International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017 47
ISSN 2229-5518

Coastal Habitats of Maldives: Status, Trends, Threats, and potential conservation Strategies

Aminath Dhunya; Qinghui Huang; Ahmed Aslam

UNEP- Tongji, Key laboratory of Yangtze River Water Environment of the Ministry of Education, College of Environmental Science and Engineering, Tongji University, Shanghai, China.

ABSTRACT
Coastal environments has been always considered as one of the significant source of natural resources for the mankind. However there is growing threats on these extremely fragile, yet richest ecosystems. Anthropogenic presence, pressures along with natural as well as climate change effects had adversely affected the wellbeing of marine ecosystems, impairing structures, functions of theses environments and compromising resource gain from marine and coastal environments. This paper would aim in describing a synopsis of the unique physical and ecological attributes of coastal ecosystem of the Maldives and analyse the main anthropogenic pressures as well as the climate related issues to these ecosystems. Coastal ecosystems of the Maldives are at risk from numerous threats with a range of impact scales from local to global level. Some of the acute stressors are those from climate variability and climate change as well as due to some unregulated fishing practices. Also, chronic stressors like coastal modifications, pollution and economic activities are serious threats to the coastal habitats of the Maldives. There are plentiful of researches available for the coral reefs of Maldives, especially with regard to the bleaching events in late1990s. However, for the mangroves, seagrasses ecosystems only a handful of studies are available. The main threats to these ecosystems are related to human settlements, infrastructure development resulting from the increasing population. In this paper we highlight the current government strategies for conservation of the habitats and also recommend some applicable ecosystem based management and conservation strategies that are practiced in other parts of the world.

Keywords*: Coral reefs of Maldives;seagrasses of Maldives; mangroves of Maldives;ecological services; conservation*

1. INTRODUCTION

Although researchers have been formally studying about the archipelago since 1840s [1] , it was last decade that Maldives, famous for the pristine water, exquisite beaches and rich marine biodiversity is being publicised worldwide due to the country's vulnerability to the slightest change in global environment. Maldives is an archipelago of 26 natural atolls with approximately 1,190 small, low-lying, coral islands stretched over an area of 860 km long chain from north to south in the Indian Ocean [2]. Coastal and marine ecosystems in the Maldives is significant, and is the dominating environment in the Maldives with more than 99% of its territory covered by sea. Maldives has a landmass of about 300 square kilometres and is among the smallest six atoll nations around the world [3] with more than 80% of the land area less than 1 meter above the mean sea level [4]. Coral reefs is the major ecosystem in the Maldives while seagrass beds and mangroves are some the other coastal ecosystems in the Maldives. In an ecological as well as socio-economic perspective, natural habitats such as coral reefs, mangroves, and seagrasses are assets for the planet, particularly for the emerging oceanic islands such as Maldives [5].

- *Aminath Dhunya is currently pursuing master's degree program in Environmental Management and Sustainable Development in Tongji University, Shanghai, China, E-mail: dhunnya@hotmail.com*

1.1 Coral Reefs

Coral reef islands are formed by aggregating biologically-produced carbonate sand and gravel accumulated on the surface of reef platforms [6], and perceived as highly vulnerable to environmental change [7]. These low-lying islands with approximately 1.5 meter above sea-level, are formed, protected and sustained almost exclusively by corals [8]. With geospatial data accumulated recently, it is identified that there are total of 2,041 distinct coral reefs in the Maldives, of which 529 are located on the rims of the 16 complex atolls, five form the rims and lagoons of the oceanic faros, four form oceanic platform reefs, also rising from deep water but lacking a deep lagoon and remaining 1503 patch reefs being scattered within the lagoons of the 16 complex atolls [9]. The sea floor of lagoons inside the atolls is 50–60 m deep, while the channels between the atolls reach a depth of 300–400 m [9]. The major ecosystem of the Maldives is coral reefs which is the building blocks of islands that makeup the atoll nation. With an area of approximately 4513 square kilometers, reefs of the Maldives is considered as seventh largest coral reef system in the world, representing as much as 3.14% of the world's reef area[10]. Biological diversity within the marine environment of Maldives are abundantly rich and outstandingly colorful. It has been documented that there are 258 species of hermatypic corals, 36 species of sponges [11], 321 species of algae [12], 5 species of seagrasses [10], and 80 species of echinoderms in the coral reefs [10]), making the coral reefs of the Maldives one of the most diverse marine ecosystems of the world [10].

ISSN 2229-5518

Currently there are 15 families of hard corals and 12 families of soft corals in the Maldives [10]. Studies indicate that there are 258 species and 57 genera of corals in the Maldivian reefs [13]. The most abundant and diverse family of corals visible in the reefs of Maldives is Acroporidae belongs under the genus Acropora [14]. In addition some threatened species listed in the IUCN red list of threatened species, such as hawksbill turtles are also found in Maldivian reef areas [10].

1.2 Mangroves and Sea grasses

There are 14 species of mangroves belonging to 10 genera grows in Maldives, which locates at the both ends of the country while no Mangroves are found in the central parts (Shazra et al. 2008; Saleem & Nileysha 2003) distributes over 74 islands and Bruguiera Cylindrica is the most common true mangrove species in the country [4]. Mangroves in the Maldives are found in saline or brackish water or in muddy soils [17]. Other than the 14 species of mangroves in the Maldives, in these ecosystems there are several other plants and wildlife. So far, 6 species of associate plants, 37 species of marine fungi, 11 species of birds are found in the mangroves of Maldives [16]; [5]; [18]. The exact number of fauna within the mangroves are not indicated in any previous research, however several species of fishes (such as barracuda, Breams, milk fish etc.), invertebrates (such as fiddlers Crab, Hermit crab, nerites, upside-down jellyfish, etc.) and seagrasses can be observed from these areas [18].

There has been limited literatures available about seagrasses in the Maldives. When observed from satellite images, there are sea grasses visible in the Maldivian seas, especially around the densely populated islands or islands with more economic activities. Researches indicate that there are five species of seagrasses under four genera identified in the Maldives, classified as Syringodium isoetofolium, Thalassia hemprichii, Thallasso dendronciliatum, Cymnodoearotundata, and cumnodocea sp, of these Thalassia hemprichii is the most abundant in the country [19]. In the Maldives seagrasses are mostly widespread on shallow reef flats and can also be discovered in mangrove habitats [18]. These are habitats of important fish species such as rabbit fishes, Shrimps, sea cucumber, sea urchins, seahorses, crabs, scallops, mussels and snails [20].

2. ECOSYSTEM SERVICES AND FUNCTIONS

Coastal ecosystems are of disproportionately high value and they are responsible for 43% of the estimated value of the world's ecosystem services [21].

2.1 Coral Reefs

Coral reefs worldwide, which is estimated to be habitat of 3 million reef species [22]; provide bountiful amounts of ecosystem services. Among these organisms are keystone process species that regulate ecosystem processes and functions through grazing and predation [23] and other organisms which supports in controlling resilience of coral reef ecosystems [24]. The movement and migration of species between adjacent ecosystems widespread such as seagrass beds provide biotic services within the ecosystem in terms of grazing, feeding, etc. [25]. Fishes and invertebrates from coral reefs can also indirectly control the productivity of benthic algae and sea-grass accumulations enriching nutrients in the water [26]. These environments are particularly valuable in regulating the cycling of nutrients which control the productivity of plants on land and in the sea [21]. Coral reefs function as a nitrogen fixers in habitats with less nutrients [27] helping the local species and pelagic fishes in the adjacent ecosystems [28]. Coral reefs can also separate and segregate anthropogenic wastes, thus providing a cleansing service [25] and act as a natural barrier for the low lying islands extremely vulnerable to climate change, buffering against floods and erosion.

