

# Harnessing the blue economy in Lakshadweep Islands through a sustainable tourism perspective

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**This study delves into the dynamics of sustainable tourism in the Lakshadweep Archipelago, India, situated within the ambit of the blue economy framework. The study is centred around achieving a harmonious balance between economic growth and environmental conservation in the Lakshadweep Islands. It critically evaluates the tourism carrying capacity of the Islands, proposing a sustainable model that accommodates varying capacities, ranging from 12 beds in Chetlat to 434 beds in Kadmat, alongside a boating capacity of 207 in Bitra's lagoon. A pivotal finding of this study is the urgent need for stringent environmental management measures, particularly focusing on the protection of fragile coral reef ecosystems against threats like plastic pollution. The limit of acceptable change is rigorously assessed, with coral reef health and water quality as crucial indicators. This study highlights the importance of implementing sustainable practices as a means to both safeguard the ecological integrity of Lakshadweep's diverse islands and drive economic development. These findings play a crucial role in informing policy-making and guiding the alignment of tourism strategies in Lakshadweep with the overarching goals of environmental sustainability and enhancing community welfare.**

**Keywords:** Blue economy, community welfare, coral reefs, environmental management, sustainable tourism.

## Introduction

COASTAL zones are of paramount importance for both ecological and economic sustainability, providing a myriad of resources and ecosystem services<sup>1,2</sup>. These areas necessitate a careful equilibrium between environmental preservation and economic development to ensure the well-being of both the environment and human population. The concept of blue economy (BE) emerges as a critical framework within this context, advocating for the responsible use of marine resources to foster economic growth while conserving ecosystems<sup>3,4</sup>. This is particularly relevant for island ecosystems,

such as India's Lakshadweep Islands, where integrating BE principles can significantly contribute to achieving the United Nations Sustainable Development Goals by protecting marine environments and their dependent communities<sup>5</sup>.

The Lakshadweep Islands, situated in the Arabian Sea off India's southwest coast, provide a unique opportunity to synergize BE and the tourism sector. These Islands, renowned for their ecological significance and cultural diversity, make the promotion of responsible tourism essential for sustaining local communities. By adopting sustainable practices, the Lakshadweep Islands can preserve their natural and cultural heritage for future generations, thereby contributing to economic growth and aligning with the global sustainable tourism trends<sup>6</sup>.

However, these Islands face unique challenges, including limited land availability, vulnerability to climate change and finite resources. These challenges necessitate the establishment of a sustainable BE for the enduring welfare of island communities. The interplay between BE and tourism is particularly notable in small oceanic islands, where both sectors aim to harness ocean and coastal resources for economic development through sustainable practices. Recreational tourism, being a primary income source in these Islands, stands to benefit significantly from adherence to BE principles<sup>7</sup>. The effective integration of these principles in management and development strategies is vital for addressing the Islands' specific needs, contributing to sustainable development, and ensuring long-term well-being.

Acknowledging environmental and socio-economic stressors in planning is crucial, and the adoption of BE concepts offers tangible benefits to local communities and the natural environment, enhancing resilience and creating economic opportunities, this study, therefore, explores the integration of sustainable tourism within the BE framework in the Lakshadweep Islands, focusing on balancing economic growth with environmental conservation and community welfare.

## Methodological approach

The Lakshadweep archipelago, positioned at 8°–12°N lat. and 71°–74°E long. (Figure 1), comprises 36 coral atolls

