tk/month * 6 months = 117,000 Yearly earnings:150 × 10,000 = 15,00,000 Tk	Days rented per year: 150
Total income for 100 rickshaw vans: 11,700,000 Tk/(150,000 USD)	Total income:15,00,000 Tk/(19,230.70 USD)
Total (Van + Cycle)	**11,850,000 Tk (151,923 USD)**

We asked the tourists about the degradation of coral reefs in St. Martin's Island, if degraded, whether a conservation and management efforts are necessary. 83% of tourists were aware that coral reefs are degraded and 17% either not degrading or they don't know. 94% of tourists opined that the government or appropriate authority, should come forward and take conservation and management efforts to save the coral island from degradation (Table 7a).

Tourists mostly travel from Dhaka (48%), Chittagong (7.6%), and Comilla (10.1%). Only 7.6% of local tourists were travelling from Cox's bazar districts, mostly (66%) travelling a distance of 400–600 km. 15% of tourists travel from 900 km out of which more than 90% travel this distance by bus and ship with family (53%). 6.3% of tourists travel alone. Group tours (comprising 30 or more tourists) are organised by colleges and universities as part of a study tour. 50% of tourists spend about 5000 BDT as travel cost only (Table 7b).

Table 8 shows the bivariate association of degradation of coral reefs with demographic characteristics. Since the p-value is less than our chosen significance level ($\alpha = 0.05$) for gender, age, education, and employment the null hypothesis of independence is rejected and it can be concluded that there is enough evidence based on this study to suggest a significant association between awareness of the degradation of coral reefs and education, gender, age and employment. 85% of the younger generation (for instance 20–39 age group) opined that the coral reefs are degraded with 88% coming from a higher studies background and 74% in employment which implies that in developing countries, the younger generation, having employment and higher education, tend to think about environment and environmental consequences as they are often the engaged and informed citizenry.

Table 9, shows the bivariate association of conservation and management efforts for the St. Martin's Island with demographic characteristics. Table 9, shows that since the p-value is less than our chosen significance level ($\alpha = 0.05$) for gender, education, and employment; the null hypothesis of independence is rejected and it can be concluded that there is enough evidence based on this study, to suggest a significant association between the recognition of conservation and management efforts of coral reefs and education, gender and employment. The tourists especially male (77%) with 83% higher studies being employed (77%) were in favour of the government's conservation and management efforts, to save the coral island from degradation and losing ecosystem services.

Table 7a
Distribution of socio-demographic characteristics of the respondent.

Variables	Frequency	Percent	
Gender	Female	108	23.1
	Male	360	76.9
Age	10–19	8	1.7
	20–29	234	50
	30–39	166	35.5
	40–49	42	9
	50–59	10	2.1
	60–69	8	1.7
Education	Primary	6	1.3
	SSC	12	2.6
	HSC	56	12
	Higher Studies	388	82.9
	other	6	1.3
Employment	Employed	358	76.5
	Unemployed	6	1.3
	Student	104	22.2
Degradation of Coral Reef	Yes	388	82.9
	No/Don't know	80	17.1
Visit Per Year	Once	344	73.5
	Twice	72	15.4
	Trice	52	11.1
Conservation & Management Efforts	Needed	440	94
	No/Don't know/	28	6

Table 7b
Distribution of socio-demographic characteristics of the respondent.

Variables		Percent	Percent
Income (BDT)	Up to 10000	95	20.2
	10001–25000	83	17.7
	25001–40000	53	11.4
	40001–55000	124	26.6
	55001–70000	47	10.1
	70001–100000	59	12.6
	100000+	6	1.3
Travelling from	Chittagong	33	7.6
	Comilla	47	10.1
	Cox's Bazar	36	7.6
	Dhaka	225	48.1
	Other	132	28.2
Travel cost per person	2k-4k	65	13.9
	5k	236	50.6
	6k-9k	59	12.6
	10k	83	17.7
	20k	6	1.3
	30k	18	3.8
Distance	1–100 km	12	2.5
	101–300 km	71	15.2
	401–500 km	53	11.4
	501–600 km	252	54.4
	601–900 km	71	15.2
Travel by	Air, Bus n ship	18	3.8
	Bus n boat	29	6.3
	BUS n ship	420	89.9
Single/Family/Group	1 (Single)	30	6.3
	2-4 (Family)	248	53.1
	5-9 (Group)	95	20.2
	10-30 (Group)	41	8.9
	30+ (Group)	53	11.4

Table 8
Bivariate association of Degradation of Coral Reef with the demographic characteristics.

Variables		Degradation of Coral Reef		Total	chi-square value	p-value
		Yes	No/ Don't know			
Gender	Female	80 (20.6)	28 (35.0)	108 (23.1)	3.864	0.049
	Male	308 (79.40)	52 (65.0)	360 (76.90)		
Age	10–19	8 (2.1)	0 (0)	8 (1.7)	19.813	0.001
	20–29	204 (52.6)	30 (37.5)	234 (50)		
	30–39	132 (34.0)	34 (42.5)	166 (35.5)		
	40–49	38 (9.8)	4 (5)	42 (9)		
	50–59	4 (1)	6 (7.5)	10 (2.1)		
	60–69	2 (0.5)	6 (7.5)	8 (1.7)		
Education	Others	4 (1)	2 (2.5)	6 (1.3)	33.743	0
	Primary	0 (0)	6 (7.5)	6 (1.3)		
	SSC	4 (1)	8 (10)	12 (2.6)		
	HSC	38 (9.8)	18 (22.5)	56 (12)		
	Higher Studies	342 (88.1)	46 (57.5)	388 (82.9)		
Employment	Student	100 (25.8)	4 (5)	104 (22.2)	12.792	0.002
	Unemployed	2 (0.5)	4 (5)	6 (1.3)		
	Employed	286 (73.7)	72 (90)	358 (76.5)		

