
Wetlands of Small Island Nations in South Asia vis-à-vis the Mainland and Island Groups in India: Status and Conservation Strategies

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Abstract

The wetlands of small island nations in South Asia such as Sri Lanka and the Maldives are compared with that of India with respect to their status, biodiversity, threats and conservation measures. Sri Lanka has diverse coastal habitats, which are known to support fishes (1800 species), marine turtles (5 species), marine mammals (38 species), corals (183 species), mangroves (40 species), birds (100 species), reptiles (33 species) and seagrasses (10 species). The Maldives boasts one of the world's richest marine biodiversity comprising 250 species of corals, over 1200 of reef fishes, 200 species of sponges, over 1000 species of crustaceans and over 100 species of echinoderms. Marine biodiversity of India comprises 12,913 species, of which more than 5800 species are reported from Andaman and Nicobar Islands. Marine biodiversity of Lakshadweep islands is represented by corals (172 species), fishes (396), sponges (95), molluscs (260), echinoderms (84), crustaceans (80), turtles (04),

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birds (142), marine mammals (6), seagrasses (07) and mangroves (03). The major threats to these wetlands of South Asian countries are climate change, extreme events like tsunami, coastal erosion, population pressure, habitat destruction and over-exploitation. The chapter emphasises the need for adopting frontier tools for biodiversity documentation and innovative strategies for their conservation.

Keywords

Biodiversity • Small island nations • Threats • Wetlands

2.1 Introduction

Ramsar Convention of 1971 defines wetlands as ‘*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six meters*’ (Navid 1989). Wetlands are among the most productive ecosystems in the world, which have for thousands of years supplied human communities with food, drinking water, building materials and countless other benefits. They also play a critical role in maintaining global biodiversity, partly through their rich productivity, which helps to support food chains, and partly through provision of habitats for specially adapted plant and animal species (IUCN Sri Lanka 2004).

Following the Ramsar Convention and increased human pressure imposed on wetland ecosystems, considerable attention is given for promotion of wetland conservation in Asia. Based on the investigation by a number of organisations (such as Asian Wetland Bureau, World Wide Fund for Nature, IUCN – The World Conservation Union, and the International Council for Bird Preservation), the number of wetlands of high importance is 947, and the total area covered by them is 120 Mha (Van Zon 2004).

Small island nations of South Asia are represented by Sri Lanka and the Maldives. While Sri Lanka has an approximate wetland area of 274,000 ha (Van Zon 2004), that of the Maldives is still unreported. The wetlands of Sri Lanka are of 03 categories, namely, inland wetlands, coastal wetlands and man-made wetlands. Many of the wetlands in Sri Lanka are today being recognised as important, both regionally and globally, and two have been declared as wetlands of international importance under the Ramsar Convention (Van Zon 2004). The Maldives enjoy some of the richest marine biodiversity in the world. As per the available reports, the coral reefs (21,000 km²) of the Maldives are the seventh most extensive in the world, representing about 3% of global coral reef area and is home to 250 species of corals teaming with over 1000 species of fish (Anon 2013). The wetlands of the Maldives and Sri Lanka

Table 2.1 Wetland classification of India, Sri Lanka and the Maldives

India ^a	Sri Lanka ^b	Maldives ^c
A. Inland wetlands <i>Natural</i> Lake, oxbow lake/cutoff meander, high altitude wetland, riverine wetland, waterlogged, river/stream <i>Man-made</i> Reservoir/barrage, tank/pond, waterlogged, salt pan B. Coastal wetlands <i>Natural</i> Lagoon, creek, sand/beach, intertidal mudflat, salt marsh, mangrove, coral reef <i>Man-made</i> Salt pan, aquaculture ponds	A. Inland wetlands Rivers, streams, marshes, swamp forests and ‘villus’ B. Coastal wetlands Lagoons, estuaries, mangroves, seagrass beds and coral reefs C. Man-made Tanks, reservoirs, rice fields and salterns	No classification available Wetlands are locally known as ‘Kulhi’ and situated within or partly along the coast. Linked to lagoons and contains mangroves

^aSource: SAC (2011)

^bVan Zon (2004)

^cAnon (2012)

also serve as the major sources of foreign income for these island nations (Anon 2013; Fernando and Shariff 2013). The flourishing tourism sector in these islands is due to their unique biodiversity. Similarly, in the case of India, compared to the biodiversity of mainland, that of islands, such as Andaman and Nicobar Islands (ANI) and Lakshadweep islands, is furthermore unique. Mostly because of the insular nature, habitats on oceanic islands are often different from those on the nearest mainland even when latitudes (climates) and the sizes (areas) are the same. Islands often support unique species that are rare and endemic, but with small population sizes (e.g. reduced body size or the so-called insular dwarfism, and dispersal). Partly because of their unique features (e.g. isolation) and conservation values, islands are extremely attractive for intensive efforts in exploration, research and conservation (Kalmar and Currie 2006).