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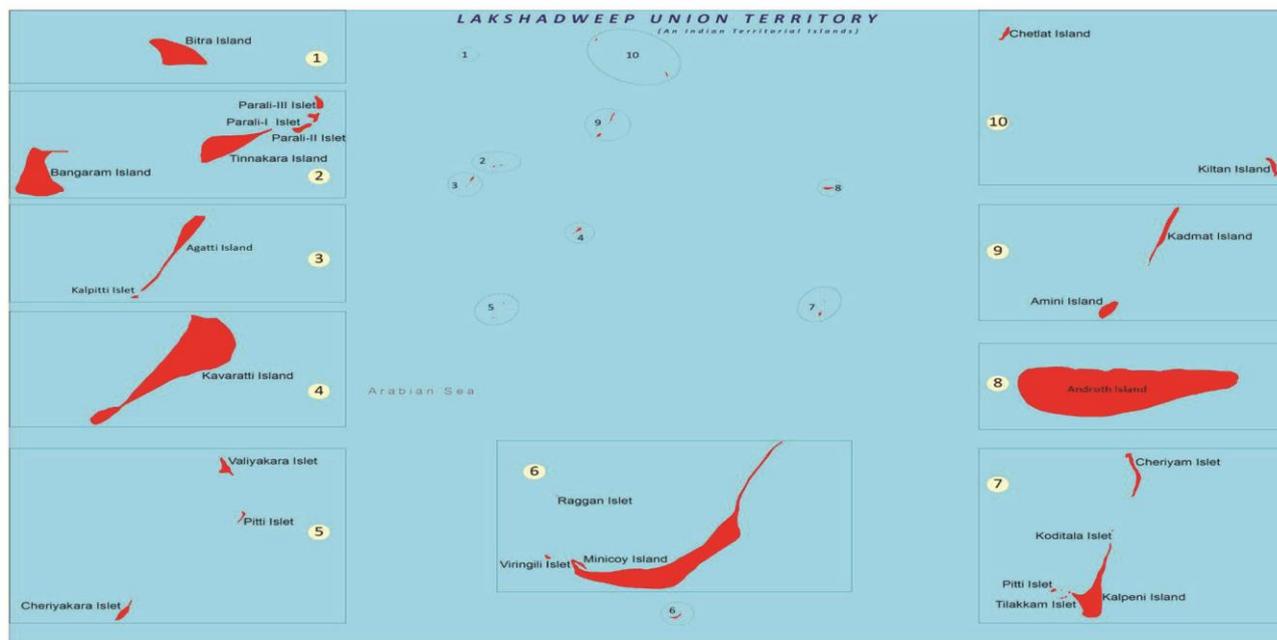


Figure 1. Map of the Lakshadweep group of islands, India.

and is India's smallest Union Territory, presenting unique ecological and socio-economic dynamics<sup>8</sup>. The methodology adopted in this study involved a comprehensive assessment of the tourism capacity of these Islands, encompassing spatial analysis and ecological considerations.

During 2016–17, a detailed survey was carried out across nine inhabited islands, using geo-referenced maps at the block, sub-block and plot levels to accurately calculate the area available for tourism development ([Supplementary Figure 1](#)), following the National Building Code of India 2016 and *The Architects' Handbook*<sup>9</sup>. This approach allowed precise estimation of bed capacity and built-up area, considering floor area ratio (FAR) recommendations and excluding no-development zones (NDZs).

The determination of boating density in the Lakshadweep lagoon utilized a weighted score analysis, incorporating a scoring matrix with 11 lagoon characteristics ([Supplementary Tables 1 and 2](#)). The methodology factored in spatial requirements for different boat types and their respective restrictive scores to compute optimal boating density, recommending a density of 20 acres per motorboat and lesser densities for smaller boats<sup>10,11</sup> ([Supplementary Figure 2 and Table 3](#)). The [Supplementary material](#) provides a detailed methodology elucidating the boating density calculated for the lagoon.

The carrying capacity of the lagoon for boat numbers was assessed by applying this optimal boating density across the entire lagoon area, crafting three distinct scenarios based on ecological parameters and specific island lagoon areas. This included maximum ([Supplementary Figure 3 and Table 4](#)), optimum ([Supplementary Figure 4 and Table 5](#)) and sustainable ([Supplementary Figure 5 and Table 6](#))

models are tailored with the ecological context of the respective islands. Ecologically Sensitive Areas (ESAs) such as seagrass, corals and fish breeding sites were included in the analysis, as well as diverse geomorphological features such as sand sheets, reef crests, reef slopes, deeper reef flats, reef flats and sandy reef flats. The lagoon features, viz. deep intermediate and shallow lagoons, were also included in the evaluation ([Supplementary material](#)).

