# OCEAN DIGEST

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Ocean Digest

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# Coral reefs in Lakshadweep: An ecosystem in Peril?

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**Abstract**

In the wake of ElNino 2023-24, field surveys were conducted along the Kavaratti Island in UT of Lakshadweep across different reef zones. A total of 80.7% of the corals were severely bleached, comparatively higher than the previous bleaching events. The bleaching response was uniform among the coral colonies across different reef zones. The bleaching response among coral colonies coincided with the continuous rise in the temperature > 29 ℃ since September 2023. Prevalence of secondary stressors such as cyanobacterial invasion, turf algae, and crown of thorns predation poses a significant challenge for the corals to recover from bleaching stress which might lead to mass mortality. The managerial and conservation efforts are inadequate to compensate the loss of corals. Potential measures to dilute the intensity of bleaching stress and promote the recovery of corals were discussed.

**Keywords:** Coral, Bleaching, ElNino, SST, Lakshadweep

## Introduction

Lakshadweep Archipelago in the Arabian Sea off the southwestern coast of India comprises a group of scattered islands, islets and submerged coral banks spread across 8-12°13" N and 71 - 74° C, 220-440 kms away from the Indian mainland with a total reef flat area of 137 sq.km (Venkataraman et al. 2003). The Lakshadweep Islands boasts some unique ecosystems with complex habitats, largely centered around its coral reefs, lagoons, and atolls, supporting a wide range of marine life including corals, seagrass, mammals, turtles, fish, and other invertebrates. These ecosystems and its associated biodiversity, in its pristine state, supports the livelihood of the Island communities through tourism, fisheries and shoreline protection (Vineeta Hoon 2003). Large scale coral mortality due to natural stress and further environmental degradation can lead to erosion and threaten the very existence of these pristine coral islands.

Corals reefs in Lakshadweep are threatened primarily by global climate change and coastal development. Specifically, an increase in the seawater temperature affects the endosymbiotic relationship between the corals and Symbiodinium microalgae, ultimately lead to a stress phenomenon known as bleaching (whitening of corals). Lakshadweep coral reefs had witnessed severe bleaching events in the past coinciding with the El Nino events in 1998, 2010, and 2016 and suffered a severe mortality with reduced recovering capabilities after each bleaching event (Yadav et al. 2018). The ongoing global El Nino event is the fourth global event on record, and the second in the last 10 years. It is predicted to be the strongest El Nino event in the record with significant climatic, social, and economic consequences (NOAA 2024).

## Results

In the wake of El Nino 2023-24, we conducted an assessment on the bleaching response among the corals in Kavaratti Island of Lakshadweep between Feb – Mar 2024 and May 2024. In total, 13 sites spanning across different reef zones ranging from the intertidal zone, lagoons, outer reef flat and reef slope were assessed for bleaching response among coral colonies (Fig.1). Belt-transects of 50 m length and 2 m width, covering an approximate reef area of 100 $m^2$ was followed to estimate the average percent of coral colonies that were bleached. The coral colonies were categorized as severely bleached, moderately bleached, and resistant based on their color during the survey (Marshall and Baird 2000). Additionally, the satellite-based sea surface temperature (SST) around the Lakshadweep Sea (8° N–12° N and 71 ° E–74° E) was computed. The necessary SST time series data for the period from September 2023 to May 2024 was extracted from the NOAA coral reef watch (CRW) (https://coralreefwatch.noaa.gov/) and ERDDAP. The data further analyzed for monthly average SST.


**Figure 1**. Image showing the locations of bleaching assessment at Kavaratti Island, Lakshadweep.

Trend of SST over time shows that the average sea surface temperatures (SST) recorded from September 2023 to May 2024 shows a distinct seasonal trend (Fig. 2). Starting at 29.23°C in September 2023, SST gradually increased through before pre-winter months, peaking at 29.90°C in November 2023. December 2023 and January 2024 saw a slight decline in temperatures to 29.40°C and 29.17°C, respectively, typical of the winter cooling period. February 2024 remained relatively stable at 29.13°C before SST began to rise notably again in March 2024. This upward trend continued into summer, with April 2024