3.5. Shoreline protection

The Saint Martin's coral reef protects the coastal people and the coastlines from storm surges, acting as a natural barrier. This is an indirect use value for the control of coastal erosion and other damage protection from storms, wave action and wind. IWM (2009) stated that during the pre-monsoon (April to May) and post monsoon (October to December) disastrous tropical cyclones form in the Bay of Bengal. An inundation risk map was prepared, based on the maximum inundation depths of 18 past cyclones that hit the Bangladesh coast over the last 47 years (1960–2007). The eastern coast experiences maximum inundation between 4 m and 6 m. The tides in Bangladesh's coast are semi-diurnal, with two successive tidal cycles per day. The most dominant principle constituents are M2 and S2, whose natural periods of oscillations are 12 h 25 min and 12 h respectively (Alam, 2003). If we consider coral reefs as a protector as sea walls, then we can consider the construction costs of shoreline protection to estimate the cost of such protection. Estimates made by the Scottish Natural Heritage (2000), show that in the UK, costs at the time varied from £200,000 to £500,000/100 m length, for seawalls and impermeable revetments.

Coastal protection benefits, are one-third of the global net benefits of coral reefs. By one estimate, coastal protection accounts for $9.0 billion, of the total $29.8 billion global net benefit of coral reefs (Cesar et al., 2003). In Sri Lanka, coastal erosion on the south and west coasts is severe and it has been estimated that the cost of replacing the coastal protection provided by these reefs would be 246,000-836,000 USD per km (Berg et al., 1998). In 2007, the coastal protection value for Guam's reefs was approximately 8.4 million USD per year (Van Beukering et al., 2007a). It is estimated that the annual net benefits of shoreline protection services of coral reefs in the Caribbean through shoreline protection services were 700,000 to 2.2 billion USD (Burke and Maidens, 2004). The benefit from coastal protection is estimated to be 366,000 USD in Jamaica's Portland Bight Protected Area (Cesar et al., 2000) and 65.0 million USD for Jamaica's Montego Bay reefs (Ruitenbeek and Cartier, 1999). The annual value of shoreline protection services provided by coral reefs, is estimated to be between 28 and 50 million USD for St. Lucia (Burke et al., 2008).

In the case of shoreline protection in St. Martin's Island, the benefits of the transfer method were used based on 1320 USD annually or 473 USD/km^2 indirect benefit of coastal protection, from coral reefs in Indonesia (Hargreaves-Allen, 2004). The indirect benefit of coastal protection from Saint Martin's reefs was estimated to be worth 5000 Euro/km^2. Losing the coral reef would have critical physical and financial impacts on the people who live in beach-front areas, close to the coral reefs. The benefits from shoreline protection is estimated at 179,487 US$ (Table 10).

Meta-analyses of sixty-nine studies, among five habitats world-wide (coral reefs, mangroves, salt-marshes, seagrass/kelp beds), show that these habitats reduce wave heights significantly. On average, coastal habitats reduce wave heights by between 35% and 71%. Coral reefs reduce wave heights by 70%, salt-marshes by 72%, mangroves by 31% and seagrass/kelp beds by 36%. Across all habitats, coral reefs emerge as having the greatest potential for coastal protection. They are highly effective at reducing wave heights and are also exposed to higher, and more powerful waves. Salt-marshes are almost as effective, in terms of wave reduction and mangroves and seagrass/kelp beds are about half as effective (Narayan et al., 2016). The high reduction by coral reefs agrees with the results of Ferrario et al. (2014); van Zanten et al. (2014) and Pinsky et al. (2013).

3.6. Entrance fee

The entrance fee that respondents interviewed would be willing to pay per visit; ranged from 0 to 2000 BDT (0–25 USD) for local tourists, and 3–40 USD for foreign tourists. The average entrance fee that tourists would be willing to pay is USD 2 to 12 for local tourists and foreign

Table 9
Bivariate association of Conservation & Management Efforts with the demographic characteristics.

Variable		Conservation & Management Efforts		Total	Chi-square value	P value
		Needed	No/not needed			
Gender	Male	14 (2.9)	346 (73.9)	360 (76.9)	8.629	0.035
	Female	14 (2.9)	94 (21.4)	108 (23.1)		
Education	Primary	2 (0.4)	4 (0.9)	6 (1.3)	50.962	0
	SSC	4 (0.9)	8 (1.7)	12 (2.6)		
	HSC	4 (0.9)	52 (11.11)	56 (12)		
	Higher Studies	18 (3.8)	370 (79.06)	388 (82.9)		
	Others	0 (0)	6 (1.3)	6 (1.3)		
Employment	Employed	20 (4.3)	338 (72.2)	358 (76.5)	104.108	0
	Unemployed	4 (0.9)	2 (0.4)	6 (1.3)		
	Student	4 (0.9)	100 (21.3)	104 (22.2)		

Table 10
Net benefits from shoreline protection.

