Journal of Advanced Zoology
ISSN: 0253-7214
Volume 46 Issue 2 Year 2025 Page 01-09

"Impacts of Anthropogenic Factors on Nesting Behaviour of Olive Ridley Turtles at Ratnagiri Coast"

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Abstract:

Anthropogenic factors such as the spread of non-degradable waste and sewage disposal can significantly influence the nesting behaviour of Olive Ridley Turtles. To assess these anthropogenic threats to olive Ridley turtle nesting sites on the Ratnagiri coast of Maharashtra, a study was conducted during the breeding seasons of 2019-20 and 2020-21. Beach profiling and non-biodegradable waste ground cover were examined across 11 beaches in the Ratnagiri District. The study revealed that many resorts discharge their wastewater and non-biodegradable solid waste directly onto the beaches. Additionally, ocean currents contribute to waste accumulation during ebb and flow. Consequently, female turtles tend to avoid these sewage-prone beach areas for nesting. While non-degradable ground cover litter was present, it did not show a significant association with nesting density. Therefore, to mitigate these anthropogenic impacts on nesting Olive Ridley sea turtles, the implementation of strict sewage and waste disposal regulations is a crucial and immediate step towards protecting these vulnerable nesting sites along the Ratnagiri coast.

Keywords: Anthropogenic factors, Olive ridley nesting, Non degradable waste, tourism

Introduction:

The Olive Ridley turtle (*Lepidochelys olivacea*) is recognized as one of the smallest and most abundant sea turtle species globally, inhabiting both oceanic and neritic zones within a single ocean basin. Notably, this species exhibits a unique reproductive behavior known as "arribada," characterized by synchronized mass nesting events, primarily observed along the coasts of Orissa on the eastern seaboard of India (Tripathy et al., 2003). In contrast to these mass nesting phenomena, sporadic nesting patterns are also evident in other regions. The main olive ridley nesting grounds include some areas in Costa Rica and others in Mexico and Odisha coastline is one of them in the Pacific and Indian oceans (Poornima, 2021).However, the population of Olive Ridley turtles is rapidly decreasing, necessitating global conservation efforts. The survival of Olive Ridley turtles faces substantial threats due to increased fishing activities in coastal waters near key nesting sites (Pandav et al., 1997). Sea turtles are highly migratory, traversing vast marine environments and utilizing diverse habitats throughout their life cycle, including sandy beaches for nesting and various pelagic and neritic habitats for foraging and development (Uribe-Martínez et al., 2021). The inadvertent capture of sea turtles in fishing gear, known as by-catch, constitutes a significant mortality factor for these animals (Sales et al., 2008).

Marine turtles encounter a multitude of threats that vary across different regions, encompassing fisheries bycatch, coastal development, pollution, pathogens, and climate change (Wallace et al., 2011). These anthropogenic factors collectively contribute to the decline of sea turtle populations worldwide, disrupting their natural behaviors and ecological roles. Tourism activities, while economically beneficial, can pose threats to turtle populations through habitat degradation and disturbance (Bahar et al., 2021). The widespread use of small mesh gillnets leads to the capture of numerous juvenile turtles, especially in riverine habitats, which diminishes the breeding population of subsequent generations and contributes to population decline (Funge-Smith et al., 2012). Conservation strategies must consider the entire life cycle of sea turtles, including the protection of nesting beaches, foraging habitats, and migratory corridors (Metz et al., 2020). It has been documented that the capture of marine mammals and other marine life in fishing gear can be a serious problem in terms of impacts imposed on marine mammal populations and public ethical concerns (Alverson, 1994). The interaction of marine mammals and other marine life in fishing gear has been shown, to be a significant problem, in the context of impact on marine mammal stocks and public ethical concerns (Alverson, 1994).
The implementation of sustainable fishing practices, such as the use of turtle excluder devices in trawl nets, is essential to minimize by-catch mortality.
Anthropogenic activities, including tourism, industrial development, and pollution, pose significant threats to nesting beaches, disrupting nesting behavior and reducing hatching success. Coastal fisheries around the world are largely regarded as unsustainable, if not already overexploited (Pratchett et al., 2011). In addition to targeted hunting, human activities such as overfishing, habitat loss, pollution, and climate change significantly threaten marine life and habitats (Arunima, 2020). The establishment of marine protected areas and the implementation of fishing regulations are crucial for safeguarding critical habitats and ensuring the long-term survival of marine turtle populations (Krueck et al., 2017). Marine environments encompass biodiversity-rich ecological units, and human reliance on marine flora and fauna is extensive. However, human activities have contributed to the degradation of resources in these ecosystems, leading to biodiversity reduction and long-term effects on the biosphere (Libini et al., 2008).