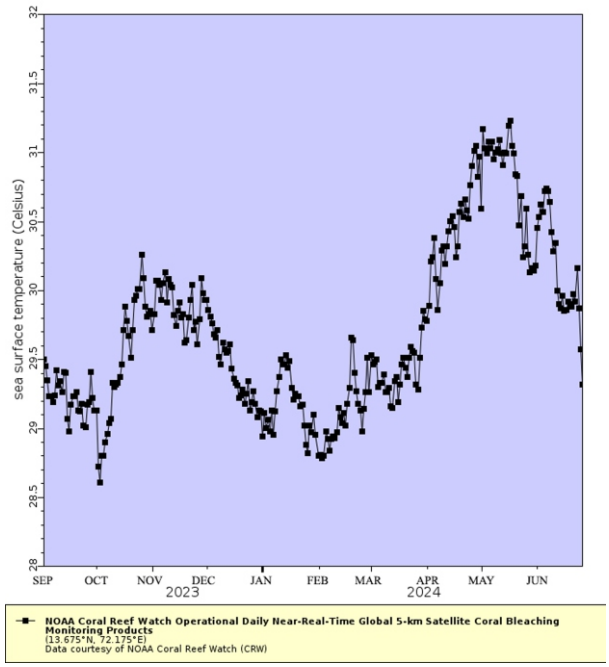


**Figure 2**. Sea Surface temperature (SST) pattern recorded since September 2023 at Kavaratti Island, Lakshadweep.

showing a significant increase to 30.46°C and May 2024 reaching its peak at 30.78°C. Following the trend in SST, initial bleaching responses among coral colonies were noticed in the middle of March 2024.

In total, 1252 coral colonies belonging to 15 genera were recorded along the transects and assessed for their bleaching response. A total of 80.7% of the corals were severely bleached and 10.9% of the corals moderately bleached. The bleaching response was uniform across the reef zones with >80% of the corals severely bleached in the Intertidal and Lagoons and 78.4% of the corals were bleached in the outer reef (Fig. 3). Less than 10% of the corals, restricted to few species belonging to Pavona and Favites were resistant to bleaching across the reef zones. One-way analysis of ANOVA revealed no statistically significant difference in the bleaching response between different reef zones (p = >0.05).

Among different coral taxa, Pavona sp. displayed resistance to thermal stress across all the reef zones. A total of 80.4% of the Pavona colonies were apparently healthy with

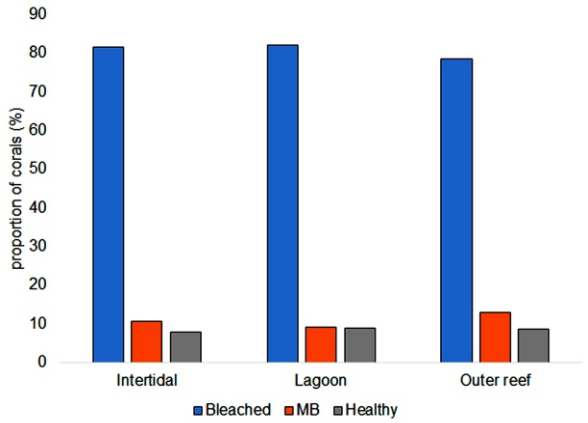


**Figure 3**. Relative proportion of corals that are severely bleached, moderately bleached, and healthy across different reef zones in Kavaratti Island.


**Figure 4**. (a-d) Severely bleached corals - (a) Porites sp., (b) Montipora hemispherica., (c) Porites compressa.; (h) Moderately bleached corals - (d) Montipora sp., (e) Acropora sp., (f) Hydnophora sp., (g) Goniastrea sp., (h) Pocillopora sp.; (i-j) healthy corals (i) Platygyra sp., (j) Favia sp.

only 2% of the corals severely bleached. Majority of the corals colonies of taxa Favia (74.2%) and Platygyra, (51.7%) were moderately bleached. Whereas >90% corals of the taxa Porites, Acropora, Montipora, Cyphastrea, Astreopora, Goniastrea, Pocillopora, Galaxea, Symphyllia, and Heliopora were severely bleached (Fig. 4). The Pearson's Chi-Square test of association showed that there is no statistically significant association between the species and bleaching response (p >0.05) suggesting that the bleaching stress was wide spread among coral colonies.

