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सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

प्रोफ़ेसर सुनील कुमार सिंह
निदेशक
Prof. Sunil Kumar Singh
Director

10/10/2023

D/NIO/Legal-NGT/48/23

To

The Hon'ble National Green Tribunal,
Principal Bench,
New Delhi.

Email: judicial-ngt@gov.in

Sub: Report of the committee to study the impact of Sea Level rise on the islands and frame policy & measures to protect these islands

Ref: (i) Original Application No. 249/2023 (Item No 11, Court No 1)

(ii) Hon'ble NGT's direction of 11/07/2023

Sir,

With reference to the above subject, please find the report enclosed herewith for kind perusal.

Thanking you

(Sunil Kumar Singh)

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REPORT OF THE COMMITTEE IN COMPLIANCE TO THE HON'BLE NATIONAL GREEN TRIBUNAL (NGT) PRINCIPAL BENCH, NEW DELHI

REPORT OF THE COMMITTEE IN COMPLIANCE TO THE HON'BLE NATIONAL GREEN TRIBUNAL (NGT) PRINCIPAL BENCH, NEW DELHI ORDER DATED 11.07.2023 IN THE MATTER OF ORIGINAL APPLICATION No. 249/2023 OF 2016 (News item published in Newspaper The Hindu dated 19.03.2023 titled "India's Sinking Island")

1. BACKGROUND

The News item titled "Several of the country's 1.382 islands are under siege from unseasonal cyclonic storms, sea erosion and new development projects and one island has entirely disappeared from the map" which appeared in The Hindu 19.03.2023 was taken up by the Hon'ble NGT, Principal Bench, Suo Moto, as Original Application No. 249/2023, in the Hon'ble NGT (PB), New Delhi.

In Paras 4 and 5 of the order dated 11/07/2023, in OA No. 249/2023, the Hon'ble National Green Tribunal (NGT), Principal Bench, New Delhi issued the following directions:

" 4. In view of the above, dangers of sea level rise and submergence of low-lying lands such as islands it is imperative that these islands should be protected as people are living. In view of the above, we may constitute a Committee comprising of
(1) Director, National Institute of Oceanography, Goa (NIO, Goa), (2) Director National Centre for Sustainable Coastal Management, Chennai (A body under MoEF & CC), (3) Director National Institute of Ocean Technology, Chennai and Director, (4) Director, Survey of India, Dehradun.

5. The above Institutions shall study the impact of Sea Level rise on the islands and frame policy & measures to protect these islands from submergence, erosion, saline ingression, flooding and other adverse environmental aspects. The above committee shall be free to include any other experts and Institutions that they feel appropriate. The Committee may also hold discussion with stakeholders if required. NIO, Goa shall be the nodal agency for the Committee. The report of the committee be
submit within three months by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/OCR support PDF and not in the form of Image PDF and first meeting of the committee shall be held within 15 days in NIO, Goa."

A copy of the Hon'ble NGT order dated 11.07.2023 is enclosed as **Annexure-1**.

Initiatives Taken by CSIR-National Institute of Oceanography (CSIR-NIO):

Subsequent to the order of Hon’ble NGT, The Director, CSIR - National Institute of Oceanography, Goa proposed a meeting with the members of the committee on 26/07/2023 through online mode and also invited more experts to the meeting. The details of the members are below who were invited to the first meeting to discuss the impact of Sea Level rise on the islands and frame policy & measures to protect these islands from submergence, erosion, saline ingression, flooding and other adverse environmental aspects. The agenda of the meeting for all the 4 conducted meetings is attached as Annexure- 2.

Table 1 Meeting details

Name	Designation	Role	1st meeting (26/07/2023)	2nd meeting (22/09/2023)	3rd meeting(29/09/2023)	4th meeting(05/10/2023)
Prof. Sunil Kumar Singh	Director, CSIR-NIO, Goa	Nodal Officer	Attended	Attended	Attended	(Could not attend due to prior commitment)
Dr.Subbareddy	Scientist C, NCSCM, Chennai	Representative of Director, NCSCM	Attended	Attended	Attended	Attended
Dr.B.K.Jena	Scientist G, NIOT, Chennai	Representative of Director, NIOT	Attended	Attended	Attended	(Could not attend due to prior commitment)
Mr.Varuna Kumar	DSG, NIGST, Survey of India	Representative of Director, Survey of India	Attended	Attended	Attended	Attended
Dr.Srinivasakumar T	Director,INCOIS, Hyderabad	Invited member	(Could not attend due to prior commitment)	Attended	(Could not attend due to prior commitment)	(Could not attend due to prior commitment)
Prof. Prasad Bhaskaran	IIT, Kharagpur	Invited member	(Could not attend due to prior commitment)	(Could not attend due to prior commitment)	Attended	Attended
Dr.Neetu S	Principal Scientist, CSIR-NIO, Goa	Invited member	Attended	Attended	Attended	Attended
Dr.Mani Murali R	Principal Scientist, CSIR-NIO, Goa	Convener	Attended	Attended	Attended	Attended

The first meeting was conducted within 15 days of the NGT order and subsequently 3 more meetings were also conducted (Table 1).