The spread and classification of wetlands of India and two island nations (Sri Lanka and the Maldives) are tabulated in Table 2.1, and it suggests that the wetland classification is almost similar in India and Sri Lanka, except that creek, sand/beach and intertidal mudflats are considered as wetlands in India. There is no report on classification of wetlands in the Maldives. The wetlands in the Maldives, locally called ‘Kulhi’, are located along the coast, sometimes linked to lagoons and usually supporting mangroves. In the Maldives, coral reef is not considered as a wetland (Anon 2012).

2.2 Wetland Ecosystems and Associated Biodiversity

2.2.1 Status of Wetlands in Small Island Developing States: An Overview

Majority of the 'Small Island Developing States (SIDS)' are situated in the tropics. Thus, many of these islands are bestowed with vast extent of coastal wetland ecosystems that include coral reefs, mangrove forests and seagrass beds rich in marine biodiversity. Mangroves and corals protect shorelines and contribute significantly to the fisheries by acting as nursery grounds to fish seeds and fingerlings. Apart from raising the shores of the islands and protecting them against sea level rise (SLR), the coral reefs and mangroves act as barriers and natural breakwater and protect small islands against storm surges and tsunamis, as observed during the 2005 tsunami in the Indian Ocean. By providing shelter to fish stock, they also support the fishery industry and help in revenue generation for these small islands. Coral reefs also generate revenue from tourism and recreational activities such as diving and snorkelling. Thus, these ecosystems are significant in sustaining the economy of these small island states.

2.2.2 Wetlands of India and the Small Island Nations in South Asia

2.2.2.1 Sri Lanka

Sri Lanka is an island country, south of India in the Indian Ocean with a land area of 65,610 km². It has a coastline of 1340 km. The country's jurisdictional area that extends up to the Exclusive Economic Zone (EEZ) is 530,684 km². Sri Lanka is divided into nine provinces, which are subdivided into 25 states. The coastal boundary of Sri Lanka stretches across 14 districts. The coastal regions in Sri Lanka are fast developing and have seen remarkable changes for the ongoing economic reforms. One of the major factors to this economic boom is the resources, such as flora and fauna, and wide-ranging habitats such as coral reefs, mangroves, seagrass beds, tidal flats, lagoons, peatlands, beaches, cliffs and spits. These habitats play a critical role in the economy of the coastal regions.

Wetlands of Sri Lanka are of three main categories (*viz.* inland, coastal and man-made) and 14 types, namely, rivers, streams, marshes, swamp forests, villus, lagoons, estuaries, mangroves, seagrass beds and coral reefs, tanks, reservoirs, rice fields and salterns. Inland wetlands are represented by streams, rivers, villus wetlands, fresh water marsh and swamps. Sri Lanka has an extensive network of rivers and streams and 103 natural river basins. The largest river basin is Mahaweli, covering 16% of the island and has high ecological and socio-economic value. Villus are the floodplain lakes, covering an area of 12,500 ha and mostly located in the Mahaweli floodplains in the east. Freshwater marshes are inland depressions, which have a source of water, peat and waterlogged sticky soil. In Sri Lanka, the largest freshwater marsh is located in Muthurajawela. Freshwater swamp forest, which is

seasonally inundated with river water, is the most rare wetland type in Sri Lanka, and it comprises trees that are adapted to shallow stagnant water (Van Zon 2004).

Coastal wetlands are an integral part of Sri Lanka, having 45 estuaries, 42 coastal lagoons and a mangrove cover of less than 1000 ha. The Gulf of Mannar region, the stretch between Trincomalee and Kalmunai on the east coast and several areas in the south and south-western coasts are rich with coral reef habitats. Seagrass beds are present in the northwest coast of the country. The coastal wetlands of Sri Lanka harbour nearly 1000 species of fishes and many other marine species, and they attract migrant birds and marine turtles for nesting.

Man-made wetlands are represented by tanks, reservoirs and rice fields. The major irrigation reservoirs cover an area of 7820 ha, and seasonal/minor wetlands account for 52,250 ha. The rice fields account for an area of 780,000 ha, accounting for approximately 12% of the total land area.

The coastal wetlands are the most exploited resources and hence face serious threats. Most of the threats faced by these wetlands are due to the upstream activities such as agriculture and residential and industrial projects, but the most damaging impact is when these wetlands are considered as wastelands for dumping garbage. The coastal wetlands are also being used for prawn farming and other aquaculture activities. In order to conserve and protect these wetlands, the government of Sri Lanka has gone ahead with a series of legislations to regulate and keep the threats away from damaging the wetland ecosystems and its biological diversity.