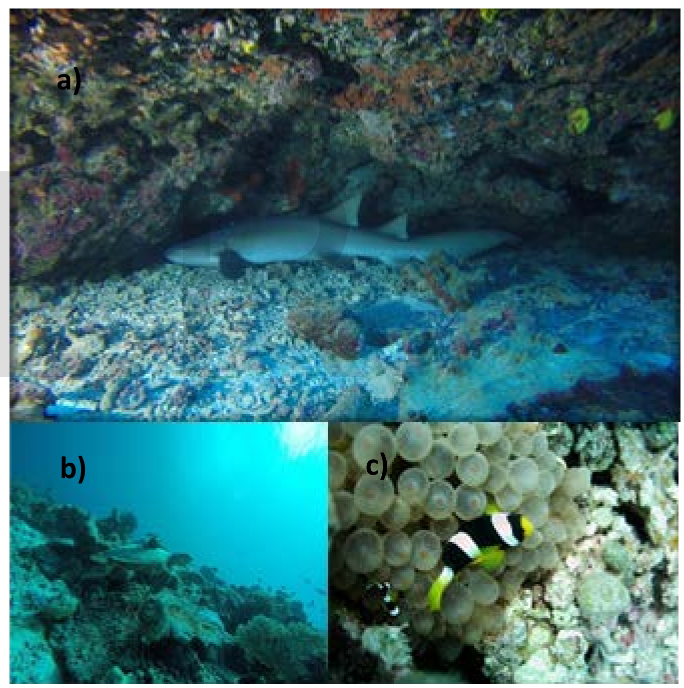

Figure 1: Coral Reefs of the Maldives: (a) A nurse shark resting (above), a (b) hawksbill turtle in a coral reef of Baa Atoll (below left), and(c) a reef fish (below right)

Coastal ecosystems plays a key role in supporting human settlements in the Maldives through climate regulation, storm buffering, and coastal protection [10]. Other than ecological services, coral reefs act as a bedrock for nation in building economy. Every year over 350 million tourists visit the coral reef coasts of the world [29]. The gardens of corals and rich biodiversity under the turquoise blue water is essential for tourism, which is the lifeblood of Maldivian economy. Divers and Snorkelers consider Maldives as the oasis of large fishes like reef sharks, etc. It is projected that biodiversity based sectors contribute 98% of exports, 89% of GDP, 71% of national employment, 62% of foreign

ISSN 2229-5518

exchange and 49% of public revenue [30]. Tourism industry also act as a stimulus to almost all the other sectors in the economy from transport, construction, trade, financial services and fisheries. The direct and indirect contributions to GDP by tourism are estimated at more than 75% [31]. Tourism being the key contributor to the economy in the Maldives, is precisely reliant on natural healthy ecosystems to provide fundamental benefits. Reefs yield a variety of seafood products such as fish, mussels, crustaceans, sea cucumbers and seaweeds. Average annual consumption of fish per person in the Maldives is an astounding amount of 180 kilograms per person, which is 77 percent of all animal protein eaten in the country [29].

People living in the coastal areas are considered healthier and happier than those living in cities [32]. Coral reefs, also contains numerous medicinal properties. It has been claimed that the discovery of prostaglandins in many of the gorgonians in the early 1970s was reason for the expansion of marine natural products [33]. Old tomb stones, ancient and historical buildings are evidence that for centuries Maldivians have been using corals as building and constructional material. Before the introduction of cement to the Maldives, lime made by corals were used as a mean of cement. Nowadays large corals are used in building coastal protection infrastructures such as seawalls, harbours, etc. [34].

Figure 1: (a) Mangroves of Kaafu Huraa (up) and (b) Fiddler Crab (Uca burgersi) in Huraa mangrove area (lower)

2.2Mangroves and Seagrass

Mangrove forests are one of the world's most dynamic ecosystems as they enrich coastal waters, harvest commercial products, defend beaches, and support coastal [35]. In Maldives economic benefits of existing mangrove habitats have largely been unrecognized and there has been a very few scientific researches done to study the mangrove ecosystem of the Maldives [15]. Currently in Maldives there are 74 islands with mangrove swamps in either mud flats, brackish water or saline water [17];[4]. These mangrove swamps provide numerous ecological and socio-economic services to the ecology as well as to human wellbeing.

Seagrasses is a habitat that provides ecological benefits such as sediment stabilization, nutrients for the reef structures; and act as a nursery and breeding area for several species which contributes offshore fisheries and to the other coastal habitats such as coral reefs and mangroves (Ali 2004); (Miller &Sluka 1999); (Short et al. 2007). Seagrasses and other coastal habitats have symbiotic relationship as theses habitats contributes to the species inhabited in the other habitats. The reefs act as a barrier to defend coastline and the protect the lagoon in between reefs and shore from waves while providing habitats for seagrass beds; consequently seagrasses strain sediments from the sewage discharges from islands and providing a nursery and feeding ground for the reef species (Short et al. 2007). When the beaches receive inputs from marine vegetation such as algae and seagrasses it enhance diversity of crustaceans and insects (Defeo et al. 2009). In the Maldives nests of turtles and numerous shorebirds are found in the beaches.

3. ANALYSIS OF ECOLOGICAL RISKS ASSOCIATED WITH STRESSORS

Human encroachment in the marine environment has drastic impact to the environment. Coral reefs all around the world are ecologically declining [29] due to multiple threats, ranging from direct destruction by coastal development to overfishing, pollution and climate change as a consequence of anthropogenic impacts, natural stresses and climate change [37]. While tackling along with international climate change issues, it is crucial to deal with locally induced stressors [29]. Threats to the coastal ecosystems can be categorised into acute stressors such climate change, natural calamities and destructive fishing methods, and chronic stressors such as coastal modifications, pollutions and destructive economical activities. One of the major threats to coastal and marine ecosystems in the Maldives include increase in the level of Sea Surface Temperature (SST) resulted from climate change, pollution and coastal developmental activities [4].

3.1Issue 1: Pollution and Water Quality

Pollution in the marine and coastal environment can be increased through land-based sources such as solid waste, untreated sewage disposal; or sea-based sources like oil spillage and ballast water [4]. Marine pollution is primarily associated with the unregulated waste management practices of the country [38] such as dumping of municipal wastes in island periphery and open burning of waste by generating toxic fumes harmful for both human and other organisms [4]. With the increasing population and growth in the number of visitors coming to the country, the amount of waste generated is escalating and Maldives is considerably challenged in the sustainable management of approximately 365,000 tonnes of wastes produced per year, excluding medical wastes, commercial and construction waste, liquid and raw sewage waste, produced daily [39]; [40]. Most common categories of waste visible from the beaches of Maldives are construction wastes, food wastes, plastic wastes such as empty bottles, cans, bags, etc. (see

Figure 3: (a) Waste dumping areas of Kaafu Maafushi (upper left), (b) Thilafushi (upper right), (c) Thulusdhoo (lower left) and (d) Thaa Guraidhoo (lower right)

Figure 3).

3.1.1 Impact to habitat and marine resources

Pollutants originated from food waste, cosmetic wastes, runoffs and oil spillage from marine transport and other activities can degrade coral reef habitats, change the distribution and density of species, and decrease the capacity of corals to withstand and recover from coral bleaching events [10]. In most islands food wastes and fish wastes are dump to the sea which results in nutrient influx leading to algal bloom [4], resulting eutrophication. Eutrophic water has a reduced oxygen level, high turbidity which reduce growth of marine vegetation and increase in harmful algal bloom which is toxic to both human and marine organism [41]. Untreated sewage contains numerous polluting substances such as pathogens, organic substances, heavy metals and trace elements, which has both direct and indirect effects to the reef habitats and organisms [4].The documented mass fish kill events of 2007, 2008 and 2012 in which huge number of dead fish; especially reef fishes like trigger fish and surgeon fish found ashore of some islands, could be related to changes of chemical and physical condition of the marine environment, algal bloom, infections or combination of these causes [42].The main risks associated with plastic include ingestion by and entanglement in the reef, harming turtles, corals and other marine life. [43]. Also, there is a growing concern about amount of hazardous wastes such as electronic waste and chemical waste produced in the country. However due to lack of proper monitoring, and absence of data, it is unable to evaluate the amount of waste generated [4].

Furthermore it is observed that the atoll with most of the fish catches in the year 2014 according to the statistical yearbook of 2015, has more areas of seagrasses in comparison to the island with less fish catches. In *figure 5* is satellite images of GA. Kooddoo, an island with a fish processing plant located in the atoll with 15% of total catches in Maldives in the year 2014; and an island located in Vaavu atoll which has least fish catches in 2014 according to the statistics which is 0.6% of the total fish catches in the Maldives. This might be an indication that more fish waste can result in more seagrass cover in the

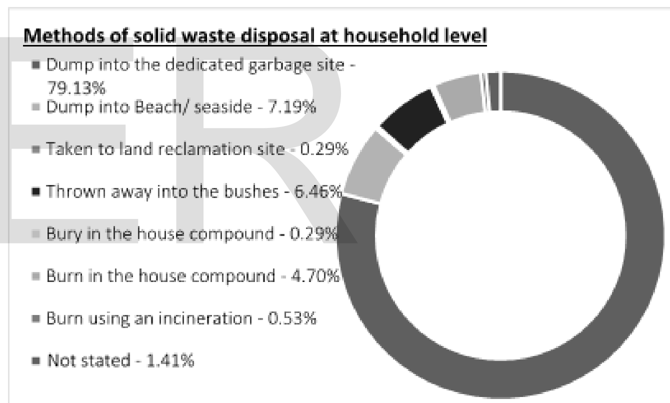

Figure 4: Methods of solid waste disposal at household level. Source MEE, 2017

islands [44].