2 Details of the meeting:

A meeting was convened to hear the updates, and research carried out by the participating institutes on the climate change impacts on the islands and requested to provide maximum information available with their institutes on the subject directed by the honourable NGT. Accordingly, the participating institutes provided the information as below. CSIR-NIO also communicated to the Andaman and Nicobar and Lakshadweep administration to provide the inputs to this committee.

2.1 Inputs from Each institute:

a) CSIR-National Institute of Oceanography:

Work carried out relevant to this committee:

CSIR-NIO has been carrying out a lot of scientific and consultancy studies on various Islands of India. Most of the projects were on biodiversity, EIA, coastal developmental projects, bathymetry and oceanographic data observation. In 2015, CSIR awarded a network project "Vulnerability Assessment and Development of Adaptation Strategies for Climate Change Impact with Special Reference to Coasts and Island Ecosystems of India (VACCIN)" comprising 15 different institutes. CSIR-NIO carried out WP-6 which dealt with the Coastal inundation mapping due to Sea Level Rise on 10 Islands of Lakshadweep. The results of this project gave an idea about the Lakshadweep Islands in terms of Land Use /Land Use cover changes, shoreline changes and vulnerability assessment to the future Sea Level rise. Coral reef extent was decreasing in all 10 islands and progressive erosion was observed. Probable inundation regions for different SLR scenarios were demarcated for all 10 islands using the available DEM data. The results obtained conclusively pointed out that sea level rise scenarios will bring profound effects on land use and land cover classes as well as on coastal landforms. Coastal inundation would leave islands highly vulnerable.

CSIR-NIO also carried out coastal subsidence studies along the 3 mainland deltas and the results proved the erosion and inundation is accelerated when combined with SLR and subsidence rate. Population growth and excess groundwater withdrawal in islands also would lead to the same situation and increase the vulnerability of the islands.

b) NCSCM :

Work carried out relevant to this committee:

NCSCM has undertaken physical vulnerability studies for Kavaratti, Kadmat, Minicoy and Suheli islands of Lakshadweep, Little Andaman in the ANI group, and Gulf of Mannar, Tamil Nadu and Sagar Island, West Bengal on the mainland coast of India using extreme events such as climate change, storm surge, and tsunami. The outcomes of the studies are discussed in the following sections.

2.1.b.1 Lakshadweep Islands

Lakshadweep Islands are highly sensitive to extreme events such as cyclones, storm surges, and sea level rise due to climate change and tsunamis. The islands are often experiencing intense cyclonic storms and heavy rains. The average elevation from the mean sea level is in the range between 2 and 5 m. Records of severe storms are documented in the years 1847, 1891, 1922, 1963, 1977, 2004, 2017, and 2021. Tidal waves up to 6m in height have been witnessed during these events along the coast of these islands. The storm waves and wind fields have led to severe coastal erosion, uprooting the coconut trees and other coastal vegetation that line the coast, and have caused damage to properties and infrastructure.

Sea-level rise (SLR) is considered one of the most prominent consequences of climate change, posing several environmental and developmental challenges, especially to low-lying small islands. Rising sea level due to global warming is likely to damage the coastal areas and even submerge some of the low-lying areas of the islands. This will affect the island economies, with a negative impact on infrastructure, fisheries, tourism, natural ecosystems such as coral reefs and seagrass beds, and freshwater resources.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) estimates a global sea level rise of 0.8–2.0 m by the end of this century (Church et al., 2013). However, this sea level rise will not be geographically uniform and will vary across regions due to the influence of melting glaciers, wind systems, and other localized processes that affect the local sea levels. Global climate models (GCM) developed under the Coupled Model Inter Comparison Project (CMIP5) have proven to be more realistic in predicting the future climatic change scenario (Bilbao et al., 2015).