In general, bleaching is a reversible response in which the bleached coral colonies return to their normal state upon the return of optimal environmental conditions and reduction of anthropogenic threats in the reef (Gilmour et al. 2013). Anthropogenic footprints in the reef indirectly encourage the growth of secondary stressors which can reduce the recovery rate of corals from bleaching stress (Ravindran et al. 2012). Recent studies from Lakshadweep suggest the reduced rate of coral recovery after bleaching events (Yadav et al. 2019). Our survey during the bleaching event at Lakshadweep Islands also revealed the prevalence of a variety of secondary stressors which could potentially inhibit the recovery of corals from bleaching stress (Fig. 5).


**Figure 5**. Different stressors prevalent among the bleached corals in Kavaratti Island, Lakshadweep. (a) Porites compressa smothered with cyanobacterial mat, (b) turf algae and cyanobacterial mats in bleached Acropora colony, (c) crown of thorns sea star predating on Porites sp.

In total, >60% of the corals were affected by one or more secondary stressors including infestation of turf algae and cyanobacterial mats which are known to reduce the light, weaken the coral skeleton and inhibit the coral growth (Krause et al. 2019; Ford et al. 2018). Corals of branching morphotypes belonging to Acropora and Montipora were highly vulnerable to the turf and cyanobacterial infestation in the Lagoon of Kavaratti Island. Whereas crown of thorns (COTS) sea star, an apex coral predator was prevalent in the outer reef flat and reef slope zones targeting the massive coral colonies. In general, corals exist in a compromised health state during bleaching stress and prevalence of such secondary stressors during bleaching event enhances the chances of coral mortality and prevent the recovery of reef.

With >80% of the corals bleached, the present bleaching event in Lakshadweep Islands is the most severe one compared to previous mass bleaching events in 1998, 2010, and 2016. The prevalence of secondary stressors such as invasive cyanobacteria, turf algae, and coral predators with competitive advantage over corals might play a crucial role in inhibiting the recovery of coral from bleaching stress. Although the factors causing coral bleaching are beyond local management and mitigation control, having a comprehensive bleaching response plan is essential to dilute the intensity of stress and promote the recovery of reefs. This plan should include predicting risk, measuring impacts on individual and reef scales, and implementing measures to reduce damage severity and assist coral recovery from bleaching stress. At present, there is no such comprehensive response plan for the Lakshadweep Islands, aside from monitoring bleaching severity and estimating the recovery status of affected reefs.

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Besides the Wildlife Protection Act (1972), managerial interventions in Lakshadweep Islands are limited to coral transplantation and coral gardening in selected Islands. However, given the prevalence of secondary stressors and the severity of ongoing bleaching stress, these efforts might not be sufficient to offset coral loss. Additional managerial efforts including (i) determining reef-specific thermal thresholds through long-term spatial and temporal monitoring using automated tools, (ii) Conducting focused research to understand the implications of bleaching stress on ecosystem scale and reef services, (iii) advancing coral gardening and nursery development to include the transplantation of nursery-grown corals to affected reefs, and (iv) monitoring water quality and herbivore fish populations to inform management and facilitate pollution reduction at the source level are crucial for building reef resilience against bleaching stress.

**Acknowledgement:** The authors thank the Director, CSIR-NIO for his support; Department of Science and Technology, Kavaratti, UT of Lakshadweep for their logistical help and support. This work was supported through Core Research grant by Science and Engineering Research Board, New Delhi.

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## Large Contribution of Continental Aerosol in Northern Indian Ocean through Long-Range Transportation


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**Based on publication**
**Kumar, H., Tiwari, S., 2023. Climatology, trend of aerosol-cloud parameters and their correlation over the Northern Indian Ocean, Geoscience Frontiers, 14 (4), 101563**

Scientists, led by Shani Tiwari from CSIR- National Institute of Oceanography, Goa analysed the satellite derived long term aerosol and cloud data over the Northern Indian Ocean (NIO) and found a strong heterogeneity in their spatio-temporal variation. They found an increasing trend in aerosol optical depth (AOD: attenuation of light due to aerosol in an atmospheric vertical column) with maximum amplitude (> 0.003 $yr^{-1}$) along the coastal region suggesting a significant impact of sub-continental outflow over the NIO.