2.2.2.2 The Maldives

The Maldives is a group of small islands in the Indian Ocean that lies southwest of Sri Lanka. It comprises 1190 islands grouped into 26 atolls and has a landmass area of 298 km², whereas the overall area of the country inclusive of the marine waters between island masses is more than 90,000 km². The Maldives has a coastline of 644 km, and being an island group, its area under EEZ is 916,189 km², second only to India. The coastline of the Maldives is gifted with numerous ecosystems and, most importantly, with the coastal wetlands, *viz.* mangroves. The Maldives has the seventh largest coral reef system in the world. The Maldivian wetlands are said to be highly productive, which serve as a source of food and other ecological services for the people. As the Maldives is not a heavily populated country, there is not much pressure on the coastal ecosystems, but still there is a gradual deterioration due to the effects of climate change and dumping of waste in the sea and along the coast areas. The pressure from land reclamation, timber harvest, aquaculture and tourism also results in loss of coastal biodiversity.

The wetlands of the Maldives are mostly located within or partly along the coast (Anon 2012) and are either fresh or brackish water. Of the 1190 Maldivian islands, only 41 islands have wetlands. In the Maldives, coral reefs are not classified as wetlands. The wetlands and coral reef ecosystem of the Maldives are the major contributors to the economy of the country. An earlier study showed that 71% of national employment, 49% of public revenue, 62% of foreign exchange, 98% of exports and 89% of gross domestic product (GDP) are biodiversity dependent in the country (Anon 2012).

2.2.2.3 India

2.2.2.3.1 Mainland India

The wetland inventory of India prepared by the Space Applications Centre (2011) and published as 'National Wetland Atlas' categorises the wetlands of India into two: inland and coastal. There are 188,470 inland wetlands, which spread over 10,564,899 ha in the country. Similarly, the coastal wetlands are 13,033 in number and are spread over 4,140,116 ha. The area of inland wetlands (69.23%) is much more than coastal wetlands (27.13%). These wetlands encompass numerous varieties of flora and fauna and are the hotspots of biodiversity (Venkataraman 2008).

The country has a landmass area of 3,287,590 km² and has a long coastline of 5422 km that spreads across nine states and two union territories (Venkataraman 2008). The coastline of India is resourced with mangroves, coral reefs, sand dunes, mudflats, salt marsh, seagrass beds, turtle nesting sites and bird nesting grounds. The country's seaward jurisdictional area, which extends to the EEZ, is about 2,290,278 km². The coastal wetland spread along the coast of India accounts to about 3,703,971 ha that comprises lagoons, creeks, sand/beach, intertidal mudflat, salt marsh, mangroves and corals. These wetlands serve as habitats for several migratory and resident birds, thousands of coastal aquatic vertebrates and invertebrates.

India has 26 wetlands, declared as Ramsar Sites, of which five are coastal wetlands, *viz.* Ashtamudi Wetland and Vembanad-Kol Wetland of Kerala, Point Calimere Wildlife and Bird Sanctuary of Tamil Nadu, and Chilika Lagoon and Bhitarkanika Mangroves of Odisha (Sarkar 2011). The coastal wetlands of India are witnessing steady depletion of their ecosystems, leading to decline in a wide variety of species, few of which are 'threatened'. India has put in force a number of policies and legislations to govern and regulate the coastal wetlands for the purpose of restoring and protecting the ecosystems.

2.2.2.3.2 Island Groups in India

India is surrounded by water on all three sides with the Bay of Bengal Sea in the East, the Arabian Sea in the West and the Indian Ocean in the South. The major island groups of India are the Andaman and Nicobar Islands and the Lakshadweep group of islands.

Andaman and Nicobar Groups of Islands

The Andaman and Nicobar Islands in the Bay of Bengal form an archipelago of 1382 islands, islets and rocks. The islands are home to highly diverse terrestrial and marine ecosystems, with a variety of habitats ranging from densely forested hills to sandy beaches and some of the intact coral reefs. Mangroves occupy an area of 614 km² in Andaman Islands and 3 km² in Nicobar Island (Ragavan et al. 2014). The mangroves of Andaman and Nicobar Islands are recognised as the best in the country in terms of density and growth (Dagar et al. 1991).

