Journal of the Andaman Science Association Vol. 26(1):14-23 (2021)
ISSN 0970-4183, Printed in India

Natural Resource Management vis-à-vis Climate Change Impacts on Lakshadweep Islands

Velmurugan, A[1]., Abdul Gafoor, V.M[2]. and John Mathai[3]

[1] *ICAR-Central Island Agricultural Research Institute, Port Blair*

[2] *Krishi Vigyan Kendra, ICARI-CIARI, Kavaratti, Lakshadweep*

[3] *Department of Agriculture, Government of Kerala, Thiruvananthapuram*

Email: velu2171@gmail.com

Abstract

The Union Territory of Lakshadweep, India is an archipelago located in the Arabian Sea. The lagoons of this island are very unique ecosystem of these islands which normally occurs in the western side of the islands. The islands are mostly flat, coralline origin having sandy to gravelly coral soils with low organic matter and water holding capacity. Fresh water is stored in the shallow lens located just below the surface of these islands. The coral ecosystem having more than 140 species provide ideal habitat for variety of flora and fauna. At the same time the observation indicated the sea level rise, change in sea surface temperature and rainfall pattern. Downscaling of some of the global level studies on climate change indicated possibilities for increase in climate extremes such as hot days, heavy rainfall and drought over these islands. Besides this, anthropogenic activities pose a major challenge to the sustainable utilization of natural resources of these islands. This paper summarizes the impact of observed and projected changes in climate on the natural resources of these islands.

Key words: *climate change, Tropical Island, natural resources, biodiversity, conservation*

Introduction

There is strong evidence that global warming over the last millennium has already resulted in increased global average annual temperature and changes in rainfall, with the 1990s being likely the warmest decade in the Northern Hemisphere at least. Climate variability and change have triggered natural disasters and climate extremes causing heavy losses of life and property. These changes is explained by the term climate change which refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007).

During the past century, changes in temperature patterns have, for example, had a direct impact on the length of growing seasons with significant implications for agriculture, land resources and forestry. Land cover changes, changes in global ocean circulation and sea surface temperature patterns, and changes in the composition of the global atmosphere are leading to changes in rainfall. These changes may be more pronounced in the Tropics and affect islands more than continental countries.

IPCC assessment of small islands (Mimura *et al*., 2007) showed that characteristics such as limited size, proneness to natural hazards, and external shocks enhance the vulnerability of islands to climate change. This conclusion was largely driven by the fact that the expected sea-level rise will exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements, biodiversity and facilities that support the livelihood of island communities. This is more pertinent to Lakshadweep islands located in the Arabian Sea. These islands are limited by not only geographical extent but also natural resources such as soil, water, crops, and minerals except marine resources (Sivaperuman *et al*., 2018). Thus a study was carried out by collecting published scientific information, subjecting it to pre-processing and interpreting them to understand the natural resources, climate changes and the interaction between them that drives the livelihood of the island population.

Study area

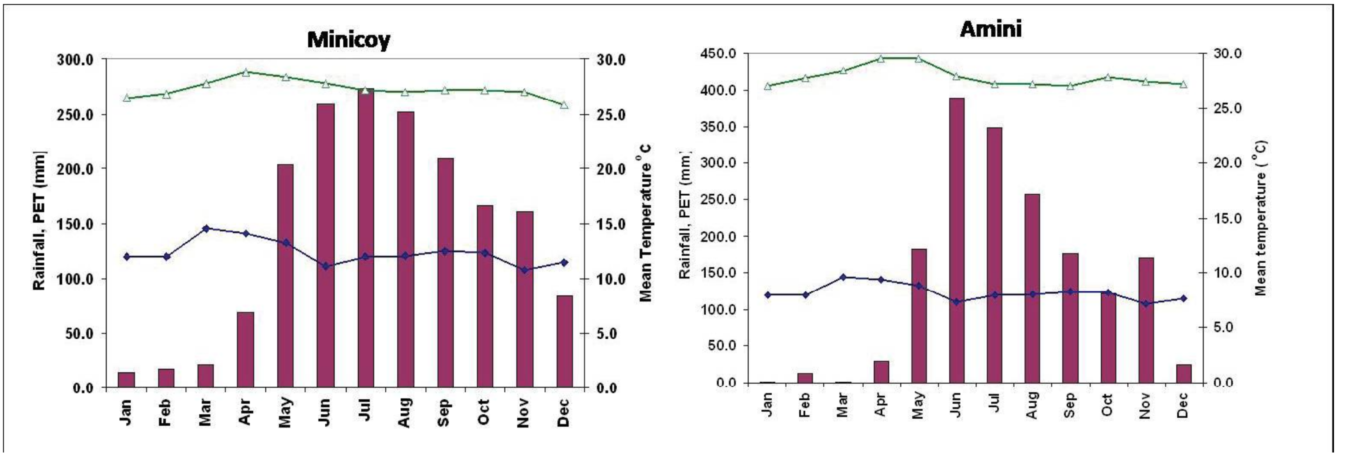
The Union Territory of Lakshadweep comprises of a group of islands in the Arabian Sea about 220 to