3.1.2Current Solution

Currently there are no treatment facilities available in the islands except very few resort islands, for sewage and waste water discharges, and is discharged directly to the lagoons or coral reefs around the islands [40]. However government of Maldives recognized the significance of bringing sustainable, integrated waste management approaches to solve the problem of pollution. In this regard, the government established nation's very first integrated waste management centre in 2015 with advanced incineration and fully engineered landfill which would lodge waste from total 66 islands of 4 atolls [4]. The aim of government is to provide sustainable waste management facility to every island in the Maldives within the few years ahead. Consequently, importance should also be given in treatment of the sewage and other wastewater that is

ISSN 2229-5518

directly or indirectly entering to the marine environment through point and nonpoint sources.

3.2Issue 2: Poaching and Resource Depletion

Fisheries is the second major sector contributing to the economy of the Maldives [4].. The coastal resources of the Maldives can be categorised into bait, reef and aquarium fisheries, sea cucumber, lobster, grouper, giant clam, black coral, and turtle exploitation [45]. Studies indicate that reef fisheries were not much exploited in the Maldives until the late 1990s, with only two reef resources being exploited in the Maldives; live baits for tuna fisheries and cowries [46]. However with the increase in number of resorts, local demand for the reef fish amplified, simultaneously, expanding export market for reef fish products [47]; [48]. It is estimated that tourist resorts purchase 167 kg of fish per night to feed their guests and staff and 38% of which was estimated to be reef fish (snapper, emperor and grouper) [49]. The total annual catch of reef fish from Maldives is estimated to be between 10,400 MT to 29,145 MT, with Elagatis bipinnulata (Rainbow runner), Aprion virescens (Green job fish), Lutjanus gibbus (Humpback snapper), Lutjanus bohar (Red snapper) and various species of the trevallies being commonly exploited reef fishes in the Maldives [50]. Other than fishes there had been reports that endangered species like turtles, shark fins are still been secretly exploited. Despite the legislation banning exploitation of turtles or turtle eggs, poaching is a high threat to the fate of turtle species in the Maldives [51].Coral mining, for construction purposes, has also been practicing in the Maldives for generations, and is one of the major cause of environmental degradation in the Maldives. Corals are mined in the in water depths of l-2m on shallow reef flats where, Acropora, most abundant coral genus of Maldives are plenteous in colonies. Coral mining takes place in water depths of l-2m on shallow reef flats throughout the islands, where the coral colonies are dominated by bigger species and most abundant coral genus in Maldives, Acropora, which are appropriate for limestones and building materials (Zahir & Naeem, 1996); (Sheppard, R. et al. 1991); (Wallace, C.C., 1997). Corals are exploited for different purposes such as a substitute for bricks which is used for construction or use to produce lime to replace cement, to construct breakwaters for coastal protection, or as more recent times corals are sold to tourists as ornamental objects.

3.2.1 Impact to habitat and marine resources

The impacts of fishing are particularly severe in coral reefs, most complex and diverse marine ecosystem [52]. Recent fisheries status indicated a diminishing of fish stock, reef fishes such as groupers [53]. Fishing method can damage coral reefs; such as usage of illuminations like mercury lights for bait fishing during night and domestic chemicals like bleach and chlorine for exploiting [45] molluscs like octopus in the coral reef habitats. These destructive methods of fishing kills or breaks apart the living substrates provided by the reef. When the fishing boat is anchored or halting in proximity with the coral reefs for long durations can also damage the coral reefs. Some habitats such as coral reefs takes many years to recover from the impairment resulted from fishing activities [54].

As the majority of the reef fishes caught are carnivorous, such as grouper and snappers, etc. their absence affect the effective functioning of the coral reef ecosystem [55]; [52]; [45]. Environmental changes can be the cause of infectious diseases when natural habitats are destructed or degraded and the number of predators being lessen, altering the dominance of species, or creating favourable environments for disease hosts [56]. Fisheries harvests already exceeds sustainable levels on many coral reefs. Failure to prevent ecosystem overfishing will lead to a long-term reduction in habitat quality, which in turn will reduce biodiversity and the productivity of the fishery for future generations [56]. Furthermore sedimentation and pollution associated with coral mining can results in significant threats to coral reefs [57].

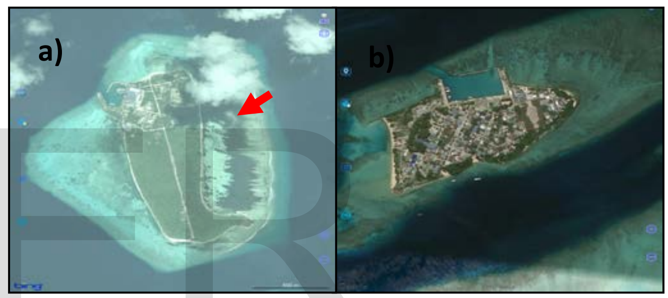

Figure 5: (a) Satellite images of Ga. Kooddoo (Left), an island from the atoll with most fish catches in 2014 and (b) Vaavu Keyodhoo (Right), an island from the atoll with least fish catches, showing difference in formation of seagrasses

3.2.2 Current Solution

Because of overfishing there was a diminishing in the stock of groupers, etc. in the previous year's [50], therefore government implemented strategies to prevent overexploitation and these creatures from becoming extinct, such as mariculture of grouper farming (MRC, 2015 in press). Previous studies estimated that by the year 2000 nearly 400, 000 m3 of corals would be exploited to meet the needs of people in Male' alone [58] and because of such predictions it encouraged the government in formulating a mitigation strategy: a) by raising awareness, b) by regulation and c) by providing alternatives [38].

3.3 Issue 3: Coastal Modification

Coral Reefs which act as a barrier against strong waves; sometimes is not enough to defend these tiny sand cays in the Maldives. Thus coastal engineering such as harbour dredging and sand bagging act as a buffering to resist powerful waves from destroying the shores. Likewise coastal engineering projects such as causeways, dredged boat channels and reclamation to the coastal zone that interact with reef-top processes [59] is adopted in order to accommodate for the outgrowing coastal population. The types of general hard engineering structures used for coastal development includes near and offshore breakwater, seawalls, revetment and groynes. In addition there are few causeways and a bridge being constructed in the Maldives (Ministry of Housing and Infrastructure, 2016. Personal communication).

Reefs and lagoons are being reclaimed to provide land for both population settlement and economic uses. Since 1911 population of Maldives has increased by fourfold, making the tiny inhabited islands steadily populous. Among 196 islands where human settlement exists 22 have a population density of more than 50 persons per hectare [10]. However replacement of natural coral reefs of the 193 inhabited islands is costly and is estimated to be between MVR 20 billion and MVR 34 billion [30]. Almost 1,300 hectares of reef or lagoon area have been reclaimed in some 98 inhabited islands. Hulhumale' is the largest land reclamation project where nearly 430 hectares were reclaimed to reduce population pressure on Male'. There is also an emerging trend to reclaim reefs for tourist resort development [10].

3.3.1 Impact to habitat and marine resources

There are consequences associated with coastal engineering and developmental activities where even the best of intentions results in undesirable environmental impacts. The diggings, moving and removal of sediments may lead to various adverse impacts on adjacent habitats such as coral reefs [60]; [61] or seagrass beds [62]. With the coastal modification activities have direct impacts on shallow corals condition and indirectly effects reef structures profile as slithering of sediments at greater depths are more probable [63]. Non-anthropogenic pressures such as waves and currents might also affect coral reefs triggering hard covers of the corals to shrink [64]. Water turbidity, results from human and natural events, increase sediment loads and reduce penetration of sunlight which degrades the environmental conditions for zooxanthellate corals [65]. Sedimentation causes problems in reproductive functions and recruitment of corals, as well as persistence and habitation of coral larvae [64]. Also impact is in reduction of hard coral cover, increase of algal cover, and dramatic augmentation of non-living substrate [66].