Lakshadweep Islands

The Union Territory of Lakshadweep, a group of 11 inhabited and 25 uninhabited tiny islands, is geographically isolated and segregated at 200–400 km from the Malabar Coast along the west coast of India. The only atolls in the Indian Union, they attract the attention of naturalists for centuries. The archipelago consists of 12 atolls, three reefs and five submerged banks. Except Androth, the biggest island, all other islands have a lagoon. Bitra is the smallest island with a large and magnificent lagoon. Pitti or the bird island, which is designated a bird sanctuary, is a small reef with a sand bank visited by thousands of birds for nesting (James 2011). The islands range in area up to 440 ha. Seagrass zones are conspicuous in the lagoons of all atolls except Bitra and Kiltan. They form dense beds alongside the islands in calm zones (0.5–3.0 m depth). Mangroves are limited to Minicoy Island on its south-eastern and south-western sides, of which one site is landlocked and the other opens to seawater (Nasser et al. 1999).

2.2.3 Wetland Biodiversity of the Small Island Nations in South Asia

2.2.3.1 Sri Lanka

Sri Lanka's varied coastal habitats include estuaries and lagoons (126,989 ha), mangroves (6083 ha), seagrass beds, salt marshes (23,797 ha), coral reefs and large extent of beaches including barrier beaches, spits (5621 ha) and dunes (15,546 ha). These habitats contain a significant part of the country's biodiversity (Table 2.2).

Sri Lanka's tidal variation being low (rarely exceeding 75 cm), mangroves generally occur as a narrow belt in intertidal areas of lagoons, estuaries or associated islands and river mouths. However, they do not occur in all intertidal areas, and they are confined to the areas with low wave action. Although mangroves rarely extend beyond 1 km landwards from the mean low tidal level (Amarasinghe 1996), they may spread to the upper limit of brackish water intrusion areas in some riverine

Table 2.2 Major coastal and marine biodiversity of Sri Lanka

Group	Number of species
Freshwater fish (riverine or marsh dwelling)	65
Marine fish	1800
Marine turtles	5
Marine mammals	38
Corals	183
Mangroves	40
Mangrove fishes	53
Birds	100
Reptiles	33
Seagrass	10

Source: MOFE (1999), Ekaratne (2000) and CZMP (2003)

estuaries, extending even up to a distance of 20 km (e.g. Galatara in the Kalutara district, CRMP 2002).

Reefs in Sri Lanka are categorised under coral reefs, sandstone reefs and rocky reefs. All three habitats are distinct, but may be found mixed together (Rajasuriya and White 1995). It has been estimated that about 2% of the coastline contains fringing coral reefs (Swan 1983). Barrier coral reefs, consisting of ridges of coral lying some distance from the shore, parallel with it and forming a broad 'reef lagoon', are rare in Sri Lanka; but some are found at Vankalai and Silavathurai in the north-western coast (Rajasuriya and White 1995). Seagrass beds often occur in association with coral reef ecosystems or estuaries and lagoons such as the basin estuaries and lagoons of Puttalam, Negombo, Mawella, Koggala, Kokilai, Jaffna and Batticaloa (CRMP 2002).

Around 23,797 ha of salt marshes exist in the country (CRMP 2002). While the conditions under which salt marshes occur vary, they are often close to landward margin of the intertidal zone where the soil salinity is relatively high due to insufficient freshwater runoff to flush out the accumulated salts. Extensive salt marshes occur in the Mannar area (mainly on tidal flats containing about 56 species of marsh vegetation) in the coastal belt from Mantai to Vankalai. Patchy salt marshes occur mainly in sediment lagoon/estuarine areas such as Hambantota, Puttalam, Kalpitiya and Mundel (Samarakoon and Pinto 1988).

2.2.3.2 The Maldives

In contrast to the relatively impoverished terrestrial biological diversity, marine biological diversity in the Maldives is outstanding in richness. Indeed, the marine biodiversity of the archipelago is among the richest in the entire region, and the Maldives have been recognised as having one of the world's most diverse marine ecosystems. More than 250 different species of hermatypic corals have been reported from the Maldives. Over 1200 species of reef fishes, as many as 5000 different shell species, around 200 sponge species, more than 1000 species of marine crustaceans and over 100 species of echinoderms are reported from the Maldives. Large ranges of different types of marine algae have been documented. Different species of sharks, eels, rays, dolphins, whales and aquarium fish are commonly observed throughout the archipelago. Five species of endangered turtles, namely, loggerhead turtles, green turtles, hawksbill turtles, olive ridley turtles and leatherback turtles, are known to inhabit Maldivian waters (Kalvinde 1999).

2.2.3.3 Island Groups in India

2.2.3.3.1 Andaman and Nicobar Islands

Flora

From the islands, 2426 species of angiosperms, 8 species of gymnosperm, 300 species of medicinal plants, 130 species of orchids, 150 species of fruits and vegetables, around 10 species of oil-yielding plants and 34 species of mangroves are reported (George 2015). There are also several introduced species, besides agricultural crops and fruit trees, including Australian trees such as *Acacia auriculiformis*

and *Eucalyptus* sp. Other introduced species include large palms, bamboos, fence plants and ornamental garden plants.