440 km off the Kerala coast between latitude 8 ° and 12 ° 30' N and between longitude 71 ° and 74 ° E. The Lakshadweep islands consists of coral formations built upon the Laccadive-Chagos submarine ridge rising steeply from a depth of about 1500 m to 4000 m off the west coast of India. There are in all 27 islands, 3 reefs and 6 submerged sandbanks (Figure 1). Only 10 islands are inhabited (Agatti, Amini, Andrott, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy).Each island is fringed by coral sands, and is marked by huge, shallow, calm lagoon on the western side which separates it from incoming swells of the outer sea by the wall of a reef made-up of massive coral boulders and live corals. The total geographical area of the territory is 32 sq. km. All land is classified as agricultural land and the land use area is 28.5 sq. km.

Climate of Lakshadweep

The overall climate of these islands is humid tropical monsoon type. The mean annual rainfall in this zone ranges from 1715 (Amini) to 1934 mm (Andrott) of which 80% is distributed from May to November. Annual rainfall decreases from South to North. Winds are light to moderate during October to March. Mean annual temperature ranges from 27.3 to 27.9°C. The annual potential evapotranspiration demand is about 1480 mm. The length of dry period ranges from November to April (approximately 5 and 6 months). The temperature and moisture regimes are *isohyperthermic* and *ustic*, respectively. Climatic diagrams for the Islands of Minicoy, Amini, Agatti and Andrott are given in Fig. 1. Rainfall is well distributed during May to November - December in all islands except Agatti where rainfall is well distributed only from May to September – October. Among different stations for which rainfall record is available, Agatti located in the East receives less total annual rainfall (1255 mm) while Andrott located in the west receives maximum total annual rainfall (1933). In contrast, summer monsoon (Post-monsoon) in Andrott is very less while Minicoy receives good amount of showers in 8-9 rainy days.

The water source is fully dependant on performance of rainfall. Ground water being very limited and tapping of excessive ground water lead to possible salinity hazards therefore, rainwater harvesting and storage should be part of island sustainable management plan. As soil moisture is very essential for the plants to complete its phenological stages, moisture stress or long dry spell will limits the species abundance and distribution. Further the plants will evolve to adjust to the existing pattern of dry and wet spell in these islands (Sivaperuman *et al*., 2018). Therefore, it is fairly correct to say that the climate of these islands largely decides the distribution of vegetation and indirectly affects the biodiversity. The sea surface temperature, salinity, rainfall and bathymetry besides other factors significantly influence the in-shore flora and fauna.