Table 1: Land area reclaimed in Maldives

Atoll	**Island**	**Area Reclaimed (ha)**
North Thiladhunmathi (Ha)	Dhiddhoo	35.4
South Thiladhunmathi (Hdh)	Kulhudhuffushi	44.2
South Miladhunmadulu (N)	Velidhoo	17.9
South Maalhosmadulu (B)	Dharavandhoo	15.3
South Maalhosmadulu (B)	Eydhafushi	29.4
South Maalhosmadulu (B)	Thulhaadhoo	28.2
Faadhippolhu (Lh)	Hinnavaru	40.5
Faadhippolhu (Lh)	Naifaru	34.4
Male' Atoll	Hulhumale'	200.9
Male' Atoll	Hulhumale' Phase 2	226.95
Male' Atoll	Male'	94.7
Male' Atoll	Hulhule'	76.0
North Ari Atoll (Adh)	Maamigili	73.8
South Nilandhe Atoll (Dh)	Meedhoo	20.0
South Nilandhe Atoll (Dh)	Kudahuvadhoo	69.7
Kolhumadulu (Th)	Villufushi	40.2
Kolhumadulu (Th)	Thimarafushi	26.2
South Huvadhu Atoll (Ga)	Villingili	55.0
South Huvadhu Atoll (Ga)	Dhaandhoo	13.8
North Huvadhu Atoll (Gdh)	Gadhdhoo	14.9
North Huvadhu Atoll (Gdh)	Thinadhoo	71.4
North Huvadhu Atoll (Gdh)	Fares-Maathoda	19.2
Addu Atoll (S)	Hithadhoo	53.0
Addu Atoll (S)	Meedhoo	11.5
Addu Atoll (S)	Gan	32.5

Source: [10]

Mangroves lives in the littoral areas they are well adjusted to cope with natural stressors such as temperature, salinity, anoxia, ultraviolet rays, yet they are mostly sensitive to human-induced stressors [67]. Reclamation of mangrove habitats has led to severe erosion in several islands of Maldives [5], and degradation of the mangrove ecosystems in the Maldives. In a previous study its stated that mangroves are found in 150 islands of Maldives [16], however a more recent estimates shows that the amount trimmed down to 74 islands, with total area of 7.93 km2 [10]. This might be an evidence that several mangrove habitats have been destroyed in the Maldives. The reason for these degradations could be improper environmental management strategies, coastal modification, and destruction of the swamps due to less awareness and by considering the areas as 'wastelands' or breeding ground for mosquitoes (*Figure 6*).

Coastal modification activities also have a negative effect on seagrasses around the islands [68]. As seen from the satellite images taken before reclamation and after reclamation in Guraidhoo of Thaa Atoll, it is visible that seagrass beds in lagoons were being destroyed after coastal modifications (See *Figure 7*). Despite the fact that seagrass beds are feeding area for numerous reef fishes and is particularly useful for the costal ecosystem, most tourist resorts also consider them as visually unpleasant and remove those at the vicinity to resort island, using dredging techniques or domestic chemicals [45]. This result in loss of habitat for those fishes, fungi and other organisms subsists in this ecosystem.

3.3.2 Current Solution

The major reasons for loss of habitats during reclamation are lack of information and appreciation of reef ecosystem, lack of planning guidelines at the atoll/island level, lack of understanding of carrying capacity, and non-compliance with environmental regulations and guidelines [10]. Identifying measures to lessen or avoid adverse impacts on coral reefs needs enhancement in design, and construction of coastal projects should be undertaken with incorporation of environmental objectives [69], such as ecological baseline surveys, environmental impact assessments, monitoring, etc. Also, fragile habitats such as mangroves and seagrasses should be protected to safeguard them from natural and, particularly human interventions. Furthermore as per interrogation with responsible departments, it is understood that government is aiming to minimise the use of coral, cements/ sand bags during coastal engineering projects and rock boulders imported from India, geo bags or geo tubes are trending would be using as an alternative

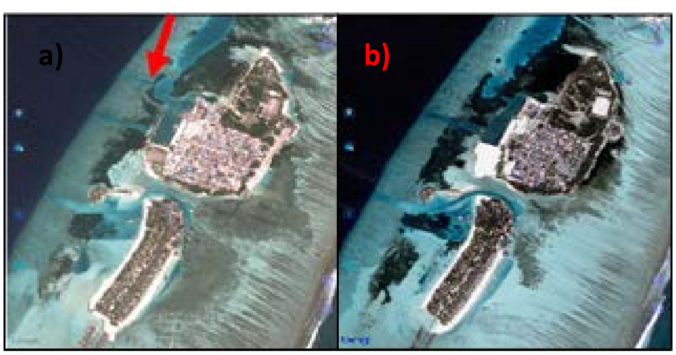

Figure 6: (a) Satellite Images showing changes in mangroves of Kaafu Huraa after (left) and (b) before (right) construction of entrance channel

to those methods.

3.4 Issue 4: Climate Variability and Changes

The global average surface temperature (SST) is projected to increase by 1.4 to 5.8 ºC by 2100, in the Indian Ocean region, temperature is expected to increase by 2.1 ºC by the 2050s and 3.2 ºC by the 2080s [70]. In Maldives, the annual maximum daily temperature is predictable to increase by around 1.5 ºC by 2100 [10]. The mass coral bleaching event of 1998 had severely impacted the reefs of the Indian Ocean [71]; [72] with following bleaching-induced mortality degrading coral cover of the Maldivian reefs from about 42% to 2% [73]. More recently, due to the Eli Nino Southern Oscillation Event, there has been another mass bleaching occurred in the reefs of Maldives where around 60% of corals reefs studied were effected [74].

3.4.1 Impact to Habitat and Marine Resources

Figure 7: (a) Satellite images of Thaa Guraidhoo showing the changes in seagrasses before (left) and (b) after reclamation (Right)

Higher level of SST can result in coral bleaching and outbreak of crown of thorn starfish (Acanthaster planci) which impacted the Maldivian reefs in the 1980s [75]; [4]. Coral bleaching occurs when sea surface temperatures (SSTs) are abnormally high (Bozec, YM, et al. 2016). The Maldivian Archipelago was seriously affected by a coral bleaching event in 1998, which resulted in coral mortality of up to 100% with unpredictable effects liable on species and locality [76]. It is being predicted that by 2030s about half of the world's coral reefs would experience thermal stress sufficient for coral bleaching in most of the years, and the amount is expected to be increased by 95 percent by 2050s [4]. Similarly issues like sea level change, thermal stress, radiation exposure, or increased storm activity might reduce the distribution and diversity of seagrasses [77]; [78] which is yet to be studied in the Maldivian environment. Beach erosion, aggravated by climate change and sea level rise, is regard as a severe environmental issue in the Maldives [4]. As the majority of the land area in the Maldives is less than 1 meter above sea level, with the pressure of climate change and sea level rise, beach erosion is one of the significant challenges in some low alleviated islands in the Maldives. Erosion is mainly caused by the changes in wind and ocean currents as a result of monsoonal changes [4]. Reef fishes as well as corals with seasonal spawning cycles would have disturbance in their spawning, failure in the recruitment due to the changes in environmental conditions, hence survival of the larvae of

ISSN 2229-5518

these organisms depend on the health of pelagic or marine environment [79]; [80]; [81].

3.4.2Current Solution

As the country lacks technological and economical capacity, it is challenging to cope and mitigate climate change and its impacts. However the government trying to make the country more resilient to climate change issues by incorporating it into sectoral planning and (MEE 2017). There can also be solutions within the ecosystems itself, like in a recent studies which demonstrated that seagrasses can reduce the impact of ocean acidification [82]. However more scientific studies need to be conducted to find better solutions for the problems.