Fauna

Andaman and Nicobar Islands are considered as paradise of faunal diversity (both terrestrial and marine), with 8425 species of fauna, of which 846 species are endemic (Chandra et al. 2012), nearly 67% of them belonging to the marine habitat. It is known that 12 out of 22 animal phyla found in these islands exist in sea. Of these, 5 species of sponges, 6 species of Gastrotricha, 56 species of crustaceans, 2 species of marine molluscs and 2 species of echinoderms are endemic to these islands. The coral reefs of the islands, with an estimated area of 12,000 km², rank next only to the Australian Great Barrier Reef, in terms of biodiversity, in the world. Seagrass beds occur in shallow coastal waters and sheltered bays where clear water allows light penetration. Raghunathan et al. (2013) compiled the marine biodiversity of ANI based on the surveys conducted by researchers elsewhere and concluded the presence of more than 5846 species belonging to 13 major groups (Table 2.3).

Table 2.3 Marine biodiversity in ANI in relation to those in India and the world

Category	Number of species		
	World	India	ANI
Porifera (sponges)	5100	519	146
Platyhelminthes	11,690	42	38
Cnidaria	10,211		789+
Scleractinian corals	1574	478	424
Gorgonians			51
Antipatharians			8
Sea anemones			31
Others			275
Polychaeta	12,632	428	191
Crustacea	24,375	2970	837
Mollusca	56,235	3751	1586
Polyplacophora			12
Gastropoda			888
Ophisthobranchia	6500	456	296
Cephalopoda			332
Bivalvia			350
Scaphopoda			7
Echinodermata	7291	765	430
Fishes	16,733	2546	1485
Marine reptiles	110	35	30
Marine mammals	135	25	
Seaweeds	7450	844	300+
Seagrasses	68	16	9
Mangroves	75	40	35
Total	160,179	12,913	5846+

Source: Raghunathan et al. (2013)

The small island conglomerations are often hotspots in terms of biodiversity and have a great probability of having endemic fauna due to their remote locations and isolation from other landmasses, which calls for protection of the organisms and their habitats from over-exploitation, pollution, destructive fishing techniques and habitat loss.

Parks and Sanctuaries

The archipelago has four national parks: Mahatma Gandhi Marine National Park, Mount Harriet National Park, Rani Jhansi Marine National Park and Saddle Peak National Park, all in the Andaman Islands. The Nicobar group of islands have two national parks and a biosphere reserve.

2.2.3.3.2 The Lakshadweep Islands

Marine Diversity

Marine biodiversity of Lakshadweep islands is very rich with 95 species of sponges, 172 species of corals, 80 species of crustaceans, 260 species of molluscs, 84 species of echinoderms, 396 species of fishes, 4 species of turtles, 142 species of birds, 6 species of marine mammals, 7 species of seagrass and 3 species of mangroves.

Seaweeds and Seagrasses

Marine algal distribution is generally sparse and heterogeneous. Sixty-two genera and 114 species of seaweeds have been recorded from Lakshadweep (Kaliaperumal et al. 1989). Among them, the most abundant species are the *Gracilaria edulis*, *Sargassum duplicatum* and *Turbinaria ornata* that grow luxuriantly on the lagoon beds of many islands. Seagrasses are found in all the islands of Lakshadweep, and seven species (*viz.* *Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis*, *Halophila ovata*, *Halophila ovalis*, *Syringodium isoetifolium* and *Thalassia hemprichii*) have been recorded from the islands. The most common of these are the *C. rotundata* and *T. hemprichii*, which the green turtles predominantly forage upon in the lagoon (Jagtap 1987). The major reasons for destruction of seagrass beds were anthropogenic activities and grazing by turtles and sea urchins.

Mangroves

Mangroves have been recorded in Minicoy and Kalpeni. The extent of mangrove area in Minicoy is 13 ha, while in Kalpeni, it is in the emerging stage. *Avicennia marina*, *Bruguiera cylindrica* and *Ceriops tagal* have been reported from Minicoy (Nasser et al. 1999).

Corals

In total 172 species of corals have been reported from the islands of Lakshadweep (Pillai 1971; Suresh 1991; Navas 1993; Jeyabaskaran 2009; Balasubramanian and Ajmal Khan 2010). *Acropora*, *Porites*, *Montipora* and *Heliopora* are the widely distributed genera of corals in Lakshadweep group of islands (Wafar 1986; Pillai and Jasmine 1989). Besides, *Fungia* and *Favia* are also reported from the island

lagoons (Wafar 1986; Pillai 1989). Various anthropogenic activities like quarrying corals, removal of surface soil (Pillai 1986), domestic pollution, destructive fishing activities and other factors like coral predators, cyclones and elevated sea surface temperature impact the island reefs (Arthur et al. 2006; Arthur 2008).