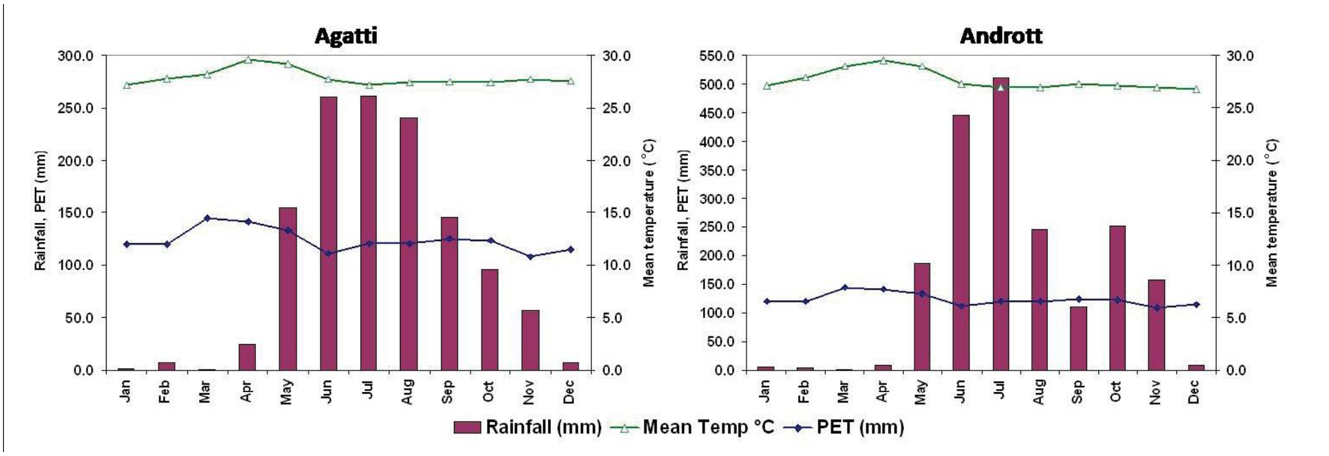


Fig. 1 Climatic parameters recorded at different Lakshadweep islands

Physiography and soil

The islands have a coral reef, stretching from north to south. The islands lie near the eastern side of the reef whereas on the western side lie extensive lagoons intervening between the shore and the reef (except in Andrott, which is east to west oriented and has a very indistinct lagoon on the southern side; Amini also has only an indistinct lagoon) Tinnakara is aligned east - west and has a vast lagoon on all sides. In general the eastern sides of all islands are replete with rocky relicts consisting of fossiliferous, clayey conglomerates of sandstone and are subjected to heavy action of waves and wind (Fig. 2). The land area of the islands is generally flat and the elevation is about 2-7 meters above MSL. They are vulnerable to storm and sea erosion.

The soil is structure less, formed by the disintegration of corals. Over 95% of soils consist of $CaCO_3$ without any sand, silt or clay. Soil is alkaline and is poor in organic content. The major factor responsible for soil formation in the islands was the action of physical forces like wind, waves and hot and humid temperature which disintegrated the hard coral reef. Presence of sand dunes is restricted in the west coast and slightly heavier texture, higher organic matter, better aggregation and cementation and presence of coarse fragments in the eastern side. As a result soil development progressed at higher level in the east when compared to the recent deposits in the west.

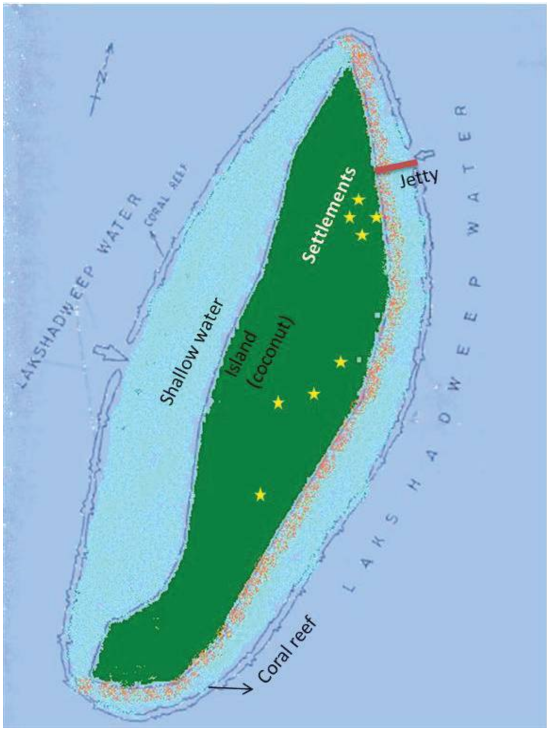


Fig. 2Typical Lakshadweep Island with large lagoon in its western side and eastern land made up of coral sand

Important bio-resources

Absence of hills and river systems coupled with shallow soil severely limits the variety of plants that can grow in these islands. In spite of that nearly 400 species of plants have been reported from these islands but no endemic plant species has been reported from Lakshadweep islands. The green cover of the island is mainly due to coconut groves which occupy nearly 80-85 per cent of the green cover. Coconut is the major crop grown here and the main industry in the islands is coconut fiber extraction and conversion of its fiber products. A large number of crop plants (rice, vegetables, fruits, tubers, spices and arecanut) were introduced from the Indian mainland, along with domestic livestock such as cattle, goats, domestic cats and poultry chicken.

Coconut covers more than 95% of the cultivated area in the islands and wide diversity is observed. Therefore, the diversity in coconut was analyzed. On the basis of fruit component analysis, coconuts have been classified as '*Niukafa*' and '*Niuvai*'. The ancestral '*Niukafa*' forms are characterized by a higher proportion of husk in nut and a low proportion of endosperm, traits which would have aided in its natural dissemination via oceanic currents to newer regions where they got established. In contrast, the '*Niuvai*' type, characterized by a low proportion of husk and high proportion of water in nut, were possibly selections made by humans (Harries, 1978).