The sea level trend for Lakshadweep Islands estimated using tide gauge observations was 0.5 mm/yr during 1981–2005 (Unnikrishnan et al., 2006). Most recently, the sea level rise projections were assessed using various global climate models in the Lakshadweep archipelago, predicting the range from 0.4 mm/year to 0.9 mm/year (Jennath et al., 2021). The UT Administration has taken up shore protection measures for nearly 57.4% of the eroding coast using hard structures such as tetrapods, retaining walls, dumping of rocks, sandbags, etc. The physical vulnerability of the island was assessed against the IPCC`s Representative Concentration Pathway (RCP) scenarios for sea level rise by 2100.

The assessment has been carried out using data sets such as field-measured topography (PPK instrument), SRTM DEM elevation data, tidal amplitude (Tide gauge, INCOIS deployed tide gauge), SLR (0.8m) from the RCP 8.5 scenario, storm surge (IMD data), tsunami (TUNAMI-N2 model predictions from peer-reviewed publication), erosion rates (NCSCM), land use and land cover, island infrastructure. The inundation assessment (Table 1) for events such as sea level rise, storm surge and tsunami was estimated and identified as a vulnerable area along the island coast.

Table 2.1: Estimation of water level rise due to the climate change, storm surge, and tsunami events

Event	Water level rise (m)	Remarks
Sea level rise	2.2	Tidal amplitude (1.4 m) + global SLR (0.8 m) under the RCP8.5 scenario
Storm surge	3.2	Surge height (1.0 m) + tidal amplitude (1.4 m) + global SLR (0.8 m)
Tsunami	3	Wave run up height (0.8 m) + tidal amplitude (1.4 m) + projected SLR (0.8 m)

a) Kavaratti

Kavaratti (10° 34' 12.00" N and 72° 37' 12.00" E) is the third-largest inhabited island of Lakshadweep, with a land area of 3.6 sq. km. The northern end of the island is wide, and tapers to a narrow width towards the southern end. The built-up area has increased by 200% and is below 1MAMSL (Metres above mean sea level) for the last 14 years. Long-term shoreline change was assessed for a period of 43 years (1972–2015) and on a short term for 15 years (2000–2015). Kavaratti Island is dominated by artificial structures (79%) along the coast; however, the artificially protected coast is observed to be eroding on the lagoon side. Approximately 4% of the coast exhibits erosion, and 17% of the coast has accretion. The highest erosion rates of −4.23 m/year on the northern side, and −2.94 m/year on the southwestern side of the chicken neck area have been observed though protected by seawalls (termed as artificial coasts). The highest accretion rate of 5.09 m/year was recorded on the north-eastern side of the island. RCP8.5 scenario indicates submergence of the low-lying area of an elevation below 1m above MSL along the Kavaratti Island.

b) Kadmat

Kadmat Island (11°10′ - 11°16′ N and 72°45′ - 72°48′ E) has approximately 20 km of coastline, which is covered by sandy beaches. Nearly 70% of Kadmat Island exhibits erosion (including the artificial coast). The average net shoreline change rate is -0.10 m/yr around the Kadmat island and it signifies that the island is eroding. Based on the shoreline change analysis, approximately 20%, 31%, 41% and 8% of the coast is under erosion, accretion, artificial and stable coast respectively. The inundation extended to areas inside the island for a 1m rise in sea level. About 0.7 sq. km is estimated to be affected due to the sea level rise, about 1.23 sq. km due to the combined effect of seal level rise and storm surge, and finally, with the effect of the SLR and tsunami, about 1.06 sq km along the island.

c) Minicoy

Minicoy Island (8° 16' 60.00" N and 73° 01' 60.00" E) in the southernmost region of Lakshadweep is separated by a 9-degree channel with an orientation in the north-south direction. The island's lagoon on the western side stretches to a length of about 22 km. The built-up area has increased to about 0.19 sq. km from 2014 to 2018. The statistics of shoreline change assessment clearly indicate that approximately 49%, 35%, 17%, and 16% of the coast exhibits erosion, accretion, protected by artificial structures, and stable coast respectively. The inundation is estimated at about 0.45 sq. km due to the sea level rise, about 0.92 sq. km due to the combined effect of sea level rise and storm surge, and finally, with the effect of SLR and tsunami, it is estimated at about 0.77 sq. km along the island's coast. Almost 25 percent of the island area has an elevation of

<=3 MAMSL and it is estimated that nearly 30% of the island will submerge by 2100 under the RCP8.5 scenario.

d) Suheli

Suheli Island (10°7'48.63" N and 72°19'41.17" E) is located in the southwestern part of Kavaratti, South of Agatti, West of Kalpeni, and NNW of Minicoy Islands. The total length of the island is 3.9 km. Shoreline change analysis estimates indicate a maximum erosion rate of -2.78 m/yr and an accretion rate of 6.95 m/yr around the island. Statistics of the shoreline change analysis indicate that approximately 37% and 63% of the coast exhibit erosion and accretion respectively. Island inundation is estimated at about 0.11 sq. km, 0.18 sq. km, and 0.17 sq. km due to the sea level rise, the combined effect of seal level rise and storm surge, and the combined effect of the SLR and tsunami run-up respectively.