Mollusca

In total 260 species of molluscs have been reported from Lakshadweep. The giant clam *Tridacna* (*Tridacna maxima*) is found on the reef flat of many islands, while octopuses (*Octopus vulgaris*, *O. membranaceus* and *O. cyaneus*) are common in the lagoon bottom. In addition to this, 48 species of gastropods and 12 bivalves have also been documented from the Lakshadweep archipelago (George et al. 1986; Appukuttan et al. 1989). Among the gastropods, cone shells (*Conus leopardus* and *C. litteratus*) and cowries (*Cypraea caputserpentis* and *C. tigris*) are the commonly found molluscs in the island reef bottom.

Sponges

Ninety-five species of sponges are identified from the Lakshadweep group. Only the class Demospongiae is documented from this area. Being the earliest metazoans, sponges are known for their survival instincts since the beginning of metazoans in the history of life. They support diverse groups of associated bacteria, because of which sponges are looked upon as the major targets for 'drugs from the sea' programmes globally. Tropical islands such as Lakshadweep and Andaman are rich sources of sponges and can play a big role in marine bioprospecting and conservation mariculture programmes.

Marine Turtles

Four species of turtles, namely, *Chelonia mydas* (green turtle), *Lepidochelys olivacea* (olive ridley), *Eretmochelys imbricata* (hawksbill) and *Dermochelys coriacea* (leatherback), have been reported in Lakshadweep islands (Bhaskar 1978). The green turtle (*Chelonia mydas*) is the common species that nests in inhabited islands, whereas hawksbill (*Eretmochelys imbricata*) and leatherback nest more frequently in the uninhabited islands. The major threats of the turtles include degradation of nesting habitats, disturbances to nesting habitats due to beach lighting, recreational activities and incidental catching. The conservation measures for marine turtles include monitoring nesting sites, avoiding infrastructure development close to the shore and tracking their migration through tagging initiatives.

Birds

Over 140 sea/shorebirds have been reported from these islands including one endangered species, Barau's Petrel (*Pterodroma barau*), seven near-threatened species (Swinhoe's Storm Petrel, *Oceanodroma monorhis*; Jouanin's Petrel, *Bulweria fallax*; Black-tailed Godwit, *Limosa limosa*; Eurasian Curlew, *Numenius arquata*; Ferruginous Duck, *Aythya nyroca*; Pallid Harrier, *Circus macrourus*; and Lesser Flamingo, *Phoeniconaias minor*) and one vulnerable species (Great Knot, *Calidris tenuirostris*) (Avibase 2016). Sooty Tern (*Sterna fuscata*) and Brown Noddy (*Anous*

stolidus) breeding have been reported from these islands (Pande et al. 2007). The Pitti island of Lakshadweep is inhabited by three species of terns, namely, the Noddy Tern (*Anous stolidus pileatus*), Sooty Tern (*Sterna fuscata nubilosa*) and the Brown-winged Tern (*Sterna anaethetus*). Besides, there are Grey plovers, Golden plovers, Crab plovers, whimbrels, curlews and Common sandpipers around the islands (Betts 1938; Mathew and Ambedkar 1964; Daniels 1999).

Marine Ornamental Fishes

Over 160 marine ornamental fishes, belonging to 20 families, have been reported from nine islands in Lakshadweep (Murty 2002). Among them, Labridae (wrasses, 32 species) has the largest number of species, followed by Pomacentridae (damsel-fishes, 26 species), Serranidae (groupers, 09 species), Acanthuridae (surgeonfish, 17 species), Chaetodontidae (butterfly fish, 14 species), Scaridae (parrotfish, 12 species), Mullidae (goatfish, 10 species), Balistidae (triggerfish, 6 species), Holocentridae (squirrelfish, 11 species), Apogonidae (cardinal, 9 species), Siganidae (rabbitfish, 3 species), Scorpaenidae (lionfish, 3 species), Canthigasteridae (putter fish, 2 species), Pomacanthidae (angelfish, 2 species), Tetraodontidae (puffer/porcupine fish, 2 species), Synodontidae (lizard fish, 1 species), Ostraciontidae (boxfish, 1 species) and Zanclidae (Moorish idol, 1 species).