For solid waste and sewage assessment, guidelines from the Central Pollution Control Board, Government of India and Urban and Regional Development Plans Formulation and Implementation guidelines were developed by the Ministry of Urban Development. A marine litter survey, adhering to Oslo and Paris Conventions (OSPAR) guidelines, was conducted on select islands to categorize and quantify marine litter, employing the clean coast index (CCI) for assessing the cleanliness level of the coast<sup>12–14</sup>.

The limit of acceptable change (LAC) for Lakshadweep Islands was determined using key indicators like coral reef health and water quality, following established methodologies<sup>15</sup>. This comprehensive methodological approach enabled a nuanced understanding of the tourism potential and environmental constraints of the Lakshadweep Islands, offering a model for sustainable tourism development within the framework of BE.

## Results and discussion

A comprehensive SWOT analysis delineated the strengths, weaknesses, opportunities, and threats regarding sustainable development and environmental conservation in the Lakshadweep Islands (Figure 2 and [Supplementary Table 7](#)).



**Figure 2.** SWOT analysis for tourism development in the Lakshadweep Islands.

The unique challenges of these Islands, such as their vulnerability to climate change and limited resources, significantly impact their fishery potential, aesthetics, tourism and local livelihoods<sup>16,17</sup>. The analysis identified key areas for strategic planning and sustainable development, emphasizing the need for a multifaceted approach to address these challenges.

#### *Tourism carrying capacity*

The concept of tourism carrying capacity (TCC) in the Lakshadweep Islands is central to this study, where we aimed to determine the maximum sustainable tourist population that the Islands can support without causing ecological or socio-economic harm<sup>18</sup>. Our assessment considered three distinct TCC scenarios: sustainable, optimal and maximum models, each tailored to specific ecological parameters and island capacities.

The sustainable model, recommended for its ecological sensitivity, indicates accommodation capacities ranging from 12 beds on Chetlat Island to 434 beds on Kadmat Island. This model provides a balanced approach, offering opportunities for both present and future tourism expansion while preserving the Islands' fragile ecosystems (Figure 3 a and [Supplementary Tables 8–10](#)). In terms of boating capacity, the analysis revealed that the number of boats permissible on the lagoon varied significantly across the Islands. For instance, Chetlat Island could accommodate up to 11 boats at a given time, while Bitra Island could support up to 207 boats (Table 1). These figures underscore the need to regulate boating activities, particularly in ecologically sensitive areas like coral reefs and seagrass beds<sup>19</sup>.

The TCC analysis serves as a model for sustainable tourism in small island ecosystems, illustrating the importance of balancing economic development with environmental stewardship. The nuanced approach in determining the TCC values for each island ensures that the unique environmental and socio-economic characteristics of each

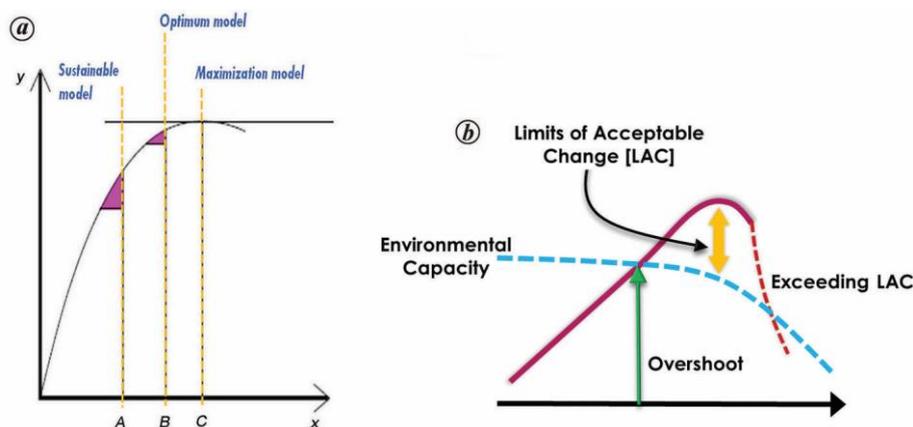
location are considered, setting a precedent for sustainable tourism practices in the island ecosystems<sup>19</sup>.