Interestingly, they reveal that the northern Arabian Sea coast experiences highest aerosol loading throughout the year but showing a decreasing trend in AOD during the last two decades which suggest the possible changes in land use, land cover and precipitation pattern over the adjacent arid land which strongly influences the dust activities and need detailed study.

They performed cluster analysis of air mass back trajectories and found a significant contribution of continental sources in aerosol loading over the different regions of NIO through the long-range transportation, emitted from different regions viz. south Asian countries (up to 35%) and Indian landmass region (up to 49%).

They also suggest that the interaction between aerosol and cloud may not be casual and depends on several other factors like regional meteorological conditions, aerosol/cloud types etc. and need to be studied on an urgent basis to evaluate their impact on oceanic ecosystems as well as Indian Summer Monsoon.

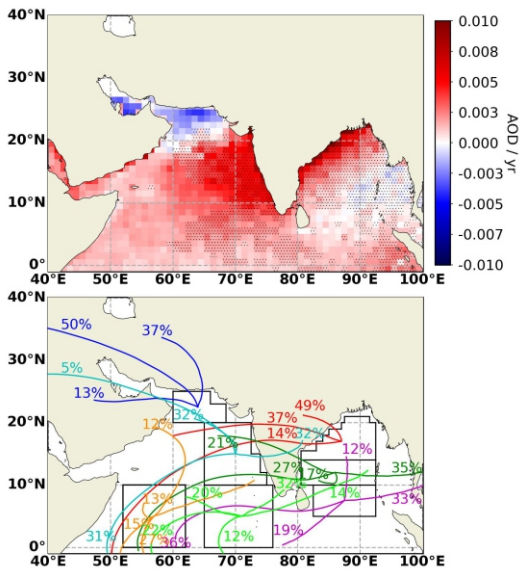


**Figure 1** . Aerosol trend over the Northern Indian Ocean (upper panel) and 5-days airmass back trajectories cluster showing possible aerosol contribution over the different region (modified from Kumar and Tiwari 2023)

# Chronicles of the Coral Kingdom: A Symphony of the Seas

Supriyo Chakraborty
Department of Atmospheric and Space Sciences Savitribai Phule Pune University, Pune

We are corals, the tiny beings who thrive in the marine environment
With millions and billions together, we build our settlement
They are 'coral reefs', the natural wonder, full of life and vitality
They grace the tropical ocean with their charm and dazzling beauty
Coral reefs are more than a rock; they are the home of countless lives
They thrive in the colourful waters; they are the garden of the seas
A reef ecosystem is home to hundreds of gorgeous creatures
Such as the sea horse, molluscs, shells, and the great sea cucumbers

Majestic turtles and colourful fishes roam around
In the coral reef, they have a happy playground
The sea is their kingdom; the reef is their home
A world of wonder where they freely roam

The turtle glides with grace and poise
The fish dart with speed and noise
The octopuses release ink to fool their prey
The dolphins jump and splash and play

The coral reefs offer a wealth of information
From fisheries to pearl to scientific investigation
If there are changes in ocean acidity or temperature
The atoms and molecules of our body act as their recorder
When sea temperature goes up, we restrict oxygen eighteen.
To enter our carbonate matrix but favour its sister, O-sixteen.
A process known as isotopic fractionation (1)
Provides a means to measure sea temperature fluctuation (1).

Millions of corals across the seas
Monitoring the changes registering several degrees (2)
A giant clam, our close relation in the Minicoy Island
Recorded a high temperature event ten years after two thousand (3,4)
Should you want to decouple the effect of temperature and salinity
Measure the strontium/calcium ratio apart from O-isotope variability (5)
The seasonal shift in the water isotopic composition (6)
Could provide the monsoon onset and withdrawal information (7,8)
The scientists have investigated corals from the Lakshadweep (9, 10)
Studied the monsoon vagaries caused by westerly sweep (11)