The summarized information on shoreline change statistics, water level rise, and inundated areas for the four islands are presented in Table 2.2.

Table 2.2: details of shoreline change statistics, water level rise, and inundated area for four islands under the climate change, storm surge, and tsunami

Island	**Shoreline change**	**Water level rise (m) under extreme events**			**Area of Inundation (km^2)**
		Sea level rise (SLR)	**SLR + surge**	**SLR + wave run-up**	
Kavaratti	Erosion: 4% Accretion: 17% Artificial Coast: 79%	0.8	3.2	3	submergence of the low-lying areas 1m above MSL
Kadmat	Erosion: 20%, Accretion: 31%, and Artificial Coast: 41% [Artificial coast are those stretches of the coast that are already protected by seawalls due to high erosion] Stable coast: 8%				SLR: 0.7 sq km SLR + Storm surge: 0.77 sq km SLR + Storm surge + Tsunami: 1.23 sq km
Minicoy	Erosion: 49% (includes Artificial Coast: 17%) Accretion: 35%, Stable Coast: 16%				SLR: 0.45 sq. km, SLR + Storm surge: 0.92 sq km SLR + Tsunami: 1.06 sq km
Suheli	Erosion: 37% and Accretion: 63%				SLR: 0.11 sq km SLR + Storm surge: 0.18 sq km SLR + Tsunami: 0.17 sq km

2.1.b.2 Andaman Islands

Little Andaman, the southernmost and fourth largest island in the Andaman Group of Islands, spans an area of 734 sq. km with a 110 km coastline (10° 30′ to 10° 54′ N and 92° 29′ to 92° 31′ E). It is designated as a tribal reserve since 1957, with undulating terrain and the highest point at 210 m in the central region and lower elevations (0–12 m) in the north and northwest. The island has undergone severe damage from the 2004 tsunami, resulting in a death toll of up to 37 people (Ministry of Home Affairs, 2005).

Physical vulnerability of Little Andaman Island was studied using four decades of shoreline change analysis and impacts of SLR on land use and land cover (LULC) using using remote sensing (RS) and Geographic Information System (GIS) techniques.

The assessment highlights the vulnerability of the coastal areas in Little Andaman to various hazards such as flooding, including permanent inundation, occasional flooding, increased erosion, seawater intrusion, and the potential destruction of vital ecosystems such as wetlands and forests. Additionally, approximately 1042 hectares of the study area are at risk of submergence due to a 1-meter sea level rise (SLR), and this is expected to be a gradual process. This impending SLR poses a significant threat to these areas in the near future, impacting both coastal ecosystems and socioeconomic factors. Therefore, it is imperative to implement protective measures to mitigate potential losses.

2.1.b.3 Gulf of Mannar Islands

The Gulf of Mannar is situated between Longitudes 78˚5' and 79˚30 ' E longitudes and 8˚ 47, and 9˚ 15’ N latitudes in South and Southeast Asia, running down south from Rameswaram to Kanyakumari in Tamil Nadu, India. The Marine Biosphere Reserve encompasses a chain of 21 islands (2 islands already submerged) and adjoining coral reefs off the coasts of the Ramanathapuram and Tuticorin districts. The morphological characteristics of sandy islands are very dynamic, and the fringing reef of corals along the windward side of the islands protects the islands from direct wave action. The morphological variations of islands occur due to natural and anthropogenic stress. The natural agents include erosion, accretion, wave, current, sea level variation, neotectonic activity, and anthropogenic impacts such as the construction of breakwaters and discharge of effluents. These are the main causes of erosion and accretion in and around the islands.