Impact of Waste and Sewage:

Non-degradable waste and sewage disposal represent significant anthropogenic factors influencing the nesting behavior of Olive Ridley turtles, and the discharge of wastewater and disposal of non-biodegradable solid waste on beaches is a pervasive issue, particularly in areas with resorts. The accumulation of marine debris, including plastics, fishing gear, and other anthropogenic waste, poses a direct threat to sea turtles through entanglement and ingestion (Tibbetts, 2015). The presence of marine debris in coastal areas leads to silting, narrowing of river basins, and decreased water quality, ultimately impacting public health (Faizal et al., 2021). Entanglement in plastic bags, pot gear, trap nets, and ropes can cause injury, drowning, or starvation, while ingestion of plastic debris can lead to internal injuries, digestive blockages, and reduced nutritional intake (Blais & Wells, 2022).
The introduction of untreated sewage into coastal waters introduces pollutants that can degrade water quality, disrupt marine ecosystems, and pose health risks to both marine life and humans. The large amount of waste generated from fishing activities, including bones, shells, heads, skins, and visceral parts, contributes to marine pollution and can impact marine life (Teixeira-Costa & Andrade, 2021). Contamination resulting from improper handling of plastic waste can lead to adverse effects on human health and wildlife, as well as pollution of oceans and fresh waterways (Parajuly & Fitzpatrick, 2020). The valorization of seafood waste, through the extraction of valuable components like alginate, protein, and chitin, offers a sustainable solution to reduce waste and create eco-friendly alternatives to artificial polymers (Zhan et al., 2024). Inadequate management of plastic waste poses a significant threat to marine ecosystems, potentially leading to reduced economic welfare due to impacts on marine life (Issifu & Sumaila, 2020).
Moreover, the accumulation of plastic debris in the marine environment represents a global concern with far-reaching consequences (Seeley et al., 2020). Macro and micro-plastic contamination has become ubiquitous in marine ecosystems, impacting biodiversity and potentially affecting human health through the food chain (Xie et al., 2022). Plastic litter, a dominant form of marine debris, poses a complex problem in aquatic ecosystems, damaging aesthetics and harming biota through various diseases, food web disruptions, and reduced fish productivity (Anggraini et al., 2020). The increasing amount of plastic waste in aquatic ecosystems, projected to reach 29 million tons per year by 2040, poses serious risks to marine life through entanglement, suffocation, and ingestion of microplastics (Yu & Flury, 2024). The degradation of plastics into micro and nano sizes leads to widespread contamination in air, water, and soil, causing negative impacts on both terrestrial and aquatic animals, including ingestion, entanglement, ulcers, low reproduction, and oxidative stress (Pilapitiya & Ratnayake, 2024). Additionally, the degradation of mismanaged plastic waste into smaller fragments poses a notable threat to the environment and biota, with plastic debris found in numerous marine organisms (Fok et al., 2019).

Materials & Methods:
Study Area:

