

Vulnerability and Adaptation of Ecologically Sensitive Mangrove Habitats to the Changing Climate

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Islands of Maldives atolls in the Indian Ocean on Chagos Laccadive Archipelago (Fig.1) are geologically of very recent origin. However, they are relatively older formations compared to Lakshadweep group of islands, in the Arabian Sea on the same archipelago, which are in the process of genesis (Ahmad, 1972). Relatively well established seagrass and mangrove habitats from Maldives islands are suggestive of their earlier formations and more stability, compared to those from Lakshadweep (Jagtap, 1998; Jagtap and Untawale, 1999). Most of the Maldives islands except Male and other similar islands impacted by tourism activities, harbor better formations of seagrass and mangrove habitats (Jagtap and Untawale, 1999).

Maldives consist of 26 atolls comprising 1190 islands within 0° 42' S – 7° 05' N latitude along 73° E Meridian (Fig 1). Atolls are mostly circular coral reefs enclosing lagoons (Stoddart, 1973), and islands without windward or seaward side remain above sea level. Soils mostly young, vigorous and shallow, are composed mainly of coral debris admixed with sandy loam containing humus. Soils are rich in Ca and alkaline in nature with very poor water retaining capacity (Forberg, 1976).

The region lies outside the cyclone zone. Climate generally remains warm and humid with atmospheric temperature ranging from 25.7 – 30.4°C (IMD 1931-60). An average annual rain is 1950 mm, received mainly from south-west monsoon, during May- October. Mean tide is about 0.7 m while spring tide reaches to 0.9m.

Extensive mangrove formations (Fringing and basin types) exist on the islands of the north atolls. However, Male atoll is devoid of mangroves due to their total reclamation mainly for tourism and urbanization. Mangrove flora comprised of 12 spp (Table 1) and dominated by *Bruguiera cylindrica*, followed by *Lumnitzera racemosa*, *Ceriops tagal* and *Rhizophora mucronata*. Many of the islands exhibit luxuriant and tall (7-20m) mangroves with an average density of 7 trees 100m² (Table 2). The regeneration rate was observed to be very high in rhizophoraceae members and *Avicennia marina* (Jagtap and Untawale, 1999).

Species like *Thespesia populnea*, *Hibiscus tiliaceus*, *Pandanus spp*, *Pemphis acidula*, and *Scaevola taecada* were reported to be commonly associated with mangroves habitats (Table 1). *Pemphis*

acidula acts as pioneer species on newly deposited soil, while *S. taccada* remain dominated along the sandy shores.

Ecologically sensitive marine habitats (ESMH) such as corals, seagrasses, mangroves and sand dunes being at the proximity of sea, form potential natural barriers to stabilize and protect shoreline and sea bottom from calamities like cyclones, hurricanes, tsunamis etc. These habitats are also of a great significance in land building by enhancing sedimentation, and keeping pace with sea level changes. Reclamation of mangroves from Haa Dhaolu islands of Maldives, in the north has resulted in a severe erosion. This has been noted in the other parts of the world that increasing anthropogenic activities in low lying regions have deteriorated these ecologically important habitats, subjecting coastal zone to natural hazards. Oceanic islands, particularly group of islands of Laccadive archipelago are more unstable and at a great risk of predicted sea level rise (SLR). These atolls and islands are 1-2 m above sea level, and feared to be flooded in the near future (IPPC, 2001).

The CO₂ concentrations have been predicted to reach 840 ppm by 2100, raising global temperature and sea level by 0.3°C and 6mm 10Yr⁻¹, respectively (UNEP / UNESCO, 1992). The sea level may rise up to 94 cm of present mark, even though CO₂ levels are stabilized at 750 ppm (Parry and Livermore, 1999). The decade of 1990 was the warmest (Attri, 2003). The rainfall increased by 0.2-1% 10Yr⁻¹ in the northern hemisphere and in tropics (between 10°N to 10°S), while it decreased by 0.3% in the subtropics. The global sea level has risen 10-20cm during the Twentieth century. General Circulation Models (GCM) projected a 9.88cm rise in sea level, increased extreme weather events and precipitation over the Asian region (UNEP / UNESCO, 1992, IPCC, 2001). However a lot is discussed on global SLR, INQUA (2000) reports fall in sea level at Maldives with firm morphological evidence (Morner et al., 2003). The flooding, erosion and shoreline changes from Maldives during recent year have been strongly linked to anthropogenic activities (INQUA, 2000, Morner, et al., 2003).