The shoreline change analysis was carried out using the Landsat 4, 5 TM, and Landsat 8 OLI-TIRS sensor images having a horizontal spatial resolution of 30 m by the Digital Shoreline Analysis System (DSAS) adopting the End Point Rate (EPR) method around the islands during 2009–2019, clearly indicated that the total percentage of erosion and accretion is about 42.81% and 35.57%, respectively. Hence, the size, shape, and location of these islands have changed considerably. The majority of the coast is advancing toward erosion as well as an increased accretion rate. The Tuticorin and Ramanathapuarm coasts are prone to less erosion induced by the cross-shore sediment with less energy from waves. Vilangushuli Island is one of the islands in the Tuticorin group, situated at 6.25 km from Sippikkulam fishing village which was submerged due to illegal coral mining (BBC, 2011) and an increase in sea level. Puvarasanpatti Island is one of the islands in the Keelakkarai group, located 6.90 km from the Kalachimundal coast. The entire island has eroded due to the direct attack of the waves, and its level is below sea level. The percentage of erosion on this island was estimated to be 33%. Vaan Island is the southernmost of the 21 islands in the Gulf of Mannar, one of the four islands of the Tuticorin group has split in two, and immediate interventions by the Tamil Nadu State Environment Department have protected Vaan Island by deploying artificial reefs. Initially, the islands were spread across 16 ha and at present, only 5.7 hectares in less than three decades was documented.

2.1.b.4 Sagar Island

Sagar Island Sagar Island is located about 100 km south of Kolkata. The island covers a large area of 224.3 sq. km, lying between 21 36 to 21 56 N and 88 2 to 88 11 E. The overall length of the island is ~100 km covering an area of 234.64 km2. This island is in the administrative jurisdiction of South 24 Paraganas District. Sagar Island is a typical deltaic island, with its apex at the north and the base at the south. The coast of the island is tide-dominated and has recorded a tidal range between 5 and 6 m. Sagar is a densely populated island, with over 200, 000 people living in 43 villages. Of the 43 villages, the hazard line either partially or entirely covers 36 villages, with a population of 173,405.

A detailed analysis of shoreline change (erosion and accretion characteristics) was undertaken for Sagar Island on long-term (1972–2018) and short-term (2000–2018) time scales. Changes in high erosion are obvious at three specific locations, namely Sibpur, Kachuberia on the southeast coast and Champatala along the northeast coast of Sagar Island. Based on the DEM results, the areas that will be inundated due to coastal flooding and coastal erosion are approximately 16%, 10%, and 24% for the time period between 1952 and 2011, 2011 and 2100, and 1952 and 2100, respectively. The net reduction of the land area lost under sea (10%) between 2011 and 2100. It is observed that nearly 13 sq. km of cropland will be inundated in the next 100 years.

c) NIOT :
Work carried out relevant to this committee :

Dr. Jena, Scientist G who represented the Director, NIOT, Chennai mentioned that NIOT had carried out desalination projects at islands and did not carry out on the subject directed by the honourable NGT. He was willing to participate in any future study related to this subject.

d) **Survey of India :**

Work carried out relevant to this committee:

Survey of India has been mandated with conducting Tidal observations all along the East Coast, West Coast, A&N Islands and Lakshadweep. As a part of the mandate, Survey of India has collected Tidal data from the tidal observatories at Port Blair, Campbell Bay, Kavaratti and Minicoy. At other Islands, SoI does not have any tidal Data. Of the above four sites, Port Blair has tidal data for a longer time series which can be utilised to study sea level rise. Practically speaking, to ascertain sea level rise at a place, the effect due to land subsidence at that place needs to be separated out. This could be possible only when we have long-term tidal data with collocated GNSS. At the tidal observatories mentioned above, SoI does not have a collocated GNSS. Hence the tidal data available with SoI may not be useful for studying sea level rise. However, the tidal data available with SoI can be made available to research institutions for their studies.

e) **Indian National Centre for Ocean Information Services (INCOIS):**
Work carried out relevant to this committee:

INCOIS has carried out the multi-hazard vulnerability mapping (MHVM) of the Andaman and Nicobar Islands based on the available historical tide gauge data pertaining to Port Blair. The MHVMs represent coastal low-lying areas exposed to oceanic disasters such as sea level rise, extreme water levels and coastal erosion on 1:25000 scales. The Hybrid topographic data generated using the (ALTM+Carto-DTM+Terrasar-X) is obtained from NRSC based on availability.