Total shoreline area = 28 km
Total cost per kilometer- 5000 euro/per year
28 km * 5000 euro/year = 140,000 euro/year
Total cost 14,000,000 (179,487 USD)

tourists respectively. Net annual benefits that could be collected as an entrance or conservation fee, from visitors to the Island would be 85,000,000 BDT (1,089,744 USD) (Table 11), which could be used/managed by the government to conserve the island. The benefits that could come from Saint Martin's coral reefs, fall within a spectrum of valuation estimated for other coral reefs worldwide.

Arin and Kramer (2002) found an average willingness-to-pay as a daily entrance fee to a marine sanctuary in Panglao Island, Bohol of 3–4 USD per individual per visit. In Bolinao, Philippine WTP value equal to PhP20.46 (US$0.45) per visit was estimated (Ahmed et al., 2007). For the conservation of a coral reef, the desired WTP was US$3.24 per person for a reef area in Curaçao and $2.08 USD per person in the Philippines (Ruitenbeek and Cartier, 1999). For Saint Martin's Island, tourists who were interviewed would be willing to pay 0-2000BDT (0–25 USD), for access to the island. Mean willingness to pay was $2.0 USD, which is higher than many other countries like the Philippines or Thailand. However, it was noticed that people were less willing to pay for the maintenance of the coral reef at Bolinao, predominantly local tourists, whereas in Saint Martin's it was surprisingly high. This implies that the conservation of natural assets and the environment might not draw the instant attention of local tourists, because of the limited economic resources in some developing nations such as the Philippines, in relation to the recreation given by the coral reefs (Ahmed et al., 2007).

Table 11
Total Economic value of Saint Martin's Island.

	Net Annual Benefit	Net Annual Benefit
Direct Use Value	BDT	USD
Extractive Resources		
Capture Fisheries	1,513,231,200	19,400,400
Gleaning	1,350,000	17,308
Seaweed Culture	165,700	2125
Non-extractive Resources		
Tourism		
Ships to and from island	382,320,000	4,901,538
Country boats/speed boats/ trawlers to and from Island &Cheradip	40,806,000	523,154
Hotels and resorts	591,660,000	7,585,385
Beach cycling and rickshaw van hiring	11,850,000	151,923
Tourism (Total)	1,026,636,000	13,162,000
WTP (entrance fee)	85,000,000	1,089,744
Indirect-use Value		
Shoreline Protection	14,000,000	179,487
Total Benefits	**2,626,382,900 (2.6 Billion BDT)**	**33,671,576 (33.6 Million USD)**

3.7. Total economic value

The economic value of the marine resources of Saint Martin's Island is estimated based on the total economic value (TEV) framework (Fig. 2). The TEV of the Saint Martin's coral reef ecosystem includes use values, each of which is comprised of several value components. Direct use value is related to the benefits obtained from the direct use of ecosystem services which may be extractive (involving consumption, for instance, of fish and shellfish for food) or non-extractive use (*e.g.*, aesthetic benefits from coral reefs), generated from direct human use of reef ecosystems (consumptive or non-consumptive) and indirect use value associated with regulating services, such as the physical protection of coastlines or erosion inhibition. Public services that are generally not reflected in market transactions are derived from the regulation services provided by reef ecosystems. Use values might be linked to private or quasi private goods, for which market prices usually exist.

The TEV concept could be used as a valuable tool to alleviate some of the external pressures causing coral reef degradation. Cesar (2000), defined TEV as the combined value of all compatible goods and services of an ecosystem. Fig. 2 gives the goods and services considered for a TEV of coral reefs. Costanza et al. (1997), estimated the value of the world's coral reefs to be about 375 billion USD each year. The global estimate of the total value of an average hectare of coral reefs ranges between 490 USD/year for the net ecosystem services, (De Groot et al., 2012). Hawai'i's coral reef ecosystems provides merchandise and enterprises to coastal populations, for example, fisheries and the travel industry. It was assessed that 360 million USD per year is contributed to the Hawaiian economy by its coral reefs, with the total value of the resources in the estimated reef area of 1660 km^2 (410,000 acres), to be nearly $10 billion in the main Hawaiian Islands (Herman and Beukering, 2004). It is estimated that coral reefs alone contribute at least US$1.06 billion annually to the Philippine economy (Burke et al., 2002). The St. Martin's coral reef, contributes around 2.6 billion BDT (33.6 million USD)to the local economy (Table 11), of which 57% of the economic revenues come from fishing, 39% from tourism, 3% from entrance fees and the remaining 1% from shoreline protection (erosion prevention) (Fig. 3 top panel).