Increased warming causes more $CO_2$ to enter the ocean (12)
Resulting in an enhancement of acid concentration
A study measured the boron isotopes in coral annual bands (13)
Found a declining pH trend that ocean acidification demands
This means the seawater is less able to buffer
The carbon dioxide emissions that humans continue to suffer
Increased levels of acidity cause coral bleaching and dissolution (14)
Slowly degrading the reef ecosystem and thwarting its evolution

The three isotopes of carbon- twelve, thirteen, and fourteen
Paved a way for scientific analysis to perform carbon dating
Analysis of radiocarbon time-series in a tree and coral specimen
Helped estimate the carbon transfer between the atmosphere and the ocean (15)
You can use current meters to measure today's circulation
To figure out the past, you count $^{14}C$ and study the band formation (16)
The Red Sea, a northern territory of the Indian Ocean
Harbours corals that are influenced by the Mediterranean (17)
A distant relative, the deep-sea coral in the Antarctic rim
Can measure the glacial age circulation- an oceanographer's dream (18)

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Indian Ocean Dipole, cooling and warming of the east-west Ocean shores (19)
Was recorded by corals, in their growth rings and pores (20, 21)
A natural phenomenon that affects the climate and the rains (22)
But also influenced by humans and their greenhouse gas gains (23)

The last hundred years suffered high temperatures in the Indian Ocean (24)
Corals from the African coast measured them with great precision (25)
The rising temperature is a danger you can't ignore (26)
To the marine life that nature lovers adore
The increasing level of oceanic heat is a severe threat
You must act now before you regret

If you are moved by our plight
Take a pledge on this World Ocean Day to restore our might
Take action and reduce your carbon footprint
Use renewable energy and recycle what you spent
Raise awareness and join the global movement
'Save the ocean and the planet', be your true commitment

**Picture credit**: A.A.Fousiya & S. Kumaresan

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## OSI-CUSAT Remote Sensing Training Programme


A five day training programme on "Remote Sensing of Ocean Colour" with experts from NRSC, NERCI, and INCOIS was organized jointly by Cochin University of Science and Technology (CUSAT), Ocean Society of India (OSI), ISRO-National Remote Sensing Centre (NRSA) and the Trevor Platt Foundation during 18-23 March 2024.. The inauguration of the program was done by the President of the Ocean Society of India Dr. N.P. Kurian. Dr. Shubha Satheyndranath from Plymouth Marine Laboratory, UK, provided insights of need of ocean colour satellite data of oceanographic and climatic science studies during the inaugural session.

Keynote lectures of the training programmes were delivered by Dr. Prakash Chauhan, Director, ISRO-NRSCand Dr. Shubha Sathendranath. This training programme introduced to enable the young researchers, teachers and scientists to understand the principles and applications of ocean colour remote sensing in the marine related research, satellite data processing, familiarising different Indian Ocean Colour sensors, Bhuvan/Bhoonidhi data portals etc. Dr. Shubha Sathendranath, Dr. Prakash Chauhan, Director, NRSC-ISRO, Dr. Nagamani P V, Scientist-SG, Group Head, OSG/ECSA, NRSC, G. Dr. Rajdeep Roy, Scientist-'SF", NRSC Abhinav NRSC, T. Devi Prasad NRSC, Dr. Nandini Menon, NERCI, M. Dr. Ranith, NERCI, Suhail NRSC, Dr. Minu P, Post doctoral fellow, KUFOS gave lead talks.

The participants learned different software tools of satellite data processing and visualisation in SeaDAS and SNAP and their application in the different oceanographic field ranging water quality components to different oceanographic process. During this training programme the participant familiarised with many interdisciplinary aspects of oceanography, which was designed meticulously by Dr. Shubha Sathendranath, Dr. Shaju S. S., and Dr. P V. Nagamani along with scientist from ISRO-NRSC and NERCI. The program covered a wide range of Ocean Colour applications, from fisheries to studies on climate change. During these 5 days the younger generation was taught to take up research in their fields using these tools and ocean colour satellites data.

The training sessions were conducted by scientists from ISRO-NRSC, MoES-INCOIS, KUFOS, CUSAT and the Nansen Environmental Research Centre India, with participation from various academic and research institutes from all over India.