Studies of coconut types of Lakshadweep classified Laccadive Micro, Laccadive Small, Laccadive Ordinary Tall (LCT) and Laccadive Dwarf as '*Niukafa*' types (Krishnamoorthy and Jacob, 1982). Later studies on the LCT collections from all over the islands indicated the existence of variations in LCT due to introgression and human selection (Fig. 3). These LCT populations were classified into '*Niukafa*' (elliptical fruit type) type, '*Niuvai*' (round fruit type) and introgressed forms (pear shaped fruit types). The elliptical shaped nuts identified showed striking similarity to nuts from Seychelles Islands suggests that these nuts might have reached Lakshadweep islands from the Indian Ocean islands (Rajesh *et al*., 2014).

(a). LCT nut types- Pear shaped, elliptical and round (from left to right).

(b). Longitudinal section of LCT nuts- elliptical, pear shaped and round (from left to right).

Fig 3.Variations in LCT type

In addition to higher terrestrial plant resources the island is endowed with seaweeds which can be utilized for improving the livelihood of islanders. A total of 114 species under 62 genera of seaweeds were recorded from Lakshadweep (Kaliaperumal *et al*., 1989). The Predominant seaweeds observed are Enteromorpha, Ulva, Codium, Laminaria, Turbinaria, Sargassum, Padina, Geldium, Gracilaria Hypena and Ceramium. It is estimated that the agarophyte resource with an abundance of *Gelidiellaacerosa* can be utilised for starting an Agar-agar unit. Agatti and Kadmat islands have more agarophytes. Caulerpa, Dictyota and Laurencia can be used as food in different forms. Siltation, sedimentation, erosion, accretion, dredging, construction, effluent discharge, sewage, grazing by fish and overexploitation are known to cause damage to seaweeds.

Climate change observations and prediction

In general small islands have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise, and extreme events (IPCC, 2007). More particularly Sea-level rise will exacerbate inundation, erosion and other coastal hazards, threaten vital infrastructure, settlements and facilities, and thus compromise the socio-economic well-being of island communities and states. In the Indian Ocean, reconstructed sea levels based on tide gauge data and TOPEX/Poseidon altimeter records for the 1950 to 2001 period give rates of relative sea-level rise of 1.5, 1.3 and 1.5 mm/yr (with error estimates of about 0.5 mm/yr) at Port Louis, Rodrigues, and Cocos Islands, respectively (Church *et al*., 2006). In the equatorial band, both the Male and Gan sea level sites in the Maldives show trends of about 4 mm/yr (Khan *et al*., 2002).

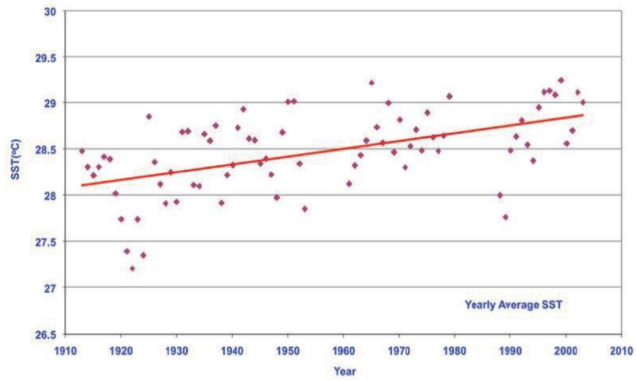
The oceanic and atmospheric gas concentrations tend towards equilibrium, increasing CO_2[atm] drives more CO_2 in to the ocean, where it dissolves forming carbonic acid (H_2CO_3) and thus increases ocean acidity: ocean pH has dropped by 0.1 (a 30% increase in hydrogen+ ion concentration) in the last 200 years (The Royal Society, 2005). In the Indian Ocean region the climate regimes of small islands are predominantly influenced by the Asian monsoon and maritime climate. These islands generally lack any large mountain system to force for orographic rainfall. Analyses of the air temperature showed that warming ranged from 0 to 0.5°C per decade for the 1971 to 2004 period in the Indian Ocean region (Trenberth*et al*., 2007). There are greater chances for increase in extreme events causing either moisture deficit or coastal flooding. Consequently any change or break in monsoon could adversely affect the flora and fauna besides decrease in freshwater resources of Lakshadweep islands. Under the SRES scenarios, small islands are shown to be particularly vulnerable to coastal flooding and decreased extent of coastal vegetated wetlands (Nicholls, 2004).