#### *Limit of acceptable change*

The LAC framework is a crucial aspect of this study, guiding sustainable tourism development in the Lakshadweep Islands. This adaptive management strategy focuses on establishing and monitoring acceptable thresholds of change in natural resources, particularly in ecologically sensitive areas like islands and coral reefs.

We applied the LAC model on a scale of 1–10 for the Lakshadweep Islands, incorporating 11 indicators subjected to sensitive risk score analysis. This comprehensive analysis involved key environmental and socio-economic factors such as coral reef health, water and groundwater quality, coastal erosion and land availability (Figure 3 b and [Supplementary Table 11](#)). Our findings indicate that certain islands, such as Agatti, Kalpeni, Kadamat and Minicoy, exhibit lower sensitivity, whereas Kavaratti, Kiltan, Amini and Andrott are classified as highly sensitive. The utility of the LAC model is particularly evident in its ability to aid the Union Territory's administration and environmental planners in formulating policies<sup>15</sup>. By establishing thresholds based on the LAC analysis, the administration can identify areas for future tourism development and expansion while ensuring environmental sustainability and the well-being of local communities ([Supplementary Table 11](#)).

The LAC framework is instrumental for Lakshadweep's sustainable tourism development, as it allows for the identification of the limits within which tourism activities can occur without causing significant harm to the local ecosystems and communities. By adhering to these limits, the Lakshadweep Islands can ensure that tourism development aligns with the broader objectives of environmental conservation and community welfare.



**Figure 3.** Tourism development model for the Lakshadweep Islands: (a) scenario-based tourism carrying capacity and (b) model for the limits of acceptable change (LAC).

**Table 1.** Carrying capacity on various inhabited islands of Lakshadweep, India (2016–17)

Parameters	Agatti	Andrott	Bitra	Chetlat	Kadmat	Kalpeni	Kavaratti	Kiltan	Minicoy
Area of Island (km <sup>2</sup> )	3.84	4.90	0.10	1.04	3.12	2.79	4.22	1.63	4.39
Maximum length of the island (km)	10	4.7	0.5	5.8	18.4	5.5	14.7	7.8	23
Area outlined for tourism (km <sup>2</sup> )*	166,271	28,287	11,178	3,239	120,676	89,331	80,672	14,681	93,661
Area falling within the no-development zones (km <sup>2</sup> )	64,200	12,176	5,846	664	62,788	30,789	22,253	12,764	22,288
Total developable area in the island (km <sup>2</sup> )	102,071	16,111	5,333	2,575	93,450	52,905	58,419	1,917	63,550
Number of beds that can be accommodated	399	86	41	12	434	235	243	39	358
Total freshwater required (kilolitres per day)	68	15	7	24	74	40	42	7	61
Total sewage/waste water generated due to tourism (kilolitres per day)	55	12	6	1.6	60	32	33	5	49
Quantity of solid waste generated due to tourism (kg per day)	200	43	21	6	217	118	122	20	180
Number of boats on the lagoon at a given time	69	46	207	11	66	116	19	12	200

\*Data from the Integrated Island Management Plan, developed by the National Centre for Earth Science Studies, Thiruvananthapuram in accordance with the guidelines stipulated in the Coastal Regulation Zone Notification of 2011.

### Marine litter assessment

The assessment of marine debris in the Lakshadweep Islands plays a vital role in our environmental studies, highlighting various kinds and amounts of waste impacting these sensitive ecosystems. This assessment is particularly relevant given the growing concern over marine pollution and its impact on island ecologies.