## Padma Shri Dr.Shailesh Nayak

It is indeed a matter of great happiness for all of us that Dr. Shailesh Nayak, Honorary Fellow of the Ocean Society of India has been conferred Padma Shri, one of the highest civilian honours of our country. He has been awarded Padma Shri in the field of Science and Engineering in 2024 by the Govt. of India considering his great contributions in research and its applications for the development of our society.

Dr. Shailesh Nayak with a doctoral degree from the M.S. University of Baroda served for long years (1978-2006) in the Space Applications Centre of ISRO and specialized in coastal and ocean processes, snow and glacier studies, coastal management, coastal geomorphology and geological/geomorphic processes, and pioneered the remote sensing application in those areas in the Country. Later during his stint as Director of Indian National Centre for Ocean Information Services, he set up the first Tsunami Early Warning System for India, and made commendable contributions in improving the advisory services on potential fishing zones, ocean state forecast and Indian ARGO project. As the Secretary of the Ministry of Earth Sciences during 2008-2015, Dr. Shailesh Nayak has provided a new vision and dynamism to the Indian Earth Sciences by initiating several new programmes / centres / activities relating to monsoon prediction, global change and the use of earth system science for overall societal benefit. Currently Dr. Nayak as the Director of the National Institute of Advanced Studies, Bangalore is engrossed on research in building strategy for the blue economy and sustainable development.

Dr. Shailesh Nayak has many professional recognitions, honours, awards and honorary degrees to his credit. Dr. Nayak is a Fellow of the Indian National Science Academy, Indian Academy of Sciences and National Academy of Sciences, and many other Scientific Societies of India. He is recognized by the International Academy of Astronautics, Paris. Dr. Nayak is the first Honorary Fellow of the Ocean Society of India. With the Padma Shri award, he joins a selected few earth scientists of our country who are awarded with this civilian honour.

The Governing Council and Members of the Ocean Society of India are happy to join the earth science fraternity in congratulating Dr. Shailesh Nayak for the Padma Shri award and in wishing him many more covetable honours in the future.

## OSI Webinar Series (January-March, 2024)

### February 2024

**Topic:** Coupled Dynamic Analysis of Combined Wave and Wind Energy Devices

Speaker: Dr. Debabrata Karmakar, National Institute of Technology Surathkal
Date & Time: 3 February 2024 (Saturday), 1600-1700 IST

**About the Talk**

The excessive exploitation of non-renewable energy sources has increased the environmental pollution and also causing serious energy crisis issues which has boosted the global pursuits to find clean renewable energy resources that could replace the traditional energy resources. The wind energy has attracted the global attention due to its greater potential and non-polluting nature. In order to reduce the cost of offshore wind energy and to provide continuous supply of power, the wind energy devices can be combined with other marine renewable energy technologies. Several new concepts combining both wind and wave energy is in progress and the focus of study has shifted toward the offshore floating wind turbine platforms integrated with wave energy converters.

### March 2024

**Topic:** Unraveling the Climate Crisis: The Indian Ocean's Role in Rising Seas, and Extreme Events

Speaker: Dr. Athira Krishnan, Scientist, CSIR-National Institute of Oceanography Goa
Date & Time: 7 March 2024 (Thursday), 1600-1700 IST

**About the Talk**

The Indian Ocean plays a pivotal role in shaping global weather patterns. As temperatures soar and ice caps melt, the oceans become a focal point for understanding climate dynamics. Warming waters fuel powerful cyclones, while rising sea levels threaten coastlines. Researchers delve into the ocean's secrets, exploring how it influences extreme events, contributes to global changes, and shapes the future of coastal communities. We uncover crucial insights into mitigating climate change's devastating effects and safeguarding coastal communities worldwide.

**Articles/research highlights of general interest to the oceanographic community are invited for the next issue of the Ocean Digest. Contributions may be emailed to osioceandigest@gmail.com**

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***Cover Photo: Acropora sp. inside the lagoon of Kavaratti Island, Lakshadweep. The branching corals are the dominant communities in the shallow calm waters like lagoons and often build complex reef habitats supporting a wide variety of organisms***
Image credit: Manikandan B, Senior Scientist, CSIR-National Institute of Oceanography, Goa, India.



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