Observations:

Long-term tide gauge records provide valuable insights into sea level variations and future projection trends. However vertical motion is fundamental in understanding sea-level behavior as the ground subsidence and uplift at the tide gauge station location can aggregate the impact of sea-level variability. It has been observed that a significant uplift signal of 24.3+-0.4 mm/y for PBRI (Andaman Islands) is related to the post-seismic signal following the Sumatra earthquake of 2004 (Paul et al. 2012). Also based on GPS observation, Nevada Geodetic Laboratory (NGL) reported 17.55 +/- 1.01 mm/y, Jet Propulsion Laboratory (JPL) reported 15.51 +/- 1.05 and GFZ reported 24.34 +/- 0.30 at BPRI GPS station (92.71213620 E and 11.63777938 N) during the 2011 to 2020 period (Sonel.org). However, as per IIT, Kharagpur studies observed under different emission scenarios show that sea-level rise can range between 0.4 mm/year to 0.9 mm/year. Hence it is necessary to quantify the vertical land motion with respect to each tide observation over the Andaman Island for future projection of sea-level rise.

f) **IIT, Kharagpur :**

Climate model projections were used to assess the potential areas of inundation over the archipelago of Lakshadweep Islands in the Arabian Sea. Using 26 models under the CMIP5 family, the study identified GFDL-ESM2G and MIROC5 as the best-performing climate models in predicting the sea-level rise over this region using statistical and spatial analysis. Estimates from the model outputs under different emission scenarios show that sea-level rise can range between 0.4 mm/year to 0.9 mm/year.

The study highlighted that the worst possible inundation scenarios projected for Lakshadweep Islands were almost similar under different emission scenarios of model projections. However, the susceptibility levels of inundation are seen to vary over different Islands. The study estimated the percentage of shorelines that would be affected by inundation due to sea-level rise. Smaller Islands of Chetlat and Amini are expected to have major land loss. Projection mapping indicates that about 60%-70% of the existing shoreline would experience land loss for Amini and about 70%-80% for Chetlat with reference to various IPCC emission scenarios.

Larger Islands like Kavaratti and Minicoy are also vulnerable to sea-level rise and are also expected to experience land loss along 60% of the existing shoreline. Sea-level rise effects are seen to have the least impact on Androth Island under all emission scenarios. Projected inundation due to sea-level rise can impact the Islanders as residential areas are quite close to the present coastline. Also, the only airport in the archipelago is located at the southern tip of Agatti Island, and there is a high likelihood of damage due to inundation from sea-level rise. Important findings reveal that all the Islands in the archipelago are vulnerable to impact from sea-level rise, and the capital Kavaratti is projected to experience inundation along larger areas of coastline under all forcing emission scenarios.

2.2 Recommendations to this committee report:

- Coastal topography and near-shore bathymetry are the main parameters which would determine the impact of coastal inundation along the coastal regions of islands. Hence, high-quality coastal topography and bathymetry need to be acquired by the concerned agencies to determine the long-term vulnerability of Indian islands. Numerical modelling at various RCP conditions and future projections on accurate SLR rates can benefit local governments in planning the precautions. A nationwide Island assessment study to understand accurate vulnerability should be carried out (Source: CSIR-NIO).

- Some of the key recommendations to overcome climate change impacts on the islands of India are included as follows (Source: NCSCM).

- Undertake Field-based topographic surveys essential to map the accurate inundation of the island under different climate change scenarios.

- Adopt new policies and advanced technologies to avoid any expected infrastructure damage due to natural hazards and particularly to coastal erosion.
- Adopt Green coastal infrastructure (GCI) as a shore protective measure along the eroding coasts to control the seasonal erosion patterns and to act as bio-shields against coastal hazards. This includes plantation of mangroves, salt marsh, coastal dune vegetation and other halophytic vegetation. Exotic species such as Casuarina or other species are to be discouraged.
- Green infrastructure projects in coastal areas are defined it as a strategically managed, spatially interconnected network of multifunctional features that deliver ecosystem services (Rucklehauss et al., 2016). Silva et al. (2017) recognized that green infrastructure is a series of natural, semi-natural or artificial multifunctional strategies to solve ecological and socioeconomic challenges simultaneously.
- Promote hybrid and natural structures that are not 100% hard solutions but a combination of vegetation and eco-friendly materials, submerged reefs, artificial reefs, oyster reefs and
- Undertake coral and seagrass transplantation and coral gardening as mitigation measures in identified hotspots and restoration of degraded reefs and seagrass beds
- Increase in Sea level monitoring stations to estimate accurate levels of seawater inundation along the islands
- Enhance capacity building to improve the skills of the community and other relevant stakeholders to combat climate change]
- Plan adaptive and risk reduction policies for the sustainable development of the island's coast.