Our survey followed OSPAR guidelines, and we conducted transect sampling within 5 m of the high tide line over a 100 m length on each island, categorizing the collected litter into seven types: plastic, metal, glass, rubber, processed lumber, cloth or fabric and medical waste.

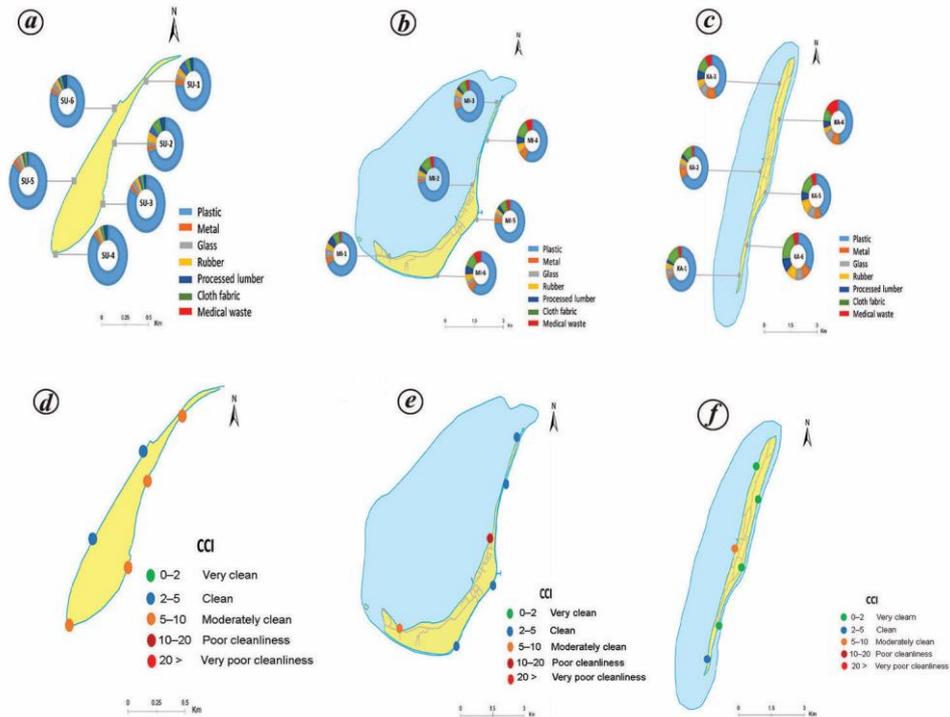
The findings of the survey revealed the significant prevalence of plastic, accounting for 69.4% of all marine litter (Supplementary Figures 6 and 7). The mean abundance of marine litter across these islands was found to be  $0.31 \pm 0.17$  items/m<sup>2</sup>, a figure comparable to regions like Vina del Mar in Chile<sup>20</sup> and North Santa Catarina Island in Brazil<sup>21</sup>.

CCI was used to determine the cleanliness level of the coast, with the highest mean abundance of marine litter found on Suheli ( $0.36 \pm 0.17$  items/m<sup>2</sup>), followed by Minicoy ( $0.35 \pm 0.22$  items/m<sup>2</sup>) and Kadmat ( $0.24 \pm 0.15$  items/m<sup>2</sup>).

CCI reflects the island’s litter status (Figure 4), with sea-based sources, including shipping and fishing, identified as the primary contributors. Notably, the presence of litter from transboundary nature suggests islands as potential sinks for extensive international litter transported through oceanic gyres<sup>22</sup>. These data point to the requirement of targeted marine litter mitigation strategies in the Lakshadweep Islands.