There were only 2000 inhabitants in St. Martin's Island some two decades ago, but this has increased to more than 10,000. (The Daily Star, 2015, 2018). Coastal zone populations within the Bay of Bengal Large Marine Ecosystem (BOBLME) area will have increased by 22% to almost 230 million by the year 2039. Meanwhile, under the "business as usual" scenario, coral reef area will contract by 40% to 10,400 km^2 while the length of mangrove and coral-protected coastline will reduce by 29% and 23%, respectively. Under the "business as usual" scenario the value of the coral reef ecosystem services will decrease due to the reduction in natural habitats. However, the annual value of economic benefits and

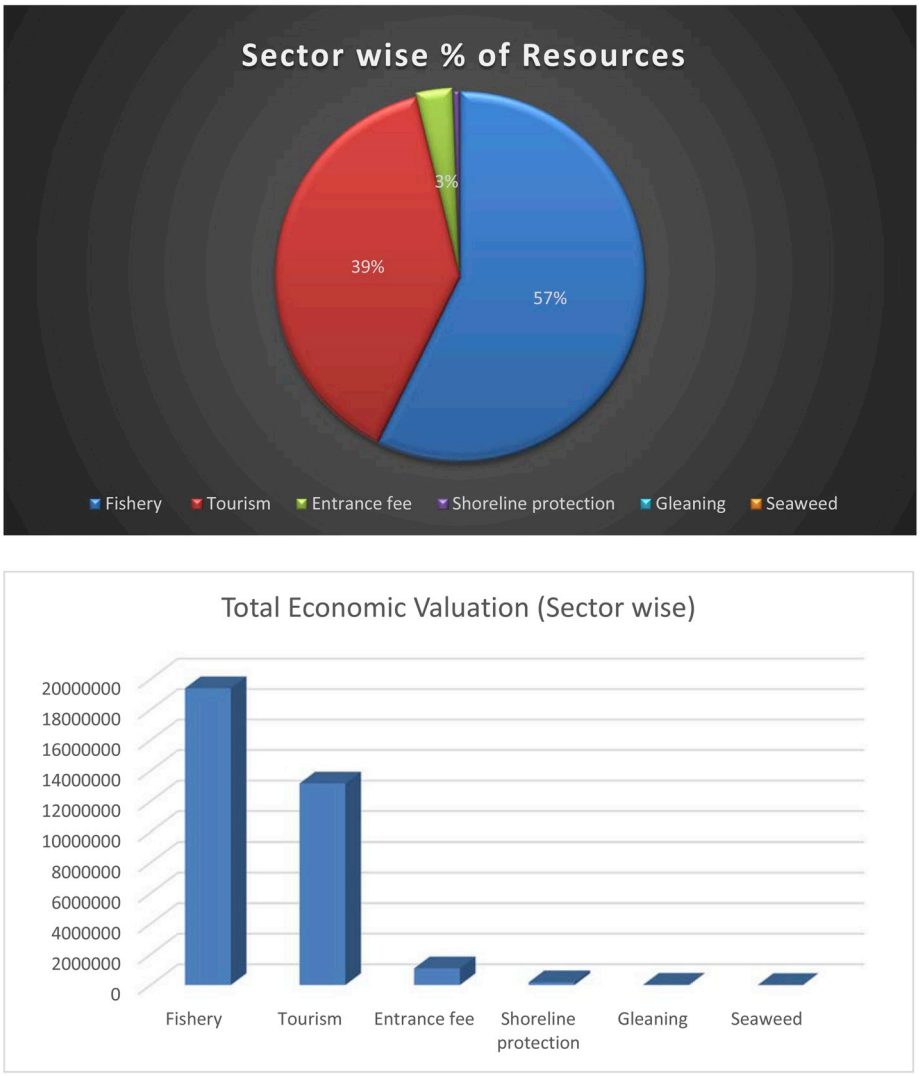

Fig. 3. Top panel: Contribution (%) of each sector in Saint Martin's Island. Bottom panel: Total Economic Value of each sector in Saint. Martin's Island (in USD).

ecosystem services, translates to a value of 86.49 million USD (Emerton, 2014). For the BOBLME region as a whole; the ecosystem value totals more than 1.17 trillion USD over the next 25 years.

Saint Martin's Island is diverse and more productive than expected for its size and the use values attributed to the direct utilization of ecosystem services provided by the island are significant. The use values, which measure the consumption price or direct use values of tangible natural resources as well as non-consumptive or indirect use values of natural resources, were estimated. Many studies have been conducted to value global reef resources in other regions such as the Caribbean, Indonesia, Philippines and Fiji (Dixon et al., 1993; Costanza et al., 1997; Fahrudin, 2003; Thur, 2003; O'Garra, 2012). The annual net benefits of the coastal and marine resources in the BMT, Philippines is PhP 182.4 million or 3.38 million USD. Municipal fisheries and tourism are the major economic sectors, generating direct use values from the Bohol Marine Triangle (BMT) resources at 1.33 million USD (39%) and 1.48 million USD (44%),respectively (Giselle et al., 2007). The most important non-market benefits that can be derived from coastal ecosystems are shoreline protection, with annual values of 169,674 USD (PhP 9.1 million) and biodiversity value of 125,703 USD (PhP 6.7 million). These non-market benefits, account for 9% of the total net benefit of the BMT, whereas in Saint Martin's Island non-market, benefits account for 2% of the total net benefits from the ecosystem services.

The total economic value of the marine resources of Danajon Double Barrier Reef in Philippines is 6.27 million USD/year, while in Saint Martin's Island the total benefits were about five times more (*i.e,* 33.6 million USD). The tourism and fisheries sectors were the major economic sectors, generating annual direct use values of 19 million USD/year and 13 million USD/year respectively (Table 8). For shoreline protection, the indirect use value is estimated at 150,393 USD/year whereas the net benefit from Saint Martin's Island was double this amount. Other values are gleaning and seaweed farming which account for 13% of the total economic value (Samonte et al., 2016). Comparatively, the benefits from gleaning and seaweed farming from Saint Martin's Island, was far lower than Danajon Double Barrier Reef.