- There is a need for accurate data to assess whether really there is any sea level rise or not. For that, a denser network of tide gauges collocated with GNSS is required. Hence it is recommended to have such tidal observatories on other islands as well depending upon the site's feasibility. As per the articles shared with the committee, irrespective of the sea level rise or any other local reason, it is true that the Islands are being submerged or eroded. In many places, going by the articles, the locals or the NGOs working there knew or estimated the source of the problem. The causative factors are different at different places. Hence, they need to be addressed differently (Source: SoI).

- The high-resolution topographic data is a critical input parameter to assess the impact of the sea levels on the coastal zone. Hence the high-resolution topographic data is necessary for all the Islands of Andaman, Nicobar and Lakshadweep. In addition, the long-term sea-level observation is not available for the Lakshadweep Islands (Source: INCOIS).

- A detailed study is warranted to understand the impact of sea level rise and extreme water levels utilizing remote sensing techniques to identify vulnerable regions in the islands' archipelago and thereby formulate soft and hard engineering solutions for the protection (Source: IIT-Kharagpur).

2.3 Suggested policies and measures to protect the islands:

Policies suggested:

1. Island-specific sustainable development and tourism policy keeping the climate risks in mind
2. Diversified economic development and controlled nature-based growth
3. Blue-economy-based activities on marine and coastal fronts
4. Alternate climate resilient practices for livelihood in the islands
5. Exploring the nature-based ecosystem restoration
6. Installation of GPS/GNSS station with respect to each tide gauge station across the Island to estimate Vertical Land motion (VLM) which can accurately quantify the future sea-level rise over Andaman and Lakshadweep Island.
7. Generate Land-Use and Land Cover, Infrastructure and Socio-economic database for better management and future actions.
8. Necessary actions for the protection of coral reefs and monitoring during coral bleaching.
9. Monitoring of shoreline change rate to identify the hotspot zone.
10. Construct coastal structures for the protection of highly eroded shoreline zones.
11. Coral reef excavation should be banned at the locations where this is the causative factor. Wherever excavated, efforts should be made to help the growth of corals by intervention.
12. Plantations may be made to arrest the erosion of the seashore. Other methods are to construct seawalls or breakwaters etc depending upon their suitability and feasibility.
13. Protection work is required with a combination of soft and hard solutions.

References:

BBC. 2011. Mining to blame for islands to sink beneath waves https://www.bbc.com/news/science-environment-13383182

Bilbao, R. A., Gregory, J. M., & Bouttes, N. (2015). Analysis of the regional pattern of sea level change due to ocean dynamics and density change for 1993–2099 in observations and CMIP5 AOGCMs. *Climate Dynamics*, *45*, 2647-2666.

Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., & Unnikrishnan, A. S. (2013). *Sea level change*. PM Cambridge University Press.

Jennath, A., Krishnan, A., Paul, S. K., & Bhaskaran, P. K. (2021). Climate projections of sea level rise and associated coastal inundation in atoll islands: Case of Lakshadweep Islands in the Arabian Sea. *Regional Studies in Marine Science*, *44*, 101793.

Ruckelshaus MH, Guannel G, Arkema K, Verutes G, Griffin R, Guerry A, Silver J, Faries J, Brenner J, Rosenthal A. 2016. Evaluating the benefits of green infrastructure for coastal areas: location, location, location. Coast Manag 44(5):504–516. https://doi.org/10.1080/08920753.2016.1208882

Silva R, Lithgow D, Esteves LS, Martínez ML, Moreno-Casasola P, Martell R, Pereira P, Mendoza E, Campos-Cascaredo A, Grez PW, Osorio AF, Osorio-Cano JD, Rivillas GD. 2017. Coastal risk mitigation by green infrastructure in Latin America. Proceed Inst Civil Eng Maritime Eng 170(2):39–54. https://doi.org/10.1680/jmaen.2016.13

Unnikrishnan, A. S., Kumar, K. R., Fernandes, S. E., Michael, G. S., & Patwardhan, S. K. (2006). Sea level changes along the Indian coast: Observations and projections. *Current Science*, 362-368.

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Item No.11 Court No. 1

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

(BY HYBRID MODE)

Original Application No. 249/2023

In re : News item published in Newspaper The Hindu dated 19.03.2023 titled "India's Sinking Island"

Date of hearing: 11.07.2023

CORAM: HON'BLE MR. JUSTICE SHEO KUMAR SINGH, CHAIRPERSON
HON'BLE MR. JUSTICE ARUN KUMAR TYAGI, JUDICIAL MEMBER
HON'BLE DR. A. SENTHIL VEL, EXPERT MEMBER

Applicant: None appeared

ORDER

1. The News item titled "Several of the country's 1.382 islands are under siege from unseasonal cyclonic storms, sea erosion and new development projects and one island has entirely disappeared from the map" appeared in The Hindu 19.03.2023 was taken up Suo Moto. As per the news item several islands along the Indian Coast as well as some of the Islands in the rivers are vulnerable for erosion and submergence. One of the main causes of submergence of island is because of Sea Level rise and global warming. There is influx of saline water in agricultural and drinking water in these islands due to sea level rise.