A few of the cyclonic depressions and storms, which form in the south Arabian Sea during April and May, affect the weather over the Lakshadweep Islands. During the post monsoon months of October to December also, a few of such systems originating in the Bay of Bengal and traveling westwards emerge into the south Arabian sea, and occasionally affect these islands. In association with these, strong winds are caused and heavy rains occur. Table 1 gives the number of storms and depressions which affected the region in the above mentioned months during the last 80 years. The devastation by the cyclone in many areas in the island resulted in uprooting and twisting of coconut trees, loss of vegetation, blowing away of roof tiles, damages to the buildings, coastal erosion and loss of domestic animals. In recent decade the number of extreme events has increased, rainfall distribution has decreased whereas the total amount of rainfall did not show any significant deviation from the normal. The post monsoon rainfall incidence has slightly decreased in Agatti, Hilton and other northern group of islands.

Table 1. Historical record of storms/cyclone and depressions which hit Lakshadweep islands

Month	Arabian Sea Storms/ Depression	Bay of Bengal Storms/ Depression	Average of last decade
April	4	-	1
May	1	-	1
October	8	-	2
November	9	7	1
December	3	3	2
Total	25	10	7

The summary of some of the studies carried out on the island vulnerability and reconstruction of past climate using coral calcification showed that the average SST around the Lakshadweep islands has increased by ~ 0.8°C from 1911 to 2003 AD (Fig. 4). This increase was greater than the mean SST increase of ~ 0.6°C for the global surface temperature. This relatively higher increase in annual SST indicate decrease in monsoonderived upwelling, lower calcification rates, since 1993, particularly in Porites corals of Lakshadweep region. This is consistent with the Great Barrier Reef records of decrease in calcification, indicating effects of ocean acidification and/or SST increase. Further the available data indicated decadal to inter-decadal climate variability in Lakshadweep corals.



(Source: Masood Ahmad, National Geophysical Research Institute, Hyderabad, India)

Fig.4 Trend in sea surface temperature of Lakshadweep waters

However, except for few observations made in other Indian Ocean islands for sea level rise and global satellite based observation of SST, the region is lacking observational records. Majority of the future projection on downscaled from global level projections which necessitates establishment of regional and global observational network to better predict the climate related changes.

Climate change impact on natural resources

Climate change can exacerbate anthropogenic threats such as extensive deforestation on biodiversity. Short- and long-term climate change impacts will interact with prevailing threats to species and ecosystems synergistically and in unpredictable ways to further complicate biodiversity conservation.

Impact on coral ecosystem

Sea level rise associated with increase in sea surface temperature is causing greater impact on the coral reef ecosystem. Any sea-level rise will allow waves to over-top the reefs, increasing coastal vulnerability to erosion and storms, at least until reef growth can catch up with sea-level. The more rapid the rate of sea-level rise, the longer the period of vulnerability, and the greater the possibility that present reefs will be unable to catch up and that they will drown. Some scientists have suggested that increased growth rate of coral reefs and more efficient sedimentation processes may offset some of the sea-level rise effects for atolls, at least for the next 50-100 years (Tegart *et al*., 1990). At the same time coral mining for building materials, and land reclamation on coral reef flats increase the risk of damage.

The rise in sea surface temperature due to El-Nino phenomenon during 1998 caused extensive coral reef bleaching impacting over 40 to 90% of live coral cover. Live coral cover was no more than 10% at Kadmat Island after the bleaching had happened. The hard corals of Porites species, found in abundance in the lagoons of the Lakshadweep islands, are facing a threat to their existence. Severe coral bleaching occurred during 1998, with mortality rates as high as 87% in some parts of Maldives and Lakshadweep Islands. Minor coral bleaching was observed in South Asia in March - April 2003 and 2004; the same months as massive bleaching occurred in 1998. This time coincides with the warm weather prior to the southwest monsoon. Coral bleaching was observed in India on some islands of the Gulf of Mannar, with 10 - 20% of massive corals bleached, but the majority recovered in the second half of the year.It is expected that 32 per cent of the reefs may be lost in the next 30 years if the threats are not reduced. Loss of healthy coral reefs will lead to elimination of primary sources of food, income and employment for millions of people around the world, as well as the extinction of many fascinating and beautiful marine species (Naseer, 2006).