The present value of the stream of net benefits obtained from the marine resources of the Saint Martin's Island, over a period of 25 years (from 2017 to 2041 and 2016 base year) using a 6.5% discount rate, amounts to 42.5 billion BDT (545 million USD) of which capture fisheries accounts for 312 million USD, tourism 212 million USD, entrance fees 17.5 million USD and shoreline protection is 3 million USD (Table 12). If we compare this value for the NPVs of other reef systems and other coral reefs, it seems that the NPV of Saint Martin's Island is even more than any other part of the world. For example; the accumulated total net benefits for the BMT resources, with a 10% discount rate, over a 10-year period is US$11.54 million (Samonte-Tan et al., 2007), which was less than Saint Martin's (*i.e.* 17.5 million USD). Estimated NPVs for Montego Bay, Jamaica were 315 million USD for tourism and

Table 12
Net present value of all sectors after 25 years (2017–2041 with 6.5% discount; 2016 = 0 year without discount).

Years	Capture fisheries	Tourism	Shoreline protection	Entrance fee (WTP)	Gleaning	Seaweed culture
0	1513231200	1026636000	14000000	85000000	1350000	165700
1	1450432105	984030606	13419000	81472500	1293975	158823.45
2	1390239173	943193335.9	12862111.5	78091391.3	1240275.038	152232.28
3	1332544247	904050812.4	12328333.87	74850598.5	1188803.623	145914.64
4	1277243661	866532703.7	11816708.02	71744298.7	1139468.273	139859.18
5	1224238049	830571596.5	11326314.63	68766910.3	1092180.34	134055.02
6	1173432170	796102875.2	10856272.58	65913083.5	1046854.856	128491.74
7	1124734735	763064605.9	10405737.27	63177690.5	1003410.379	123159.33
8	1078058243	731397424.8	9973899.169	60555816.4	961768.8484	118048.22
9	1033318826	701044431.6	9559982.353	58042750	921855.4412	113149.22
10	990436095	671951087.7	9163243.085	55633975.9	883598.4404	108453.53
11	949332997.1	644065117.6	8782968.497	53325165.9	846929.1051	103952.71
12	909935677.7	617336415.2	8418475.305	51112171.5	811781.5472	99638.67
13	872173347.1	591716954	8069108.58	48991016.4	778092.613	95503.66
14	835978153.2	567160700.4	7734240.574	46957889.2	745801.7696	91540.26
15	801285059.8	543623531.3	7413269.59	45009136.8	714850.9962	87741.34
16	768031729.8	521063154.8	7105618.902	43141257.6	685184.6798	84100.08
17	736158413	499439033.8	6810735.717	41350895.4	656749.5156	80609.92
18	705607838.9	478712313.9	6528090.185	39634833.3	629494.4107	77264.61
19	676325113.6	458845752.9	6257174.442	37989987.7	603370.3927	74058.13
20	648257621.4	439803654.2	5997501.703	36413403.2	578330.5214	70984.72
21	621354930.1	421551802.5	5748605.382	34768797.2	554329.8047	68038.85
22	595568700.5	404057402.7	5510038.259	33453803.7	531325.1178	65215.24
23	570852599.4	387289020.5	5281371.671	32065470.9	509275.1254	62508.81
24	547162216.5	371216526.2	5062194.747	30734753.8	488140.2077	59914.69
25	524454984.5	355811040.3	4852113.665	29459261.5	467882.3891	57428.23
Total (BDT)	**24350,387,887**	**16520,267,900**	**225,283,110**	**1367,656,859**	**21,723,729**	**2,666,387**
Total USD	**312,184,460 (312 Million)**	**211,798,306 (212 Million)**	**2,888,245 (3 Million)**	**17,534,062 (17.5 Million)**	**278,509**	**34,185**

All Sectors Total
42487,985,872 (42.5 Billion BDT) USD 544,717,767 (545 million)
Bt = benefit in period Ct = cost in period
dt = discount factor dt*(Bt-Ct) = Net present value

recreation, fisheries (1.31 million USD) and coastal protection (65 million USD). Moreover, the present value of the stream of net benefits from the marine resources of the Danajon bank over a 20-year period, using a 10% discount rate, amounts to 59.6 million USD, which is also less than the St. Martin's Island (Samonte et al., 2016).

4. Discussion

An economic assessment of the use of ecosystem services can improve the information base available to policy makers when making decisions about the use of marine resources and potentially inform choices on their conservation and sustainable use (King, 1995). The benefits generated from marine resources include direct benefits from fisheries, gleaning, and recreation/tourism and indirect benefits from shoreline protection. Saint Martin's coral reef areas, yields a value at 2.6 billion BDT, which is equivalent to 33 million USD in annual benefits. This implies that in terms of management efforts, the protection and conservation of coral reefs should be prioritised. With these corresponding values, appropriate financial and human resources should be allocated for the protection and conservation of the island. The loss of coral reefs impacts fisheries, thus limiting the livelihood options in low-income groups (Israel, 2004). More than 70% of people rely on the coral reef ecosystem for their livelihood on St. Martin's Island. Yeasmin (2018) showed that other than the anthropogenic impact, climatic hazards like cyclones, rainfall, floods and storm surges have a consequential impact on the islanders' livelihood. Local fishermen should be taught about the potential benefits of coral reef conservation, such as conservation of spawning stocks, recruits to fishing grounds, and increasing the number of catches in neighboring reef via emigration (McClanahan and Mangi, 2000; Roberts and Polunin, 1993).