4. MANAGEMENT AND CONSERVATION OF HABITATS

4.1Government's Policies for conservation

With 99% of its territory being ocean, Maldives has concern about protection and preservation of environment, and it is indicated in the constitution of Maldives. In Article 22 of the Constitution of the Maldives it is articulated that the State has a fundamental duty to protect and preserve and protect natural environment, biodiversity, resources and beauty of the country. Article 67(h) of Maldivian Constitution more specifically states that the Executive has the duty to prevent all forms of pollution and ecological degradation for the benefit of present and future generation. Apart from the laws, regulations and acts to protect environment, stated in *table 3*, there are several transboundary agreements which Maldives is a signatory. Some of those includes; Vienna Convention and Montreal Protocol; United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol; Basel Convention on Control of Transboundary Movements of Hazardous Waste and their Disposal; Male' Declaration; Stockholm Convention on Persistent Organic Pollutants; Climate and Clean Air Coalition (CCAC); Convention on Biological Diversity (CBD); Cartagena Protocol on Biosafety; Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES); International Plant Protection Convention and Indian Ocean Tuna Commission (IOTC) [4]. Also impact and risk assessments are conducted for reclamation projects.

These assessments all determine whether the project or activity poses a low or manageable risk. The cumulative (over time) or combined (simultaneous) impacts of these activities on an ecosystem or species should be evaluated. Risk assessments are often undertaken for specific species rather than overall marine biodiversity [10]. However, environmental impact assessment in the Maldives is still inadequate (Zubair et al. 2011).

4.1.1 Marine and Terrestrial Protected Areas

An important action taken by the government to conserve the environment is establishing Marine Protected Areas (MPAs) in 1995 [4]. Currently there are 42 protected areas, protecting an area of 24,942 hectares which is 0.2% of national territory [10] consisting a biosphere reserve in Baa Atoll, mangroves and wetland areas, islands, lagoon, beaches and sandbanks, channels and areas with historical value, etc. scattered around both inland and marine areas of 13 distinctive atolls of Maldives. When human encroachment is outlawed, Marine Protected Areas help the degraded habitats from any further destruction and let the natural resilience of the communities to restore and flourish. [83]. There are more areas which is biologically important such as the two north most atolls of the country with several mangroves, and other coastal habitats, which needs to be protected and conserved.

4.2 Potential Conservation Strategies

4.2.1 Ecosystem Approach to Management

Ecosystem approach of management can help in overcoming current issues in the Maldives such as declining of fish catches [45] due to various stressors, by sustainable management of natural resources such as fish stock, their habitats by considering societal priorities based on the ecosystem services. The concept of Ecosystem approach to management is still in the process of evolving. This concept of management concentrates on ecological functions, relationships and interactions with humans and consider management trade-offs [41]. For a country like Maldives where livelihood depends on coastal ecosystems, especially coral reefs, Ecosystem-based Adaptation (EbA) provides an efficient and cost effective way to prepare for and cope with the impacts of climate change [74]. Although mangroves and other coastal ecosystems compared with coral reefs are not crucial in livelihoods of Maldivians, government and important stakeholders can try to apply EbA to these ecosystems as well.To sustainably increase the diminishing stock of the fishes within habitats, integrated aquaculture can be implemented. Integrated aquaculture is a practice that mix varieties of aquaculture (e.g. fish, shellfish and seaweed cultivation) to reduce the environmental impacts by creating balanced ecological systems. This method has been used in freshwater ecosystems, nevertheless its capacity to withstand in the marine ecosystems is yet to be understood [56]. It is important that the functioning elements of ecosystems, such as habitats, to be conserved in order to implement ecosystem approach of management [41].

ISSN 2229-5518

Table 2: Goods and ecological services of coral reef ecosystems

Goods and ecological services of coral reef ecosystems								
Goods		**Ecological Services**						
Renewable resources	**Mining of reefs**	**Physical Structure Services**	**Biotic Services**		**Bio geochemical Services**	**Information Services**	**Social and Cultural Services**
			Within Ecosystems	**Between Ecosystems**			
Sea food products such as red snappers, groupers	Coral blocks. Rubble and sand for building	Shoreline protection and buffering	Maintenance of habitats	Biological support between other ecosystems such as seagrasses, mangroves	Nitrogen fixation	Monitoring and pollution record	Support recreation
Medicinal Properties	Substitutes for cement	Build-up of land	biodiversity preservation and conservation of a genetic library	Export of organic production, and plankton to pelagic food webs	CO2/Ca Budget Control	Climate record	Aesthetic values and artistic inspirations
Other raw materials (seaweed and algae for agar, manure, fertilizer etc.)	Mineral oil and gas	Promoting growth of mangroves and seagrass beds	Regulation of ecosystem processes and functions		Waste assimilation	Sea level change record	Sustaining the livelihood of communities
Curio and Jewellery		Generation of coral sand				Biological maintenance of resilience	Support of cultural, religious and spiritual values
Live fish and coral collected for the aquarium trade							

Adopted from [25]

Table 3: Established Laws, Regulations and Acts in the Maldives to protect environment

National Laws, Policies and Regulations	**Year**	**Purpose**
Policies		
Maldives National Energy Policy and	2010	Energy efficiency and conservation towards the target of renewable energy based

ISSN 2229-5518

Strategy		electricity supply
Maldives Climate Change Policy Framework	2015	Five policy goals; 1) sustainable financing, 2) low emission development and ensuring energy security, 3) adaptation actions and building a climate-resilient infrastructures and communities, 4) building local capacity & taking advocacy role to international level and 5) fostering sustainable development
National Solid Waste Management Policy	2015	Implement 3R concept to reduce waste, and environmentally friendly waste management practices with constant monitoring, better technologies and infrastructure and spreading more awareness
National Biodiversity Strategy and Action Plan (2nd)	2016	Protection and conservation of biodiversity
Acts		
Act on Sand mining	1978	Protect Coral Reefs and beaches by requiring to obtain permission from authorities for sand mining
The Fisheries Act of Maldives	1987	Protection against over exploitation, trade or export of several species
Environment Protection and Preservation Act of Maldives	1993	Legal basis of protection and preservation of environment by conservation of biological diversity, management of protected areas and natural reserves, EIA procedures and guidelines, disposal of waste, oil and poisonous substances, and transboundary movement of hazardous, toxic or nuclear waste.
The Maritime Zones of Maldives Act	1996	Defend internal waters, territorial sea and contiguous zone and the Exclusive Economic Zone (EEZ) of the Maldives
Maldives Tourism Act	1999	Contains provisions for regulations on protection and conservation of environment
Ozone Protection Act	2015	Reduce, control and manage the import and usage of ozone depleting substances, alternatives to ozone depleting substances and its equipment to the Maldives
Regulations		
Fisheries Regulation	2000	Regulates fishing in the lagoons and reefs of inhabited islands and resorts, prohibits activities which might harm biodiversity or habitats, and outlaws extraction of some species of corals, fishes and species in the reef.
Regulation on Coral and Sand Mining	2000	Regulates coral and sand mining in the Maldives by requiring prior permissions
Regulation of Cutting, Uprooting and Removing and Transfer of Palms and other trees between islands	2006	Removal of vegetation around coastline of islands or around the wetlands and mangrove swamps, extending to a 15 meters into the island is prohibited and these foliage
Regulation of Protection and Conservation of Environment in the Tourism Industry	2006	Encourages and facilitate sustainable development of tourism as well as protecting the environment
National Wastewater Quality Guidelines	2007	Improve public health with enhanced sanitation and providing a safe and clean environment by regulating wastewater disposal
Regulation for determination of penalties and obtaining compensation for damages caused to the environment	2011	To prevent repetition of environmental violation and to penalize and obtain damages caused to the environment
Waste Management Regulation	2013	To implement national policies related to waste management for conservation of the environment to reduce the direct and indirect impact due to improper waste management

	on human health and environment with the use of better infrastructure, technology and human capital, to introduce polluter pay principle, encourage and implement 3R policy in waste management which is reduce, reuse and recycle of waste.

Source: Information extracted from State of Environment 2016, Ministry of Environment and Energy, Maldives

4.2.2 Management through Habitat Restoration

Habitat loss occurs when the habitat is degraded or destroyed and reach to a point where they cannot provide their ecological functions. To recover ecological functions of those affected environments, habitat restoration is necessary. When planning for the restoration of degraded, fragmented or destroyed ecosystems, the principles of ecosystem management should be incorporated for the sustainability and effectiveness of techniques implementing.