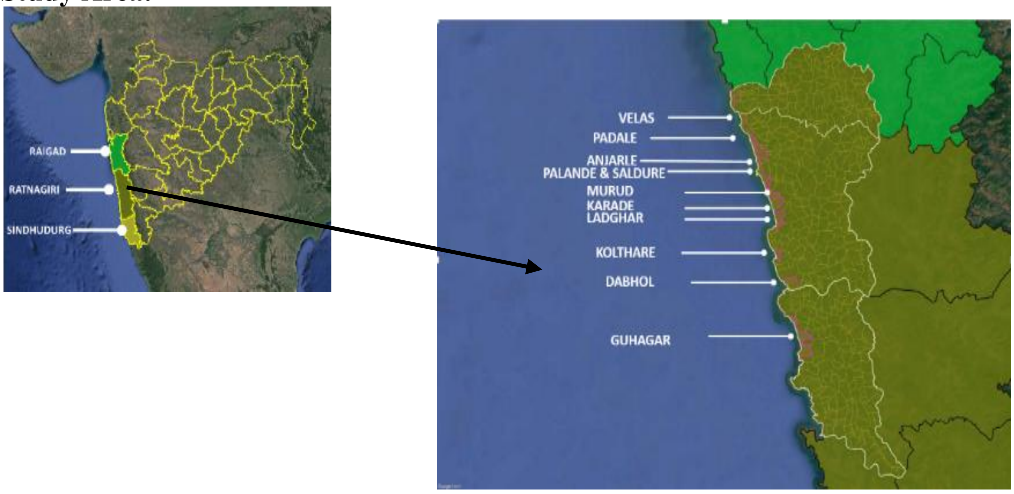

Fig. No.1: Location of Study Beaches (**Map Source-** Google Earth)

The study was conducted from 10th November 2020 to 31st December 2021. The study area constitutes the coast of Ratnagiri district on the west coast of Maharashtra. There is sporadic nesting of Olive ridley along the entire coast with a few good nesting beaches in Ratnagiri district like Velas, Dabhol, Guhagar etc. Most of these beaches selected are based on nesting density as per Table No.1. The study area constitutes 11 beaches of the Ratnagiri district viz. Velas, Padale, Anjarle, Palande, Saldure, Murud, Karde, Ladghar, Kolthare, Dabhol and Guhagar on west coast of Maharashtra. The study area covers a horizontal distance of about 90 km from Velas to Guhaghar. Beaches were selected to cover a gradient of high, moderate, low and no nesting beaches (Table No.1).

Table No.1: Selection of beaches as per nesting density of Olive Ridley Turtles

Sr. No.	Nesting Density	Name of Beaches
1.	High	Velas, Kolthare, Guhagar
2.	Moderate	Anjarle, Murud, Dabhol
3.	Low	Karde & Ladghar
4.	Nil	Palande, Padale & Saldure

Beach Profiling for Tourism Resorts, Sewage Disposal & Non-degradable Waste disposal:
Permanent Belt Transects (BT) GPS coordinates were recorded during field visits by Garmin GPS 72H as well as permanent paint markings at the shoreline stones. The selected beaches were surveyed for the distribution of nesting density and non-degradable waste.
The belt transects were laid from the shoreline towards the lowest low tide line with a distance of 100 m between two consecutive transects. In all about 11 Km of sampling is completed for both study seasons (2019-20 & 2020-21). The anthropogenic impacts in terms of beach tourist resorts, number of tourists, solid waste dumping sites, sewage disposal, and number of stray dogs were recorded

Sr. No.	Name of Beach	Number of Belt Transects Laid
1.	Velas	8
2.	Padale	8
3.	Anjarle	18
4.	Palande	10
5.	Saldure	2
6.	Murud	16
7.	Karde	10
8.	Ladghar	14
9.	Kolthare	9
10.	Dabhol	7
11.	Guhagar	8
	Total:	**110**

Table No.1: Beach-wise number of transects laid

Non-Biodegradable Waste Assessment:

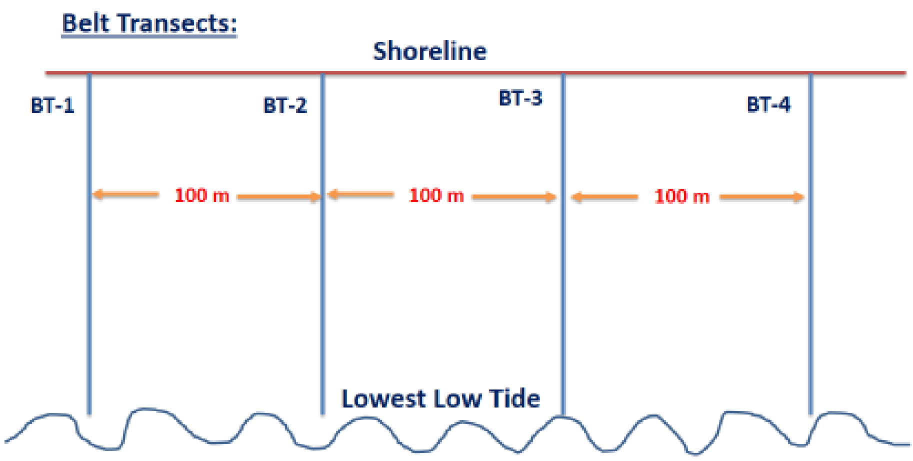

Fig No. 2:- Layout of Belt Transects from shoreline

A 1 metre by 1 metre PVC pipe quadrate with 25 equal divisions was used to assess the ground cover of non-biodegradable waste spread. The quadrate were laid along permanent belt transects at every 10 meter interval from the shoreline to the lowest low-tide mark. The percent ground cover & type of non-degradable waste was recorded using datasheets. The amount of non-degradable debris spread per quadrant was counted by visual identification and counting. The non-biodegradable waste spread quadrates were revisited & data was collected for season 2020-21 by the same method for comparative assessment.

Results & Discussion:

I) Beach Profiling for Tourism Resorts, Sewage Disposal & Beach Armoring/ Flood Resistant wall:
The highest number of beach-facing resorts were found at Murud, Karde, and Ladghar beaches, followed by an intermediate density at Anjarle, Saldure, Guhagar, and Palande beaches, respectively. The least number of resorts were found at Padale beach, with no beachside resorts at Velas, Dabhol, and Kolthare beaches. The highest tourism density was recorded at Murud, Karde, Ladghar, and Guhagar Beaches. Intermediate tourist density was observed at Anjarle, Palande, Saldure, and Padale beaches, with the least tourist density seen at Kolthare, Dabhol, and Velas beaches. Natural nesting was more common in beach areas less frequented by tourists.

It can be observed that nesting is more common on beaches where there are fewer resorts. Ghuhagar, Dabhol, Kolthare, and Velas beaches have the highest number of nests and no beachside resorts. The data indicates a negative trend between the number of tourism resorts and nesting density. Murud beach is the only outlier, with both a high number of resorts and an intermediate nesting density, likely because of the beach's length and width, which provide areas less frequented by tourist.

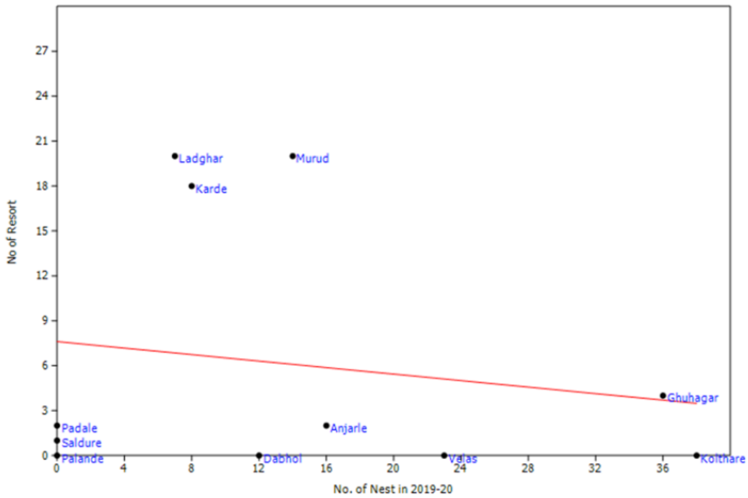

Fig No.3:- Numer of Nests vs. Number of Resorts

Beaches with beach armoring or flood-resistant bunds, such as Ladghar, exhibited lower nesting density. Dabhol beach, despite having a flood-resistant bund, showed high nesting density due to its large beach width and length, with nesting concentrated in areas without beach armoring. Flood resistant walls, constructed by rock pitching, can slide down below the beach sand over time, reducing the effective beach length for nesting. Consequently, female turtles may struggle to dig nests of sufficient depth, leading to multiple attempts or abandonment of the beach in search of a more suitable location. Thus, flood-resistant walls showed a negative trend over nesting density.
The present study revealed that 60% of resorts along the beaches lack proper sewage disposal systems and release sewage directly onto the beach. Female turtles tend to avoid these sewage-prone areas for nesting, as they prefer dry sand for nest construction, while the sewage-prone areas are constantly wet, causing compaction of the sand and making it difficult for the female to dig her nest.
In the nesting season of 2019-20, the highest nesting density was recorded at Kolthare and Guhagar beaches, followed by Velas, Anjarle, Murud, and Dabhol beaches. The least nesting was observed at Karde and Ladghar beaches. Palande, Saldure, and Padale beaches recorded no nesting.