Impact on sea grasses

The sea grass species prevalent in Lakshadweep islands (*Cymodoceaisoetifolia, Syringodiumisoetifolium, Thalassiahemprichii*) are affected with warming ocean temperatures, which is likely to result in distribution shifts, changes in patterns of sexual reproduction, altered growth rates, metabolism, and changes in their carbon balance (Seddon and Cheshire, 2001). High temperatures (above their ambient temperatures have caused large scale diebacks of *Amphibolis Antarctica* and *Zostera*spp. in southern Australia. In addition, oil spills, pollution, over exploitation and disturbance to the sea bed could adversely affect the sea grasses.

Mangrove ecosystem

There will be positive and negative effects on mangroves, it is highly uncertain exactly what the net outcome will be as local variability will be very high, and are site specific. As temperatures rise mangroves may start to colonize higher latitudinal areas. A warmer climate may result in an increase in frequency and strength of tropical storms and previously sheltered areas, suitable for mangrove growth, may become exposed. Any changes in temperature, salinity, storm frequency or precipitation will have effects on flora and fauna composition within mangrove forests. However, it is difficult to predict the exact consequences of sea-level rise as many scenarios are dependent on sedimentation fluxes from river catchments and coastal topography or land composition. Generally opinion seems to agree that rising sea levels will lead to mangroves shifting landward, as long as the rate of rise does not exceed mangrove growth and there are no obstructions to inland expansion.

Impact on the ecosystem services

Climate change will impact the social and economic fabric of life in small islands, affecting key sectors such as tourism and agriculture, and placing critical infrastructure at risk. It has been reported that the impacts of climate change have the potential to make atoll islands such as Kiribati, Tuvalu and the Maldives uninhabitable owing to changes in precipitation which would lead to droughts that affect the supplies of drinking water and food security in general. The economy is reliant on a limited resource base and is subjected to a high degree of mainland dependence. Assessment of vulnerability of Lakshadweep Islands to both the natural and man-made hazards becomes multi-fold mainly due to their insularity, remoteness and geographical isolation from the mainland. The summary of climate change events, exposure and its possible effects on the Lakshadweep is given in table 2.

Table 2. Assessment of vulnerability of Lakshadweep Islands to the projected climate change

Climate Change	Exposure	Who or What Affected
Sea level rise and salt water intrusion	Salinization of water lenses Less fresh water available	• Human consumption and health • Water suppliers • Plant nurseries and parks • Biodiversity, protected areas
Reduced average rainfall	Less fresh water available Drought	• Aquifer recharge rates • Cisterns and reservoirs • Biodiversity
Increased rainfall intensity	Runoff and soil erosion	• Reduction in crop production • Crop quality reduced • Post-harvest losses • Sedimentation of water bodies • Blocked storm water wells
Increased evaporation rates	Soil erosion	• Farming community; crop yields • Biodiversity
Decreased temperature	Reduced minimum temperature Microclimate affected	• Soil biodiversity affected • Reduced crop yield • Crop quality reduced

Source: Adapted and Modified from Hurlston-McKenzie *et al*., 2010

Challenges to biodiversity conservation

The biodiversity of Lakshadweep islands faces a variety of pressures and challenges from various quarters. The summary is given below and the details are presented in a separate chapter on biodiversity conservation.

- Discharge of wastes and fumes from the navigating shipping vessels, while the reefs and lagoons face a similar onslaught from the ferryboats. Fishing activities are reportedly generating nearly 2000 tonnes of waste, posing a health hazard for the islander as well. The use of chemical detergents and other chemicals cause leaching of nutrients into the lagoon resulting in eutrophication and smothering of corals (Sampath, 2012). Plastic dumping is another hazard of increasing magnitude which kills sea turtles, crabs, shrimps and other crustaceans
- Pollution due to oil spills also affects the entire marine fauna
- Sewage discharge affects the corals and the habitat and introduces new pathogen into the coral ecosystem as well.
- Coastal erosion due to sea surges, removal of coral and mangrove cover
- Illegal Collection of Sand/Boulders destroys the base besides reduced habitat for wild animals
- Over Exploitation of Ground Water results in the salinization due to sea water intrusion
- Loss of Natural Vegetation due to over exploitation and grazing and severe moisture stress
- Over exploitation of fishery resources and aggressive fishing practices and poaching add to these problems.