Coral recruitment using transplantation of nursery-grown corals, translocation, reattachment of coral fragments and the provision of artificial substrate for natural recruitment has been identified as a potential methods for restoring degraded coral reefs [84]; [85]; [86]; [87]. Ecological restoration rather than engineering techniques are being used lately, such as coral gardening which is about mariculture of corals in nurseries and planting them when required in the degraded reefs [88]. However engineered solutions would still be required in case the substrate is unstable or ecological plantation is unsuccessful. For a country like Maldives, coral gardening or mariculture of corals is important as coral reefs are the bedrock of the livelihoods and ecology and is vulnerable to changes in the environment. Gardening can also be done for other ecosystems such as seagrasses and mangroves, for which further researches are needed to be conducted.

Artificial plantation is a way of successfully restoring disturbed mangroves to their natural state and also this strengthen [89]. However it is important to inspect biotic and abiotic elements of the habitat such as salinity, soil condition and hydrology of the mangrove site to know if suitable for plantation of mangrove [90]. Seagrass revegetation either transplantation of plants or seeds is successful techniques used for restoration of seagrasses [91]; [92]; [93] which can also be practiced in the Maldives. Whichever technique used for seagrass restoration, it is important to remove any kind of threat in the habitat such as dredging or eutrophication prior to plantation [94]. In terms of expenses and logistics, there may not be an ideal restoration method for restoring large degraded areas, and the best method for different countries, regions and types of habitat differs. Hence it is important to do in-depth research on the intended restoration method and to choose a method which is most suitable for the habitat, considering biotic and abiotic factors.

5. DISCUSSION AND CONCLUSION

The major long-term threat to the coastal habitats of the Maldives is due coastal modification activities. Increase in population and high population density in small islands creates need for land reclamation and dredging. Because of the growing human population and climate change issues, there is a less actions that can be taken in the short-term. However implementation of ecosystem based management approaches and legislations to conserve and restore already threatened habitats can be the crucial in alleviating the threats associate with the degradations and fragmentations of habitats. For this the first step would be eliminating any activity which would destruct the habitats.

The Maldives contribute only a small fraction of the CO_2 emissions that have created dilemma of Climate change. The Maldives is 172nd in a recent ranking of 217 countries by emissions, contributing only the equivalent of 0.01% of the CO_2 emitted by the world's top polluter (China) [74]. As the islands are only 1-2 meters above the mean sea-level, the islands are extremely vulnerable to climate change and any other natural changes. In addition to the natural changes, human encroachments such a sand mining, vegetation clearance, coastal modifications, pollution obstruct the movements of sediments around the islands which in turn change the natural process of surrounding coastlines. As the nation consists of tiny, scattered islands; transportation and supply of other obligatory services is a challenge, hence there is a trend of migrating to the islands where these basics needs are easily accessible. Thus, population density in some islands exceeds and likewise environment related issues intensifies. Thus, when implementing developmental strategies, the government as well as other stakeholders should consider the plausible threats, their root causes, and aftermaths. As the country is undergoing a tremendous growth of development, coastal developments, tourism [95]; [38]; social integration is essential for combatting with climate change and degradation of the environment [96]. The fate of marine ecosystems of Maldives and their role in providing welfare for human and marine organisms highly depend on how the human uses and impacts on the marine environment is managed and regulated. For this methodical programmes to foster awareness among the islanders is imperative as most of the islanders are unaware of the consequences of their direct and indirect harm to the ecosystem. However the main challenges with the coastal management in the Maldives is deficiency of required resources, such as skills, expertise and financial requirement to implement the policies and strategies.

There is also a significant requirement of further researches in the Maldives to understand the delicate coastal environments, the wildlife, and their functions to both human and marine biodiversity in order to fully understand and implement measures to protect these ecosystems. Initial stage of protection of any habitat is spreading awareness and information among the public and important stakeholders about the status of habitats, functions and uses for human as well as for the ecology and how the habitat is related to other species. Legitimising the participation of stakeholders in the planning and monitoring of management measures is one potential way of controlling the threats in the habitats in the short-term, promoting compliance with regulations (Defeo, O. et al. 2009).

REFERENCES

[1] G. Ciarapica and L. Passeri, "An overview of the Maldivian coral reefs in Felidu and North Male' Atoll (Indian Ocean): Platform drowning by ecological crises," Facies, vol. 28, no. 1, pp. 33–65, 1993.

[2] M. Saleem, "Socioeconomic Monitoring and Assessment for Coral Reef Management at NassimoThila and Banana Reef, Kaafu Atoll, Maldives," Unpublished, no. April, 2012.

[3] MEE, "Maldives Climate change policy framework, Ministry of Environment and Energy, Maldives," no. August, p. 39, 2015.

[4] MEE, "State of Environment 2016 - Maldives, Ministry of Environment and Energy, Maldives," 2017.

[5] T. G. Jagtap, V. a Kulkarni, and X. N. Verlekar, "Vulnerability and Adaptation of Ecologically Sensitive Mangrove Habitats to the Changing Climate," Proc. Conf. Mar. Probl. Specif. Solut., vol. 2, no. Table 1, pp. 1–4, 2008.

[6] E. P. Beetham and P. S. Kench, "Wave energy gradients and shoreline change on Vabbinfaru platform, Maldives," Geomorphology, vol. 209, pp. 98–110, 2014.

[7] K. M. Morgan and P. S. Kench, "Reef to island sediment connections on a Maldivian carbonate platform: using benthic ecology and biosedimentary depositional facies to examine island-building potential," Earth Surf. Process. Landforms, vol. 41, no. 13, pp. 1815–1825, 2016.

[8] World Bank, "Project Paper For Proposed Grant Us$ 3.83 Million To The Republic Of Maldives In Support Of The Wetland Conservation And Coral Reef Monitoring For Adaptation To Climate Change (P128278, Tf011853) Maldives: Climate Change Trust Fund (P120337, Tf071418)," 2012.

[9] A. Naseer and B. G. Hatcher, "Inventory of the Maldives' coral reefs using morphometrics generated from Landsat ETM+ imagery," Coral Reefs, vol. 23, no. 1, pp. 161–168, 2004.

[10] MEE, "Fifth National Report of Maldives to the Convention on Biological Diversity. Maldives: Ministry of Environment and Energy," no. September, pp. 3–6, 2015.

[11] J. Gardiner and J. Murray, "Lagoon deposits," in The fauna and geography of the Maldive and Laccadive Archipelagoes, vol 2, 1906, pp. 581–588.

[12] C. E. Payri, A. D. R. N'Yeurt, and L. Mattio, "Benthic algal and seagrass communities in Baa Atoll, Maldives," Atoll Res. Bull., no. 590, pp. 31–66, 2012.

[13] M. Pichon and F. Benzoni, "Taxonomic re-appraisal of zooxanthellate Scleractinian Corals in the Maldive Archipelago," Zootaxa, no. 1441, pp. 21–33, 2007.

[14] H. Zahir and I. Naeem, "Generic guide to selected corals of Maldives," 1996.

[15] A. Shazra, S. Rasheed, and aa Ansari, "Study on the Mangrove Ecosystem in Maldives," Glob. J. Environ. Res., vol. 2, no. 2, pp. 84–86, 2008.

[16] A. Saleem and A. Nileysha, "CHARACTERISTICS , STATUS AND NEED FOR CONSERVATION OF MANGROVE ECOSYSTEMS IN THE REPUBLIC OF MALDIVES , INDIAN OCEAN Characteristics of Mangrove Ecosystems of the Maldives," vol. 31, pp. 201–213, 2003.

[17] P. Sujanapal and K. V. Sankaran, Common plants of the Maldives. 2016.

[18] Live & Learn, "Field Guide to Maldivian Mangroves," pp. 1–34, 2008.

[19] MHAHE, "First National Report of the Maldives to the Convention on Biological Diversity. Male': Ministry of Home Affairs, Housing and Environment.," 2002.

[20] A. Paz-Alberto, M. Hechanova, and G. C. Sigua, "ASSESSING DIVERSITY AND PHYTOREMEDIATION POTENTIAL OF SEAGRASS IN TROPICAL REGION," Int. J. Plant, Anim. Environ. Sci., no. 4, pp. 24–36, 2015.

[21] R. Costanza, "The ecological , economic , and social importance of the oceans," vol. 31, pp. 199–213, 1999.

[22] M. D. Spalding, C. Ravilious, and E. P. Green, `World Atlas of Coral Reefs' by Mark D. Spalding, Corinna Ravilious, and Edmund Green. Published by UNEP/WCMC., vol. 44, no. 4. 2002.