Despite the fact that tropical coral reefs render a large number of ecosystem services, over the last few decades more than 40% of the world's tropical coral reef ecosystems have been damaged (Burke et al. 2011; Rinkevich, 2015) because of bleaching events, sea surface temperature rise (Hönisch et al., 2012; Wright and Schaller, 2013), overharvesting, destructive fishing, anchor damage, ship groundings, pollution, invasive species, storms, disease, eutrophication and sediment loads. Burke et al. (2001) showed that about 88% of coral reefs in Southeast Asia are now threatened and 50% of those reefs are at e risk of disappearing. 87% of the world's oceans has suffered huge anthropogenic impacts (Jones et al., 2018). Mousumi (2018) showed that more than 50% of the coral reef area has disappeared over the last 40 years in St. Martin Island. The benefits of the coral reef resources will continue over time, but only if appropriate conservation efforts are undertaken.

It was revealed from a focus group discussion that the ecosystem services, biodiversity, water quality of the St. Martin's coral reef has degraded considerably but due to a lack of systematic monitoring, it is not possible to quantitatively estimate the changes. The physical damage of the reef has been attributed to anchor damage from fishing by local fishermen, other boats and passenger ships. Information collected from local fisherman, shows that pelagic fish catches have decreased over the past few years. In order to collect information on the local views on use and management of the St. Martin's Island, focus group discussions were conducted at various parts of the island. The following actions need to be taken for the effective and improved management for the conservation of the Island:

i. Consultation and participation of local stakeholders in implementation of the management process,
ii. Increasing local awareness and education on rules, regulations and enforcement arrangements for the effective and improved conservation and management,
iii. Strict enforcement mechanisms for monitoring prohibited activities,
iv. And the establishment of monitoring and research stations, for more effective management.

The success of conservation depends on the acceptance and support of local stakeholder groups. It is vital that local communities understand the purpose and benefits of conservation. Also, local communities should be aware of the rules and regulations and enforcement arrangements for effective and improved conservation and management. It was found from consultations with local fishermen, that almost all of them were unaware that Saint Martin's is an ecological critical areas (ECA), the meaning of ECA and also the degradation status of the island. Declaring Saint Martin's an ECA is not enough. One of the most important conservation actions by the government of Bangladesh should be the development of a plan to establish an MPA in the near future. Without proper management and enforcement, it is not possible to identify the effectiveness of the MPA in Bangladesh. Studies have identified this to be a common problem, faced by many MPAs in the world (Pomeroy et al., 2004; Depondt and Green, 2006). Our analyses of the comparisons of benefits and costs of improving management at Saint Martin's may assist policy makers to develop better policies for ECA management in the future.

Reefs ecosystems around the world are still poorly protected or under traditional conservation management (Wilkinson, 2008; Bruno et al., 2007; Shafir and Rinkevich, 2009). A recent study by Giakoumi et al. (2018), showed that the MPAs are not succeeding in conserving marine ecosystems. Buxton et al. (2014), showed that no take zones will not always generate benefits. Due to the establishment of "no-take zones" or "strongly protected MPAs" (SEASTATES, 2017), poor fishers are deprived of resources from marine waters on which they are dependent for their livelihood or subsistence. 10% of the world's coastal and high seas are conserved through MPAs (CBD, 2010, Aichi target 11). It has been estimated that in 2017 about 13% of EEZ areas and 5.3% of the total ocean area fell into protected MPAs (UN, 2017). However, only 3.6% of global ocean is reported as being protected within actively managed MPAs (Sala et al., 2018). MPAs, are regarded as management tools to conserve coral reefs globally; but many fail to achieve conservation objectives despite the tough management practices that have been implemented (Rinkevich, 2008; Parnell et al., 2005; Jameson et al., 2002; Epstein et al., 2005; Coelho and Manfrino, 2007). However, Russi et al. (2016), demonstrated the benefits from MPAs in Europe and Roberts et al. (2001), showed that MPAs can improve fishing.

The Caribbean and many countries of Southeast Asia, implement user fees for management of their MPAs (Thur, 2003; Depondt and Green, 2006). Tourist surveys conducted at Saint Martin's, suggest that the tourists visiting the Saint Martin's are highly educated, have a keen interest in the marine environment, and have visited many similar destinations. Such tourists are aware that the worldwide decrease in estuarine and coastal ecosystem (ECEs), is reducing so many ecosystem services and direct benefits (Edward et al., 2011). There is no financing system for Saint Martin's reef management at this moment, and Bangladesh government's budget is insufficient to implement a better management programme for this island. Considering the threats of land and marine-based activities that cause irreversible damages to the reefs, there should be an entrance fee and also a fee for overnight stays on the island. Present study results showed that visitors to Saint Martin's Island are generally willing to pay more (*i.e.* 6.0 USD) to enter the island and stay than they were required to pay, meaning that there are opportunities for increasing management funds.