2. Based on the news item and the environmental concerns notices were issued to Ministry of Earth Sciences and Ministry of Environment, Forest & Climate Change (MoEF & CC) to file their response.

3. The matter was taken up today and the response from Earth Sciences, Director of Metrology was examined. No response was filed by MoEF & CC. As per the response of Ministry of Earth Sciences, India's

average temperature has risen by around 0.63 ^{0}c during 1901 to 2021. This rise in temperature is largely on account of Green House Gases induced warming, partially offset by anthropogenic aerosols. The rise in temperature has resulted in melting of glaciers, rise in sea levels, changing precipitation pattern and increasing tendency of weather and climate extremes on a global scale. The Report from Ministry of Earth Science also states that:

> *"The global average sea level has risen by 19 cm from 1901 to 2010 the average rate of rise measured by satellite has been 3.2 (2.9 – 3.5) mm/year since 1990s up from 1.7 (1.5-1.9) mm/year during twentieth century, obtained from historical tide gauge records. Thermal expansion and glacier melt because of anthropogenic global warming have been the major drivers of rise in global sea levels over the past century. Sea-level rise in the North Indian Ocean (NIO) occurred at a rate of 1.06–1.75 mm per year during 1874–2004 and has accelerated to 3.3 mm per year in the last two and a half decades (1993–2017), which is comparable to the current rate of global mean sea level rise. At the end of the twenty-first century, steric sea level in the NIO is projected to rise by approximately 300 mm relative to the average over 1986–2005 under the RCP4.5 scenario, with the corresponding projection for the global mean rise being approximately 180 mm."*

4. In view of the above, dangers of sea level rise and submergence of low lying lands such as islands it is imperative that these islands should be protected as people are living. In view of the above we may constitute a Committee comprising of (1) Director, National Institute of Oceanography, Goa (NIO, Goa), (2) Director National Centre for Sustainable Coastal Management, Chennai (A body under MoEF & CC), (3) Director National Institute of Ocean Technology, Chennai and Director, (4) Director, Survey of India, Dehradun.

5. The above Institutions shall study the impact of Sea Level rise on the islands and frame policy & measures to protect these islands from submergence, erosion, saline ingression, flooding and other adverse environmental aspects. The above Committee shall be free to include any other experts and Institutions that they feel appropriate. The Committee

may also hold discussion with stakeholders if required. NIO, Goa shall be the nodal agency for the Committee. The report of the committee be submitted within three months by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/OCR support PDF and not in the form of Image PDF and first meeting of the committee shall be held within 15 days in NIO, Goa.

6. A copy of this order be forwarded to Director, National Institute of Oceanography, Goa, Director National Centre for Sustainable Coastal Management, Chennai (A body under MoEF & CC) Director National Institute of Ocean Technology, Chennai and Director, Survey of India, Dehradun.

7. List this matter on 13th October, 2023.

Sheo Kumar Singh, CP

Arun Kumar Tyagi, JM

Dr. A. Senthil Vel, EM

July 11, 2023
Original Application No. 249/2023
HB

CSIR - NATIONAL INSTITUTE OF OCEANOGRAPHY
(COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH)

Meeting to discuss the impact on sea level on the islands and frame policy & measures to protect these islands

Time (hrs)	AGENDA
(1100 – 1110)	Self-Introduction of the members
(1110 – 1120)	Briefing the background and updates by Dr.Mani Murali R, Convener, NGT committee to all members
(1120 – 1130)	Welcome Address by the Director, CSIR-NIO, Goa
(1130 – 1140)	Remarks and updates by the Director, NIOT or his nominee
(1140 – 1150)	Remarks and updates by the Surveyor General of India or his nominee
(1150 – 1200)	Remarks and updates by the Director, NCSCZM or his nominee
(1200 – 1210)	Remarks and updates by Dr. Neetu S, CSIR-NIO, Goa
(1210 – 1220)	Remarks by the Director, INCOIS or his nominee
(1220 -1230)	Remarks by Prof. Prasad Bhaskaran, IIT, Kharagpur
(1230 – 1240)	Closing remarks and the way forward by the members and the Director, CSIR-NIO, Goa