The non-degradable waste spread ground cover was found to be highest i.e. 30% at Velas beach followed by Dabhol beach; the least ground cover was recorded at Karde beach where daily beach clean-up is done by village gram panchayat. Karde beach, though having the least ground cover, still has the least nesting density for the season, whereas Velas beach, though having the highest ground cover, showed the third highest nesting density of 23 nests, which shows that non-degradable ground cover has no significant correlation with nesting density. The non-degradable waste is deposited mainly in the first quadrat near the shoreline along all belt transects due to the sweeping action of waves. The spread was recorded up to 30 meters from the shoreline at all study beaches.

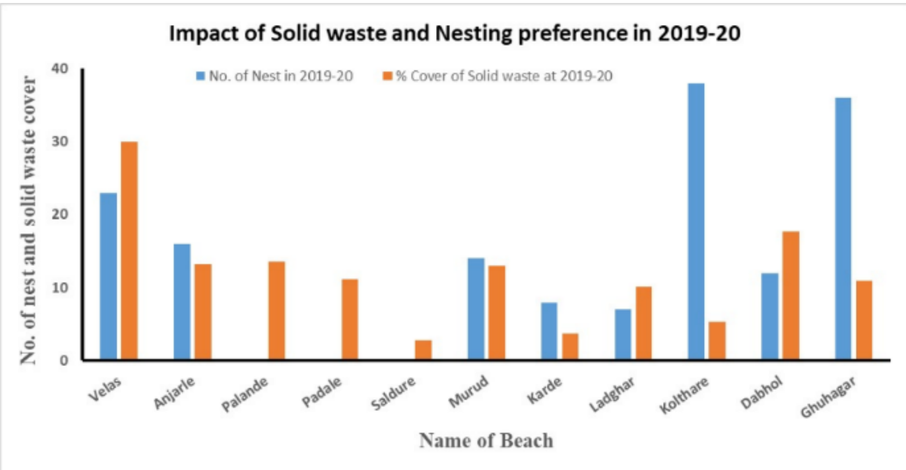

Fig No.3:- Beach wise Solid Waste Cover vs. Number of Nests in 2019-20
Similarly, in the nesting season of 2020-21, the nesting density was highest at Guhagar and Kolthare beaches, followed by Velas, Murud, Anjarle, and Dabhol, respectively. The least nesting was recorded at Karde & Ladghar beaches. However, Palande, Saldure, and Padale beaches recorded no nesting, as in 2019-20. The non-degradable waste spread ground cover was found to be highest, i.e., 34%, at Velas beach, followed by Dabhol beach, with the least ground cover recorded at 3.76% at Karde beach owing to regular beach clean-up activity. Despite having the least ground cover, Karde beach still has the least nesting density for the season, whereas Velas beach, despite having the highest ground cover, showed the third-highest nesting density of 36 nests, demonstrating that non-degradable ground cover has no significant association with nesting density. Even beaches with high ground cover like Velas & Dabhol showed high nesting density. About 45% of non-degradable waste comprises ghost nets (i.e., damaged fishing nets abandoned by fishermen on trawlers), followed by plastic bottles, food wrappers, glass bottles, thermacoal, fishing nylon ropes, bottle caps, etc.