Stakeholder consultations during Focused Group Discussion (FGD) revealed that the main damage to the coral reefs is from fishing, and anchoring by both fishing and tourist boats, and waste discarded by tourists. In order to preserve the coral reef ecosystem, the relevant government ministries should take initiatives. They need to create awareness among the islanders that the benefits of preserving the ecosystem are not only for others, but also for their own sakes. A monitoring programme should be established so that a baseline of physical, biological, chemical and other parameters can be established and changes in the health of the ecosystem detected. Monitoring parameters may include assessing corals and other associated benthic organisms, for any changes in distribution, abundance and health. Our study identified the importance of stakeholder participation in future processes of management for reef and shore environments. Apart from developing management strategies and supporting legislation and enforcement measures; there should be established economic incentives for the islanders, so that they will not destroy the reefs on which they depend, but rather protect them. The islanders may be trained how to use the reef, so that negative effects would be minimised or they may be provided with attractive alternative livelihoods, to lower pressures for use of reefs. Whatever policy the relevant government ministry adopts, must be effectively implemented with community participation. Community participation is one of the main factors, contributing to the effectiveness of reef restoration and conservation projects. Trialfhihanty and Suadi (2017), described how the community played a vital role to support the restoration of the coral reef in Pemuteran, Bali, Indonesia.

The implementation of Conservation and Management Strategies requires resources such as human and physical capital and technical expertise. According to Wilkinson (2008), the most important and least available resource is appropriate funding for such measures. In particular, funds would be required for initial capital costs such as establishment of infrastructure, procurement of required equipment, recruiting and training staff, as well as recurring costs for continued operation of the restoration, conservation and management strategies (RCMS). Table 13, gives the initial management recommendations based on literature available and discussions with the stakeholder groups. Therefore, in order to successfully implement the proposed RCMS; there should be a sufficient funding mechanism and credibility for the donors, tourists and locals in the use of funds from the trust. Some proposed funding mechanisms include the following:

i. A conservation fee collected from all tourists visiting Saint Martin's,
ii. A conservation fee charged to resorts,
iii. Establishment of an extra fee for overnight stays, apart from the usual entrance fee for tourists,
iv. Government contribution, and other donor assistance.

Table 13
Proposed management recommendations.

Management Area	Recommendations
Awareness and Education	- Develop awareness resources (leaflets, organize rally, school visits, community meetings, involving political and religious leaders, school teachers, etc.) - Conduct awareness campaigns to develop community awareness - Long-term education targeted for schools
Stakeholder Involvement	- Consult during development and review of management plans and - Involvement in implementation of management plans
Management and Enforcement Mechanism	- Set up a management arrangement i. Identify main actors and define their responsibilities ii. Identify institutional arrangements, and infrastructure for management iii. Determine resources required (funds, personnel, and equipment) iv. Determine level and training requirements v. Clearly define roles and responsibilities of management personnel - Define policy measures, penalties and incentives for controlling user behaviour - Establish reporting and response mechanism - Establish mechanisms to monitor enforcement and management effectiveness
Monitoring and Research	- Conduct daily, monthly, seasonal, yearly collection of baseline data, monitoring and reporting, - Periodically monitor and report on the health of the surrounding environment - Develop updates on changes in the health of the reef, local community, and resorts.

Neither ecological system nor the social system can be studied in isolation because the relationship between ecosystems and society are integral components. Societies and ecosystems can be merged as socio-ecological systems (SES's) (Society for Ecological Restoration Science and Policy Working Group, 2004; Collins et al., 2011) which could then address how social and ecological systems respond to pressures (Bodin and Tengö, 2012; Burkhard et al., 2012; Beier et al., 2008). Beier et al., 2008 showed that there is a close relation between socio-ecological systems and ecosystem services. There are recent coral reef restoration related papers (e.g. Rinkevich, 2014; Rinkevich, 2015; Van Oppen et al., 2017; Berg et al., 2015; Edwards and Gomez, 2007; Young et al., 2012; Rinkevich, 2008; Shaish et al., 2010; Lirman and Schopmeyer, 2016; Montoya-Maya et al., 2016) and some reef restoration guideline e.g. Marshall et al. (2015), and Edwards (2010) from which we have developed a restoration framework.

Coral reef ecosystems are strongly linked to coastal ecosystem, human communities and livelihoods (Nassl and Löffler, 2015); and there is a close relation between the socio-ecological systems and the ecosystem services (Beier et al., 2008). Socio-ecological systems (SES's) analysis, focuses on the relationship between ecosystems and society (Collins et al., 2011; Bodin and Tengö, 2012). In St. Martin Island present management is insufficient or non-existent. There is a critical need for rapid and massive restoration activities to conserve the reef ecosystem. Accordingly we have developed a coupled socio-ecological-political, restoration and management framework for the island based on this study and following Ostrom (2007), Kittinger et al. (2012) and Uribe-Castañeda et al. (2018) (Fig. 4).

Until recently; coral reef restoration was designed and evaluated from a physical-biological-ecological perspective, with relatively little regard for the social, political, and economic dimensions. The majority of literature used to build the restoration framework, was focused on restoring the ecological-physical processes of coral reefs and not the social, political and economic dimensions. The coupled framework that we have developed is intended to ensure that restoration can be designed in a way that meets both social and ecological criteria, by combining the SES framework and the restoration and management framework.

5. Conclusions

Fishing and tourism are the two main economic activities on Saint Martin's Island. The continued use of reef resources without sustainable use practices and conservation measures will lead to the degradation of these precious resources. Increasing the size of the island population and tourism-related recreational use of reefs have been identified as major risks to coral reefs at Saint Martin's.