Conclusions

Lakshadweep islands consist of coral formations built upon the Laccadive-Chagos submarine ridge. The landmass, coastline, lagoons and the reefs of Lakshadweep, along with the surrounding ocean, form a continuum of biodiversity that defy being treated in isolation. Sea level rise, increasing sea surface temperature and dry days pose a major concern for the survival of biodiversity and land resources in these islands. Several measures have been taken by the local administration to protect the biodiversity and adapt to the climate change. However, details account on climate change and its effect on the island natural resources is lacking. Agricultural intensification or modification should be carefully planned keeping in view the fragile island ecosystem and the need of the local population. The reefs of these islands are a very valuable marine, benthic ecosystem of high biological diversity and it should be preserved and protected by involving the stakeholders. There is urgent necessity for proper monitoring and assessing the effect of climate change on biodiversity of these islands by establishing more observational networks linked to high resolution satellite data.

References

Anon,(1991).Pitti Island Lakshadweep an ornithological study. Madras Naturalist Society, Madras.

Cesar, H., Pet-Soede, L., Westmacott, S., Mangi, S.&Aish, A.,(2002).'Economic analysis of coral bleaching in theIndian Ocean – Phase II' in Linden, O, Souter, D, Wilhelmsson, D and Obura, D. (eds.) Coral Reef Degradation in the Indian Ocean: Status Report 2002. CORDIO and University of Kalmar: Kalmar (Sweden), pp. 251-262.

Church, J.A.,White, N. &Hunter, J. (2006).Sea level rise at tropical Pacific and Indian Ocean islands,Global Planet. Change53, 155-168.

Das, A. K. (2002).Islands. In: Ecosystems of India. Eds. Alfred, J. R. B., A. K. Das and A. K. Sanyal. ENVIS. Zoo.Surv. India, Kolkata,pp. 1-410.

Donner, S.D., Skirving, W.J. Little, C.M. Oppenheimer,M. &Hoegh-Guldberg, O.(2005).Global assessment of coral bleaching and required rates of adaptation under climate change,Glob. Change Biol.,11, 2251-2265.

Fish, M.R., Cote, L.M., Gill, J.A. Jones, A.P., Renshoff, S.&Watkinson, A. (2005).Predicting the impact of sea level rise on Caribbean sea turtle nesting habitat, Conserv. Biol.,19, 482-491.

Harries, H. C. (1978).The evolution, dissemination and classification of *Cocosnucifera* L,Bot. Rev., 44, 265-319.

Harvell, C.D., Mitchell, C.E. Ward, J.R., Altizer, S., Dobson, A.P. OstfeldR.S. & Samuel, M.D. (2002).Climate warming and disease risks for terrestrial andmarine biota,Science296, 2158-2162.

Hurlston-McKenzie, Jeremy Olynik, Juliana Montoya Correa& Leah Grant,(2010). Climate Change Issues for the Cayman Islands: Towards A Climate Change Policy. A Technical Report of the National Climate Change Committee.

ICAR, (1990). CPCRI Report on Agronomic Practices for the Development of Lakshadweep Islands, Kasaragode, Kerala.

IPCC, (2002).Climate change and biodiversity, Technical Report- V. Intergovernmental Panel on Climate Change, Genewa, Switzerland, pp.85.

IPCC, (2007).Climate Change 2007 Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K. Pachauri and A. Reisinger, eds. (Geneva: IPCC), pp. 104.

Jones, S.,&Kumaran, M. (1980).Fishes of the Laccadive archipelago.The Nature Conservation and Aquatic Science Service. Trivandrum, pp. 760.

Kaliaperumal, N., Kaladharan, P. &Kalimauthu, S. (1989). Seaweed and seagrass resources, CMFRI Bulletin 43, 162-175.

Khan, T.M.A., D.A. Quadir, T.S.Murty,A. Kabir, F.Aktar&M.A. Sarker, (2002). Relative sea level changes inMaldives and vulnerability of land due to abnormalcoastal inundation, Mar. Geod., 25, 133-143.

Krishnamoorthy, B. & P. M. Jacob,(1982). Fruit component analysis in Lakshadweep coconuts. In: Proceedings of Plantation Crops Symposium (PLACROSYM V), CPCRI, Kasaragod, India, 15th - 18th December, 1982, pp.180-183.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet& G. Sem, (2007).Small islands. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 687-716.

Noushad, M. K., Sirajudheen, T. K. &IdreesBabu, K.K. (2014). Intertidal Ichthyofaunal diversity of Androthisland, Lakshadweep, India – a call for developing culture based fishery, Journal of Aquatic Biology & Fisheries 2(1), 304-306.