[23] T. J. Done, J. C. Ogden, W. J. Wiebe, and B. R. Rosen, "Biodiversity and ecosystem function of coral reefs," in Functional Roles of Biodiversity: A Global Perspective, vol. 1968, no. c, 1996, pp. 393–429.

[24] T. McClanahan, N. Polunin, and T. Done, "Ecological states and the resilience of coral reefs," Ecol. Soc., vol. 6, no. 2, 2002.

[25] F. F. Moberg and C. Folke, "Ecological goods and services of coral reef ecosystems," Ecol. Econ., vol. 29, no. 2, pp. 215–233, 1999.

[26] B. G. Hatcher, "Grazing in coral reef ecosystems," Perspect. Coral Reefs. Barnes, D.j. ed., 1983.

[27] B. E. Casareto, L. Charpy, M. J. Langlade, T. Suzuki, and H. O. M. Niraula, "Nitrogen fixation in coral reef environments," Proc. 11th Int. Coral Reef Symp. Ft. Lauderdale, Florida, no. 19, pp. 7–11, 2008.

[28] S. L. Williams and R. C. Carpenter, "Grazing effects on nitrogen fixation in coral reef algal turfs," Mar. Biol., vol. 130, no. 2, pp. 223–231, 1997.

[29] M. Spalding, R. Drumbaugh, and E. Landis, “Atlas of Ocean Wealth,” pp. 1–92, 2016.

[30] L. Emerton, S. Baig, and M. Saleem, “Valuing biodiversity: The economic case for biodiversity conservation in the Maldives. AEC Project. Ministry of Housing, Transport and Environment, Government of Maldives and UNDP Maldives,” 2009.

[31] MoT, “Tourism Year Book 2015,” Minist. Tour. Maldives, 2015.

[32] B. W. Wheeler, M. White, W. Stahl-Timmins, and M. H. Depledge, “Does living by the coast improve health and wellbeing,” Heal. Place, vol. 18, no. 5, pp. 1198–1201, 2012.

[33] B. K. Carté, “Biomedical potential of marine natural products,” Bioscience, vol. 46, pp. 271–286, 1996.

[34] UNEP, “Environmental Problems of the marine and coastal areas of Maldives: National Report.” United Nations Environment Programme (UNEP), Nairobi, Kenya, 1986.

[35] K. Kathiresan and B. L. Bingham, “Biology of mangroves and mangrove Ecosystems,” Adv. Mar. Biol., vol. 40, no. October, pp. 81–251, 2001.

[36] M. H. Wong, Wetlands ecosystems in Asia: Function and Management, vol. 53, no. 9. 2004.

[37] R. Buddemeier and A. Baker, “The adaptive hypothesis of bleaching,” Coral Heal. …, pp. 427–444, 2004.

[38] A. Jaleel, “The status of the coral reefs and the management approaches: Thecase of the Maldives,” Ocean Coast. Manag., vol. 82, pp. 104–118, 2013.

[39] MEE, “Maldives Clean Environment Project Environmental and Social Assessment and Management Framework, Ministry of Environment and Energy, Maldives,” no. November, 2016.

[40] MEE, “Maldives Clean Environment Project Environmental and Social Assessment and Management Framework (ESAMF) & Resettlement Policy Framework (RPF), Waste Management Depatment, Ministry of Environment and Energy, Maldives,” 2016.

[41] NMFS, “Our living oceans: Habitat. Status of the habitat of U.S. living marine resources. Policymakers’ summary, 1st edition (rev. Oct. 2009). U.S. Dep. Commer., NOAA Tech. Memo.,” p. NMFS-F/SPO-83, 32 , 2009.

[42] S. Naeem and S. a Sattar, “A Compilation of Reported Fish Kills in the Maldives,” pp. 1–30, 2007.

[43] R. Mascarenhas, R. Santos, and D. Zeppelini, “Plastic debris ingestion by sea turtle in Para??ba, Brazil,” Mar. Pollut. Bull., vol. 49, no. 4, pp. 354–355, 2004.

[44] M. W. Miller and R. D. Sluka, “Patterns of seagrass and sediment nutrient distribution suggest anthropogenic enrichment in Laamu Atoll, Republic of Maldives,” Mar. Pollut. Bull., vol. 38, no. 12, pp. 1152–1156, 1999.

[45] M. Ali, “SUSTAINABLE MANAGEMEMENT OF THE BAY OF BENGAL LARGE MARINE ECOSYSTEM (BOBLME) GCP / RAS / 179 / WBG The Maldives : National Report OF THE COASTAL AND MARINE RESOURCES OF THE MALDIVES AND THEIR THREATS,” no. January, 2004.

[46] M. S. Adam, R. C. Anderson, and H. Shakeel, “Commercial Exploitation of Reef resources: Examples of sustainable and non-sustainable utilization from Maldives,” Mar. Res. Sect. Minist. Fish. Agric. Maldives, 1997.

[47] MRC, Fishes of the Maldives, Marine Research Centre, Ministry of Fisheries, Agriculture and Marine Resources, Maldives. 2003.

[48] S. A. Sattar, “Review of the Reef Fishery of the North Province of Maldives, Marine Research Center and Maldives Environment Management Project, World Bank,” 2010.

[49] M. Van Der Knaap and Z. Waheed, “Reef fish resources survey in the Maldives, Bay of Bengal Programme and Ministry of Fisheries, Agriculture, Maldives,” Food Agric. Organ. United Nations, no. May 1991, pp. 1–61, 1991.

[50] S. Sattar, E. Wood, F. Islam, and A. Najeeb, “Current Status of the Reef Fisheries of Maldives and Recommendations for Management,” Darwin Reef Fish Proj. (Marine Res. Centre/Marine Conserv. Soc., pp. 1–84, 2014.

[51] K. Ali and M. Shimal, “Review of the Status of Marine Turtles in the Maldives, Marine Research Center, Ministru of Fisheries and Agriculture, Maldives,” pp. 1–27, 2016.

[52] Y.-M. Bozec, S. O’Farrell, J. H. Bruggemann, B. E. Luckhurst, and P. J. Mumby, “Tradeoffs between fisheries harvest and the resilience of coral reefs,” Proc. Natl. Acad. Sci., vol. 113, no. 16, p. 201601529, 2016.

[53] S. A. Sattar, A. Najeeb, M. S. Afzal, F. Islam, and E. Wood, “Review of the Maldivian Grouper Fishery and Export Industry,” Darwin Reef Fish Proj. (Marine Res. Centre/Marine Conserv. Soc., 2011.

[54] S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, and G. Dorr, “State of Deep Coral Ecosystems in the Alaska Region: Gulf of Alaska, Bering Sea and the Aleutian Islands.,” State Deep Coral Ecosyst. United States. NOAA Tech. Memo- randum CRCP-3., p. 365, 2007.

[55] A. Rajasuriya, Field guide of Reef Fishes of Sri Lanka. Colombo: IUCN Sri Lanka Office. 2013.

[56] UNEP, UNEP year book 2014: Emerging issues in our global environment. 2014.

[57] D. Bryant, L. Burke, J. McManus, and M. Spalding, Reefs at risk. 1998.

[58] R. P. Dunne and B. E. Brown, "Penetration of solar UVB radiation in shallow tropical waters and its potential biological effects on coral reefs; results from the central Indian Ocean and Andaman Sea," Mar. Ecol. Prog. Ser., vol. 144, no. 1–3, pp. 109–118, 1996.

[59] K. M. Morgan and P. S. Kench, "Skeletal extension and calcification of reef-building corals in the central Indian Ocean," Mar. Environ. Res., vol. 81, pp. 78–82, 2012.

[60] B. Brown, M. Le Tissier, T. Scoffin, and A. Tudhope, "Evaluation of the environmental impact of dredging on intertidal coral reefs at Ko Phuket, Thailand, using ecological and physiological parameters," Mar. Ecol. Prog. Ser., vol. 65, no. 3, pp. 273–281, 1990.

[61] L. K. B. Jordan, K. W. Banks, L. E. Fisher, B. K. Walker, and D. S. Gilliam, "Elevated sedimentation on coral reefs adjacent to a beach nourishment project," Mar. Pollut. Bull., vol. 60, no. 2, pp. 261–271, 2010.

[62] P. L. A. Erftemeijer and R. R. Robin Lewis, "Environmental impacts of dredging on seagrasses: A review," Mar. Pollut. Bull., vol. 52, no. 12, pp. 1553–1572, 2006.