2.3 Challenges to the Island Wetland Ecosystems vis-a-vis Biodiversity

The major challenges of the UN classified SIDS include economic dependence on import of various commodities, communication and connectivity, hiked prices, unemployment, loss of land due to subsidence and erosion and vulnerability to natural calamities and oceanic changes. The challenges are not any different in the two island territories in India. Due to their small size, remote locations and growing human populations, the small islands have extremely fragile economies. Low availability of resources, high costs of living and high vulnerability due to natural disasters are common features. The 2004 tsunami caused enormous damage to the coastal ecosystems like coral reefs and mangroves, human life and material goods in these islands.

2.3.1 Climate Change

Climate change is emerging as one of the main challenges that humankind will have to face for years to come. It is projected to affect the lives of billions of people around the world in the next few decades. It is also expected that the extent of vulnerability may differ widely in different regions of the globe, but no region or country would be an exception to its impacts. It could become a major threat to world food security, as it has a strong impact on food production, access and distribution.

Developing and lesser developed island states/nations are more vulnerable to climate change (Anon 2007).

Island ecosystems are intrinsically linked to climate in many ways. Sea level rise is a climate-related phenomenon with a foremost impact on coastlines. It has now been reasonably established that the climate change is happening and the global average temperature has risen by about 0.6 °C over the twentieth century. Globally, the ten warmest years on record all occurred after 1991. A temperature rise of 1–2.5 °C will have serious effects, including increase in the severity and frequency of extreme weather, changes in rainfall patterns leading to severe water shortages and/or flooding, melting of glaciers resulting in flooding and soil erosion and an increased risk of extinction of plant and animal species (Dam Roy and George 2010). Further, SLR will lead to destruction of coasts worldwide with some islands possibly facing complete inundation. Small Island Developing States are highly dependent on the ocean; the fragile relationship of the environment and human population with the ocean makes the resident population vulnerable to natural calamities.

2.3.2 Extreme Events

Tsunami, tropical cyclones, floods and droughts are the most destructive severe weather and climate extreme events, which would affect countries in the South Asia. A classical example of extreme events in South Asia is the tsunami of 26 December 2004. On that day, a massive earthquake of magnitude 9.0 struck the coastal area of northern Sumatra in Indonesia. These earthquakes triggered tsunamis that affected Indonesia and neighbouring countries (India, Malaysia, the Maldives, Sri Lanka and Thailand) in Asia and the east coasts of Africa (Somalia and Yemen), causing serious damage to the coastal areas and small islands, loss of life to an extent of 250,000 persons. The reports indicate that natural ecological systems, such as coral reefs, mangroves and wetlands, had suffered extensive damages due to this (Ramachandran et al. 2005). Physical damages might affect the structure and function of coastal ecosystems and their ability to sustain marine life and support livelihood of coastal communities.

2.3.3 Coastal Erosion

Erosion of land or the removal of beach or dune sediments by wave action, tidal currents, wave currents or drainage due to natural or anthropogenic causes are the issues confronting the islands. While in the mainland, the littoral transport is interfered by coastal structures that include groynes, ports and jetties; the rise in sea level also plays a major role in coastal erosion in case of islands. Coastal erosion is a long-standing problem in Sri Lanka, aggravated in recent years due to human interferences in natural processes.

Over 80% of the land area in the Maldives is less than 1 m above mean sea level, and hence the islands of the Maldives are very vulnerable to inundation and beach erosion. If the sea level rises by 01 m, the Maldives will be submerged under water (Turner et al. 2001). Presently, 50% of all inhabited islands and 45% of tourist resorts face varying degrees of beach erosion. Climate change and projected SLR would aggravate the present problem of beach erosion.

2.3.4 Population Pressure

Most settlements in small islands with the exception of some of the larger Melanesian and Caribbean islands are located in coastal region. Rapid and unplanned movements of rural and outer island residents to the major centres are occurring throughout small islands, resulting in deterioration of urban conditions. High concentrations of people in urban areas create various social, economical, infrastructural and political stresses and make people more vulnerable to short-term physical and biological hazards, such as tropical cyclones and diseases. Anomalous sea surface temperature leads to stronger and frequent cyclones, which in turn upsets the food and drinking water sources, thus resulting in disease outbreaks. Population pressure increases the vulnerability to impacts of climate change and SLR, due to reduction in their adaptive capacity.

2.3.5 Habitat Destruction

Coastal and offshore developments including land reclamation, dredging and disposal, construction of ports and jetties, desalination plants, large-scale aquaculture, etc. adversely affect marine biodiversity. Though these issues are confronted by all coastal environments, the issue of land reclamation and unplanned development are particularly acute for the small island conglomerations.