Naseer, A. (2006). Vulnerability and Adaptation Assessment of the Coral Reefs of Maldives.Technical Papers to Maldives National Adaptation Plan of Action for Climate Change.Male, Ministry of Environment, Energy and Water.

Nasser, A.K.V., Kunhikoya, A. &Aboobaker, P.M. (1999). Ecosystems of Minicoy Island.Lakshadweep. Marine Information Service, Technical and Extension Series, CMFRI 1, pp. 8-10.

Nicholls, R.J. (2004). Coastal flooding andwetland loss in the 21st century: changes under SRES climate and socio-economic scenarios,Global Environ. Chang.,14, 69-86.

PC (Planning Commission) (2007). Report of the Task Force on Islands, Coral Reefs, Mangroves & Wetlands (In) Environment & Forests, For the Eleventh Five Year Plan, (2007-2012). Planning Commission, Government of India, New Delhi.

Pillai, C. S. G. (1996). Coral reefs of India, their conservation and management. (*In*) Marine Biodiversity, Conservation and Management (*Ed.*) N. G. Menon and C. S. G. Pillai, Central Marine Fisheries Research Institute, Cochin, pp. 16-31.

Pillai, C. S. G.& Jasmine, S. (1989). The coral fauna. Central Marine Fisheries Research Institute Bulletin, 43, 179-194.

Prabhakaran, (2013). Species diversity and community structure of Ichthyofauna in the sea grass ecosystem of Lakshadweep, India, Indian Journal of Geo-Marine Sciences 42(3),349-359.

Rajesh, M.K., K. Samsudeen, B. A. Jerard, P. Rejusha&Anitha KarunEmir, (2014). Genetic and phylogenetic relationships of coconut populations from Amini and Kadmat Islands, Lakshadweep (India), J. FoodAgric., 26 (10), 898-906. doi:10.9755/ejfa.v26i10.18055.

Reef Resilience, (2011).Tool Kit for Reef Resilience. http://www.reefresilience.org/ Toolkit_Coral/C8_India.html.

Rodrigues, C.L., (1996). Taxonomic and ecological survey of the Lakshadweep for Perumal Marine Park. Project completion report, Department of Marine Sciences and Marine Biotechnology, Goa University, pp. 46.

Sampath, V. (2012). Lakshadweep: State of art environment, Geography and You 12(750),10-11.

Seddon .S.& Cheshire, A. C. (2001). Photosynthetic response of *Amphibolisantarctica* and *Posidoniaaustralis* to temperature and desiccation using chlorophyll fluorescence, Mar. Ecol.Prog. Ser., 220, 119–130.

Sivaperuman, C., Velmurugan, A., Awnindra Kumar Singh, &Jaisankar, I. (2018). Biodiversity and Climate Change Adaptation in Tropical Islands, Academic Press, Elsevier, USA, 2018, https://doi.org/10.1016/B978-0-12-813064-3.00033-8.

Tegart, W.J. McG., G.W. Sheldon &D.C. Griffiths, (1990). (eds.).Climate Change: The IPCC Impacts Assessment. Report prepared for Intergovernmental Panel on Climate Change by Working Group II.Australian Government Publishing Service, Camberra, Australia,pp. 294.

The Royal Society, (2005).Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide, pp. 60.

Trenberth, K.E., P.D. Jones, P.G. Ambenje, R. Bojariu, D.R. Easterling, A.M.G. Klein Tank, D.E. Parker, J.A. Renwick, F. Rahimzadeh,M.M. Rusticucci, B.J. Soden& P.-M. Zhai, (2007). Observations: surface and atmospheric climate change. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B.Averyt,M. Tignor and H.L.Miller, Eds., Cambridge University Press, Cambridge, pp. 235-336.

Venkatraman, K.&MohideenWafar,(2005).Coastal and Marine biodiversity of India. Indian, Journal of Marine Sciences 34(1),57-75.

Vijay Anand, P.E.,&Pillai, N.G.K. (2005). Occurrence of juvenile fishes on the seagrass beds of Kavaratti atoll, Lakshadweep, India, Indian Journal of Fisheries 52(4), 459-468.

Vijay Anand, P.E. &Pillai, N.G.K. (2007).Coral reef fish abundance and diversity of seagrass beds in Kavaratti atoll, Lakshadweep, India, Ibid 54(1), 11-20.

Received : 20th January 2021 Accepted : 15th May 2021