Harvesting coral from the reefs, apart from gleaning, is being done continuously for sale to tourists because it fetches good prices. A contributory reason behind this increasing destruction of the reefs is that the islanders have little knowledge of the importance of preserving natural ecosystems like coral reefs, and are unwilling to conserve those on the island's due to a lack of knowledge of the value of the reefs and

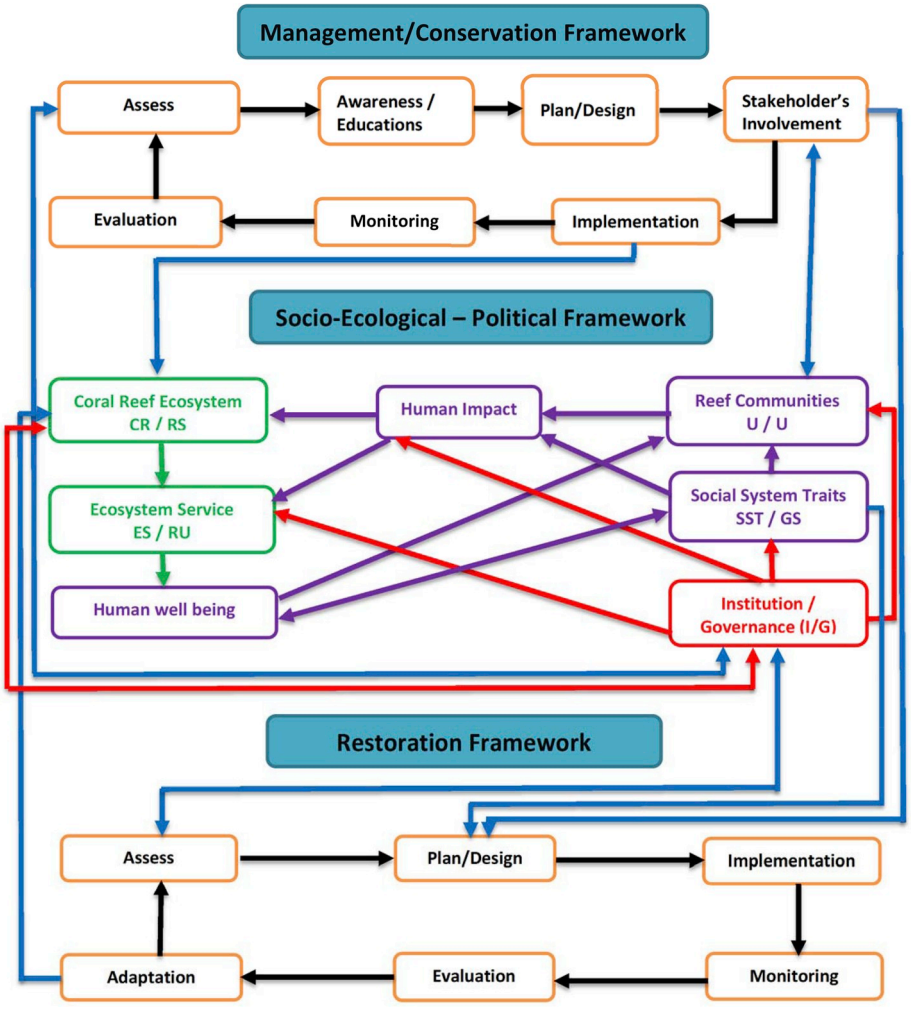

Fig. 4. Coupled socio-ecological-political-restoration-management framework for St. Martin's Coral Island (modified from Ostrom, 2007, Kittinger et al., 2012 and Uribe-Castañeda et al., 2018).

the potential costs arising from the loss of reefs.

The Ministry of Environment, Forest and Climate Change of Bangladesh should have appropriate fines and in some cases punishments, or both, for violations of protection guidelines. Different stakeholders, especially local fishermen and community groups during FGD, agreed with these proposals and opined that there should be fines and penalties for violations. The public should be made aware of these fines and penalties before they become effective. In Bangladesh, a very meagre amount is usually charged for violations of any rules and regulations in many different sectors. For instance, the fine for smoking in public places is about 0.50 USD. The fines should be greater than the economic benefits from the illegal activity. Adequate personnel with technical knowledge and sufficient equipment, would be required to make this management and enforcement mechanism a reality.

Goal 14 of the United Nations Sustainable Development Goals, is to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" (UN, 2017). The salient features of Target 14, by 2020, are:

I. sustainably manage and protect marine and coastal ecosystems,
II. conserve at least 10 per cent of coastal and marine areas,
III. effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices,
IV. and provide access for small-scale artisanal fishers to marine resources and markets

In order to meet the SDG goals, the Bangladeshi Government should declare the St. Martin Island as one of the MPAs. At the moment there is only one MPA that exists, covering an area of less than 1% of the total marine area, without any definitive political and management strategies.

In order to conserve and improve the degraded ecosystem, the government should come forward with a restoration and management plan. This paper proposes a coupled socio-ecological-political, restoration and management framework for St. Martin's Island. Researchers, managers and decision makers will use the framework to conserve, manage, and restore the degraded ecosystem of St. Martin's Island.

Declaration of competing interest

The author hereby declares no conflict of interests.

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Appendix A. Supplementary data

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