Considering IPCC scenarios, global warming and resultant SLR would immediately impact the shallow and internal habitats. The present day mangroves exist between 0.4–0.9 m above mean sea level (Ellison, 1989). The SLR of 50-350cm during next 100 years (Hoffman, 1984, Houghton, et al., 1990), will severely impact ecologically sensitive habitats from low lying region. Mangroves could cope up with a SLR of 8-9cm 100 Yr⁻¹. An excess sedimentation of 9 to 12 cm 100 Yr⁻¹, would be very stressful as mangroves may neither grow nor produce peat at SLR of 12cm 100 Yr⁻¹. Various component of an ecosystem may alter their response pattern to increased temperature and CO₂ levels and changes in hydrological set up in the surroundings. The increased concentrations of CO₂ may help in decreasing the stomatal conduction to check transpiration and thus improving the growth and productivity in different species of mangroves. However, there has to be an optimum limit for individual species to respond positively to CO₂ concentrations in ambience. The net increase in productivity of mangroves has been reported at concentration of 700 ppm of CO₂ and in combination with salinity concentration of 25 ppt (Ball et al., 1997). The increased temperature, CO₂ concentration and salinity in the surroundings would certainly increase stress on these habitats.

Mangroves at Maldives either occur as pure stands of one or two species in the basins or shallow depressions, and mostly extend below fluctuating water (Fig. 2). Frequently the tidal water enters and escapes through underground porous coral debris and sand. In a few of the islands (Funadhoo, Hithadhoo, Shariyani and Addu) mangrove formation are of fringing type (Jagtap and Untawale,

1999). The mangroves from this small oceanic island could be compared with those of estuaries or backwaters islands along the in the southwest coast of India. The tidal column along the coast of Kerala ranges from an average of 0.3 to 1.04m, very close to Maldives atolls. The state is known for its extensive backwater system and Kayals (minor estuaries). The landward extension of tidal water along these water bodies limited by embankments. Therefore, mangroves formation occurs in narrow fringes before embankment, and islands within (Fig. 3). The mangroves exist $\approx < 1$ m above present sea level. The vertical rise in the water column due to the predicted SLR, and the limitation of landward margins (Fig. 3), may result in water logging and ultimately the death of mangroves as well as other dependent and associate biota. Mangroves from Maldives may be impacted the same way. Basin as well as fringing mangroves may be water logged totally, thus resulting in permanent loss of habitats and biodiversity. Loss of mangroves and similar habitats aggravate the fury of natural calamities.

Reclamation of mangroves has resulted in severe erosion at a number of islands from Maldives, however, it is more prominent at Male, Haa Dhaalu. Emerging atolls, such as Maldives and Laccadive are unstable and likely to suffer immediate damage from adverse condition of sea including SLR. Natural habitats like mangroves, sea grassess, sand dune vegetation and coral reefs form an asset of the planet earth, particularly of small oceanic islands from the ecological and socioeconomic point of view. Some of the poorly inhabited and uninhabited islands of Maldives exhibit luxuriant mangroves formation, which are required to be protected and conserved as germ plasm centres. This is a great potential for afforestation and restoration of mangroves. The sandy shore could be protected by the dense plantation of *Scaveola* and *Pempis* spp, as well as by protecting and restoring sand dune flora.

Irrespective of SLR (IPCC, 2001) or sea level chop (Morner *et al.*, 2003), Maldives islands are likely to be under severe threat of flooding due to constantly increasing human pressure. Conservation and restoration of various ESMH would not only enhance the productivity but greatly benefit in mitigation adverse impacts of natural as well as human created hazards.

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