[63] C. S. Rogers, "Responses of coral reefs and reef organisms to sedimentation," Mar. Ecol. Prog. Ser., vol. 62, pp. 185–202, 1990.

[64] P. L. A. Erftemeijer, B. Riegl, B. W. Hoeksema, and P. A. Todd, "Environmental impacts of dredging and other sediment disturbances on corals: A review," Mar. Pollut. Bull., vol. 64, no. 9, pp. 1737–1765, 2012.

[65] K. E. Fabricius, "Effects of terrestrial runoff on the ecology of corals and coral reefs: Review and synthesis," Marine Pollution Bulletin, vol. 50, no. 2. pp. 125–146, 2005.

[66] U. Cardini, M. Chiantore, R. Lasagna, C. Morri, and C. C. N. Bianchi, "Size-structure patterns of juvenile hard corals in the Maldives," J. Mar. Biol. Assoc. United Kingdom, vol. 92, no. 6, pp. 1335–1339, 2012.

[67] D. T. Gevaña, F. B. Pulhin, and N. M. Pampolina, "Carbon Stock Assessment of a Mangrove Ecosystem in San Juan, Batangas," J. Environ. Sci. Manag., vol. 11, no. 1, pp. 15–25, 2008.

[68] F. Short, T. Carruthers, W. Dennison, and M. Waycott, "Global seagrass distribution and diversity: A bioregional model," J. Exp. Mar. Bio. Ecol., vol. 350, no. 1–2, pp. 3–20, 2007.

[69] J. E. Maragos, "Impact of coastal construction on coral reefs in the U.S.‐affiliated pacific Islands," Coast. Manag., vol. 21, no. 4, pp. 235‐269, 1993.

[70] L. A. Nurse, G. Sem, J. E. Hay, A. G. P. P. Suarez, S. B. Wong, and S. Ragoonaden, "17 Small Island States," Clim. Chang. 2001 Impacts, Adapt. Vulnerability, Contrib. Work. Gr. II to Third Assess. Intergov. Panel Clim. Chang., pp. 843–912, 2001.

[71] H. Cesar, A. Waheed, M. Saleem, and D. Wilhelmsson, "Assessing the Impacts of the 1998 Coral Bleaching on Tourism in the Maldives and Sri Lanka Report prepared for CORDIO programme Coral Reef Degradation in the Indian Ocean Supported by the World Bank , Africa Environmental Division and by," no. June, 2000.

[72] T. Spencer, K. A. Teleki, C. Bradshaw, and M. D. Spalding, "Coral bleaching in the Southern Seychelles during the 1997-1998 Indian Ocean warm event," Marine Pollution Bulletin, vol. 40, no. 7. pp. 569–586, 2000.

[73] H. Zahir, "Status of the coral reefs of Maldives after the bleaching event in 1998," Coral Reef Degrad. Indian Ocean, pp. 64–68, 2000.

[74] IUCN Maldives, "Maldives Marine Newsletter," no. 5, pp. 1–28, 2016.

[75] A. Rajasuriya, H. Zahir, K. Venkataraman, Z. Islam, and J. Tamelander, "STATUS OF CORAL REEFS IN SOUTH ASIA: BANGLADESH, CHAGOS, INDIA, MALDIVES AND SRI LANKA," pp. 213–234, 2004.

[76] C. N. Bianchi, M. Pichon, C. Morri, P. Colantoni, F. Benzoni, G. Baldelli, and M. Sandrini, "Monitoring coral bleaching in the Maldives: Lessons to be learned and new hypotheses," Oceanis, vol. 29, no. 3–4, pp. 325–354, 2003.

[77] F. T. Short and H. A. Neckles, "The effects of global climate change on seagrasses," Aquatic Botany, vol. 63, no. 3–4. pp. 169–196, 1999.

[78] F. . Short, R. . Coles, and C. Pergent-Martini, "Global seagrass distribution," Glob. seagrass Res. methods, no. October 2015, p. 25, 2001.

[79] M. A. Hixon, "Reef Fishes, Seaweeds, and Corals:," vol. 93976, pp. 1–20, 1981.

[80] M. Nyström, C. Folke, and F. Moberg, "Coral reef disturbance and resilience in a human-dominated environment," Trends in Ecology and Evolution, vol. 15, no. 10. pp. 413–417, 2000.

[81] C. Birkeland, Coral reefs in the anthropocene. 2015.

[82] M. Bjork, F. Short, E. Mcleod, and S. Beer, "Managing Seagrasses for Resilience to Climate Change," Iucn, vol. 3, pp. 1–48, 2008.

[83] P. A. X. Bologna and A. J. Suleski, “Assessment of Seagrass Floral Community Structure From Two Caribbean Marine Protected Areas,” Gulf Caribb. Res., vol. 25, pp. 19–27, 2013.

[84] R. E. Spieler, D. S. Gilliam, and R. L. Sherman, “Artificial Substrate and Coral Reef Restoration : Whant Do We Need To Know To Known What We Need,” Bull. Mar. Sci., vol. 69, no. 2, pp. 1013–1030, 2001.

[85] H. Zahir, “Assessing bioerosion and its effect on reef structure following a bleaching event in the Maldives,” Assess. Bioerosion Its Eff. Reef Struct. Follow. a Bleach. Event Maldives, no. <Go to ISI>://ZOOR14003019137, pp. 135–138, 2002.

[86] T. Yeemin, M. Sutthacheep, and R. Pettongma, “Coral reef restoration projects in Thailand,” Ocean Coast. Manag., vol. 49, no. 9–10, pp. 562–575, 2006.

[87] P. H. Montoya Maya, K. P. Smit, A. J. Burt, and S. Frias-Torres, “Large-scale coral reef restoration could assist natural recovery in Seychelles, Indian Ocean,” Nat. Conserv., vol. 16, pp. 1–17, 2016.

[88] D. Lirman and S. Schopmeyer, “Ecological solutions to reef degradation: optimizing coral reef restoration in the Caribbean and Western Atlantic,” PeerJ, vol. 4, p. e2597, 2016.

[89] I. F. Hanum, K. R. Hakeem, and M. Ozturk, Mangrove Ecosystems of Asia- Status, Challenges and Management Strategies. Springer New York Heidelberg Dordrecht London, 2014.

[90] A. F. Van Loon, B. Te Brake, M. H. J. Van Huijgevoort, and R. Dijksma, “Hydrological classification, a practical tool for mangrove restoration,” PLoS One, vol. 11, no. 3, pp. 1–26, 2016.

[91] W. J. K. and G. W. T. Fonseca, Mark S., “Guidlines for the conservation and restoration of seagrasses in the United States and adjacent waters,” Science for Solutions, vol. Noaa’scoa, no. 12. pp. 1–151, 1998.

[92] N. M. Kelly, M. Fonseca, and P. Whitfield, “Predictive mapping for management and conservation of seagrass beds in North Carolina,” Aquat. Conserv. Mar. Freshw. Ecosyst., vol. 11, no. 6, pp. 437–451, 2001.

[93] P. a. X. Bologna and M. S. Sinnema, “Restoration of seagrass habitat in New Jersey, United States,” J. Coast. Res., vol. 278, pp. 99–104, 2012.

[94] M. M. van Katwijk, A. Thorhaug, N. Marbà, R. J. Orth, C. M. Duarte, G. A. Kendrick, I. H. J. Althuizen, E. Balestri, G. Bernard, M. L. Cambridge, A. Cunha, C. Durance, W. Giesen, Q. Han, S. Hosokawa, W. Kiswara, T. Komatsu, C. Lardicci, K. S. Lee, A. Meinesz, M. Nakaoka, K. R. O’Brien, E. I. Paling, C. Pickerell, A. M. A. Ransijn, and J. J. Verduin, “Global analysis of seagrass restoration: The importance of large-scale planting,” J. Appl. Ecol., vol. 53, no. 2, pp. 567–578, 2016.

[95] B. De-Miguel-Molina, M. De-Miguel-Molina, and M. Rumiche-Sosa, “Does Luxury Indicate Sustainability? An Analysis of the Maldives,” Bussiness Ethics Organ. Stud., vol. 16, no. 1, pp. 21–32, 2011.

[96] UNRISD, “Environmental Degradation and Social Integration, United Nations Research Institute for Social Development,” UNRISD Brief. Pap. No. 3, no. 3, 1994.