### Strategies for augmenting sustainable tourism

The Lakshadweep Islands play a vital role in the BE framework, significantly contributing to sectors such as fisheries, tourism, maritime transportation and marine biotechnology. These sectors collectively create a complex socio-economic fabric in the region, with fisheries being essential for local livelihoods, tourism substantially aiding economic growth and maritime transportation facilitating regional connectivity. The region demonstrates a strong commitment to both technological progress and environmental conservation, as evidenced by initiatives in marine biotechnology, desalination and blue-carbon projects. Sustainable practices in fisheries management and seafood processing are



**Figure 4.** Marine litter on three islands of Lakshadweep: (a–c) Composition and (d–f) clean coast index (CCI) of Suheli, Minicoy and Kadamat respectively.

prioritized, underpinning Lakshadweep’s drive towards an ecologically sustainable and resilient future. This approach integrates innovation and environmental stewardship within the diverse architecture of BE.

Lakshadweep’s rich cultural heritage, embedded in traditional knowledge and practices, has sustained its communities over generations. Practices such as jaggery production, virgin coconut oil extraction, vinegar production and traditional tuna fish canning are central to the Islands’ cultural identity. These practices underscore the commitment of the residents to a sustainable lifestyle, melding cultural heritage with environmental stewardship<sup>23</sup>. The local cuisine ‘massmeen’, derived from preserved yellowfin tuna, is a candidate for Geographical Indication (GI) status, highlighting the Islands’ unique culinary traditions and potentially attracting tourists seeking authentic experiences<sup>24</sup>. Activities such as coir product manufacturing and food processing by local self-help groups represent a blend of traditional skills and community-led initiatives, fostering local subsistence and market-oriented trade. Cultural expressions like the ‘lava dance’ and ‘jahangir thoni’ boat race in the Minicoy Island are pivotal in celebrating the islanders’ maritime heritage, enhancing tourist appeal while preserving Lakshadweep’s cultural legacy.

In the context of tourism, Lakshadweep emphasizes participatory models, involving local communities in decision-making processes, and promoting responsible tourist behaviour to support environmental conservation and sustainable resource management. This participatory approach is in line with global tourism trends, including

homestays and eco-tours, which are marketed through digital platforms<sup>25</sup>. Such engagement not only improves the standard of living for local communities but also fosters a sense of stewardship over their environment, steering the Islands towards a sustainable trajectory. By focusing on high-value tourism, which includes luxury offerings like lagoon villas, seaplanes and water sports, Lakshadweep aims to generate economic benefits while minimizing environmental impacts. This strategy helps mitigate the risks associated with overtourism, focusing on attracting tourists interested in unique, high-end experiences<sup>26</sup>. Sustainable tourism indicators ([Supplementary Table 12](#)) are employed to guide stakeholders, including authorities, businesses and local communities, in making informed decisions that safeguard the Islands’ unique environmental and cultural assets<sup>27,28</sup>, as illustrated in the recreational activities depicted in the [Supplementary Figure 8](#).

#### *Ecological protection strategies for sustainable tourism in island ecosystems*

Effective ecological protection measures are essential for maintaining the delicate balance of island ecosystems while fostering sustainable tourism. This encompasses a range of strategies, from zoning to waste management, as detailed below:

- (i) Designated protected zones play a critical role in conserving marine life and ecosystems. Restricting activities such as water sports, snorkelling, diving

**Table 2.** Measures for resource management in sustainable tourism development

Key factors	Essentials of island tourism
Resource management	Environmental conservation Biodiversity protection Preserving the natural beauty of these islands Protecting the cultural heritage, traditions and historical sites Water conservation through rainwater harvesting
Sustainable tourism	Sustainable tourism ensures resource management Responsible tourism improves the quality of experience for visitors Mitigate overtourism
Infrastructure development	Ensures that tourism infrastructure aligns with the carrying capacity of the destination
Water management	Sustainable water use and rainwater harvesting
Waste management	Managing waste involves waste disposal, recycling and measures to prevent marine litter
Energy efficiency	Energy-efficient practices may be included in tourism and domestic sectors
Community well-being	Ensures the social and economic well-being of local communities
Economic sustainability	Contributes to the long-term economic sustainability of island tourism
Environmental education	Education and outreach efforts to raise awareness on the importance of conservation Promote responsible tourism

and fishing in these zones helps prevent ecological disturbances. Educating tourists about responsible behaviour, such as avoiding interference with wild-life and adhering to no-trace principles is vital.