The ecological systems of small islands and the functions they perform are sensitive to the rate and magnitude of climate change and SLR. Both terrestrial ecosystems on the larger islands and coastal ecosystems on most islands have been subjected to increasing degradation and destruction in recent decades. For instance, analysis of coral reef surveys has revealed that coral cover across reefs in the Caribbean has declined by 80% in just 30 years, largely as a result of continued pollution, sedimentation, marine diseases and overfishing (Gardner et al. 2003).

2.3.6 Over-exploitation

The most important resource of any small island is the freshwater. Most small islands have limited sources of freshwater. Atoll countries and limestone islands have no surface water or streams and are fully reliant on rainfall and groundwater

harvesting. Many small islands are experiencing water stress at the current levels of rainfall input, and extraction of groundwater is often outstripping supply.

2.4 Conservation of Sensitive Wetlands and Habitats

In the year 2010, India passed the National Wetland Rules to protect and conserve the wetlands of the country. As many wetlands in India are seriously threatened by reclamation through drainage and landfill, pollution, hydrological alterations and over-exploitation of their natural resources resulting in loss of biodiversity, the government has taken action to protect the biodiversity and to retain the goods and services provided by the ecosystems. The Coastal Regulation Zone (CRZ) Notification, 2011, and the Island Protection Zone (IPZ), 2011, provide conservation of all the ecologically sensitive wetlands along the mainland coast and islands with stringent regulatory provisions.

The Asian Wetland Directory described 41 wetland sites of international importance in Sri Lanka, covering 274,000 ha. They could be divided into three broad categories (i) inland freshwater wetlands (e.g. rivers, streams, marshes, swamp forests and villus), (ii) salt water wetlands (e.g. lagoons, estuaries, mangroves, seagrass beds and coral reefs) and (iii) man-made wetlands (e.g. tanks, reservoirs, rice fields and salterns). Central Environmental Authority of Sri Lanka (CEA) formulated the Wetland Conservation Project in 1990 to protect the wetlands of Sri Lanka. Nearly 30% of the identified sites were under some form of protection, whereas 28% were completely protected (Derek 1989). A significant number of the internationally important sites in Sri Lanka were reported to be under moderate or high threat. Most of the low-lying wetlands are buffer zones for human dwelling too.

The Maldives has enabling policy for conservation of wetlands and coral reefs from the standpoint of biodiversity conservation and climate change adaptation. The National Biodiversity Strategy and Action Plan and the third National Environmental Action Plan (NEAP) stress the importance of protecting and restoring coral, wetlands and mangrove ecosystems. The Strategic Action Plan (SAP; also called National Framework for Development 2009–2013) stresses conserving and sustainably utilising biological diversity to ensure maximum ecosystem benefits.

2.5 Epilogue

The United Nations has been instrumental in recognising the environmental importance and economic fragility of the small island states. At the conference in Rio de Janeiro during 1992, 179 nations acknowledged that these islands were vulnerable to global warming and SLR. The United Nations has also been conducting awareness campaigns among the individual islands to explain the effects of overfishing, global warming and SLR to the local people apart from major efforts in policymaking and conservation of the natural resources. The United Nations Organization announced 2014 as the ‘International year of Small Island Developing States’, in

order to garner the focus of different countries to the plight of small island nations under changing climate.

While legal frameworks and regulations contribute for checking over-exploitation and conservation of resources, community sensitisation and participation are crucial for the success of any conservation agenda. The first step towards conservation and management of coastal ecosystems is to map their boundaries. High-resolution mapping of all resources like coral reefs, mangroves and seagrasses is crucial as the services they provide are adversely affected by a wide variety of human activities. Besides ecologically sensitive ecosystems, sensitive coastal habitats like turtle nesting grounds, horseshoe crab habitats and bird foraging/breeding grounds have to be mapped. Turtles are known to migrate extensively, and frontier tools like satellite telemetry should be deployed to track their migratory patterns and map their nesting grounds. Species cataloguing is important in understanding the diversity within a region, country and collectively in the world. Besides, it is also essential for ascertaining the distribution and abundance of a particular species. While conventional methods are crucial, in order to fast-track the process and to bridge the wide gap between the estimated and actually documented species, frontier tools such as space technology (development of spectral signatures), biotechnology (development of DNA signatures) and information technology (development of digital database) are to be deployed for the purpose.

It is important to monitor, analyse and exchange lessons on the conservation of the coastal resources, and it is vital for securing the coastal livelihoods and preserving the biodiversity and habitats. Mapping of critically resilient ecosystems could help in restoration processes. Preserving nursery zones, nesting sites and foraging area could help in protecting and perpetuating various marine organisms. The key balance in the management of small island conglomerations lies in the possibility of allowing development with minimal impact on the environment. Integrated Coastal Zone Management (ICZM), a concept that is globally being used, holds the key for sustainable management of the fragile environs of the islands.

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