- (ii) Tour operators are encouraged to develop and adopt a code of conduct for water-based activities. These include using marker buoys to prevent coral reef damage, setting up protective barriers and participating in eco-certification programmes<sup>29</sup>. The establishment of oceanariums and interpretation centres aids in raising awareness about environmental conservation.
- (iii) Mitigating terrestrial light and noise pollution is crucial for protecting the habitats of endangered species such as sea turtles<sup>30</sup>. This involves controlled lighting and sound policies in tourist areas.
- (iv) Implementing zero-waste initiatives, particularly in tourist-heavy areas, is essential. This includes reducing packaging, promoting reusable items and managing waste disposal effectively. Regular waste audits are to be conducted to evaluate and improve waste management strategies periodically<sup>31</sup>.
- (v) The application of advanced treatment technologies for managing sewage, wastewater and greywater is crucial in sensitive ecological zones. The use of decentralized wastewater treatment systems, constructed wetlands, and bio-toilet facilities offers cost-effective and environment-friendly waste-treatment solutions<sup>32,33</sup>.
- (vi) Addressing water scarcity involves implementing rainwater harvesting and desalination techniques. Emphasizing energy-efficient designs and renewable energy sources such as solar panels and wind turbines helps reduce carbon emissions and operational costs.
- (vii) Establishing Marine Protected Areas is crucial for conserving critical habitats. Awareness on island conservation and sustainable tourism practices is vital for both tourists and local communities (Table 2).

- (viii) Expanding BE beyond tourism to include sectors such as fisheries, aquaculture, and renewable energy projects reduces reliance on a single industry, and contributes to overall health and recovery of the ecosystem<sup>34</sup>.
- (ix) Coastal and marine spatial planning is integral to sustainable tourism, managing the allocation of marine resources and prevention of their overexploitation. This approach supports the sustainable development of BE in islands, balancing economic growth with environmental conservation and resilience against climate change<sup>35</sup>.

### Conclusion and prospective developments

This study emphasizes on a strategic blend of economic development and ecological conservation. At its core, it advocates for the sustainable utilization of marine and coastal resources, integrating eco-tourism, sustainable fisheries and green maritime practices, while preserving the unique environmental essence of the Lakshadweep Islands.

The approach hinges on a multifaceted framework that merges stringent environmental policies, community participation, cross-disciplinary cooperation and innovation in governance. This framework is designed to support the regional BE objectives and strengthen the Islands’ resilience against climate change, thus enhancing their adaptive capacities.

Key to this approach is the continuous re-evaluation and adaptability, considering the ever-changing environmental, economic and social dynamics of small islands. This ongoing process of policy and practice refinement is crucial to achieving a harmonious balance between economic growth and ecological sustainability, securing a future for a prosperous and environmentally responsible Lakshadweep Islands.

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**ACKNOWLEDGEMENTS.** The research presented herein forms a crucial part of the TCC plans, aimed at conducting detailed assessments of carrying capacity for the sustainable development of the Lakshadweep Islands. We thank the Department of Science and Technology, Government of India and the administration of Lakshadweep for their invaluable support and contributions to this study. We also thank Prof. R. Parthasarathy (former Director, Gujarat Institute of Development Research, Gujarat), whose expert insights and thorough review significantly enriched the quality of this study. We thank Dr R. Muruganandam (National Centre for Sustainable Coastal Management (NCSCM)) for his contribution in developing the map of the Lakshadweep archipelago study area. This work is recognized as a contribution from the NCSCM, Chennai, marked as NCSCM publication number NCSCM/PUB/2024/003.

doi: 10.18520/cs/v126/i2/215-221