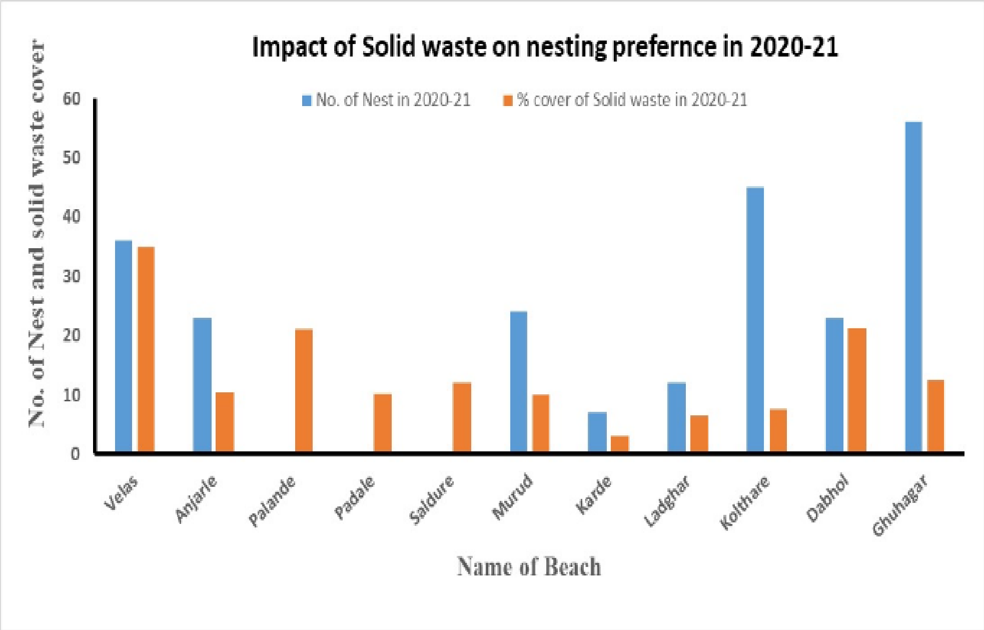

Fig No.4:- Beach wise Solid Waste Cover vs. Number of Nests in 2020-21

Fig No.5:- Non degradable waste spread along Velas Beach

Table No.2: Beach wise Number of Nests and % of Solid Non degradable Waste Cover

Name of Beach	No. of Nests in 2019-20	% Cover of Solid waste in 2019-20	No. of Nests in 2020-21	% cover of Solid waste in 2020-21
Velas	23	30	36	35
Anjarle	16	13.2	23	10.36
Palande	0	13.6	0	20.96
Padale	0	11.2	0	10.2
Saldure	0	2.8	0	12
Murud	14	13	24	9.92
Karde	8	3.76	7	3.12
Ladghar	7	10.11	12	6.51
Kolthare	38	5.33	45	7.47
Dabhol	12	17.71	23	21.3
Ghuhagar	36	10.9	56	12.5

Conclusions:

It could be concluded that beaches with more beach-facing tourism resorts were avoided by female turtles for nesting; on the other hand, beaches without resorts, or with fewer resorts, showed maximum nesting density. The study also revealed that 60% of beachside resorts have been releasing their sewage and dumping their non-degradable solid waste along beaches. There is a lack of proper sewage and garbage disposal systems along a few study beaches like Murud and Karde. The sewage-prone beach stretches are avoided by female turtles for nesting. Non-degradable waste is deposited mainly in the first quadrat, i.e., within 10 meters from the shoreline along all belt transects due to the sweeping action of waves. Non-degradable waste spread was recorded at a maximum distance of 30m from the shoreline at all study beaches. Velas Beach showed maximum ground cover, whereas Karde Beach has minimum ground cover in both study seasons. Thus, non-degradable waste ground cover was found to have no significant correlation with nesting density. Even beaches with high ground cover like Velas and Dabhol showed high nesting density. Though non-degradable waste spread does not play any role in nesting density, it decreases the effective available space for nesting. There is no direct correlation between the non-degradable waste spread and nesting preference; however, it was observed that females avoid the areas covered with non-degradable waste. Hence, there is an immediate need at a few beaches for regular beach clean-up drives and the provision of solid waste collection facilities by gram panchayats of respective beaches.
Female Turtles were found to avoid beach armoring or flood-resistant bund areas for nesting owing to sliding rocks under the sand, which makes digging difficult for the female. It was observed that after several unsuccessful attempts at digging, she may change the beach area or migrate to a nearby beach for nesting. It was also observed that beach armoring results in decreased effective beach length for nesting.
It could thus be concluded that, in Olive Ridley turtles, nesting beach selection is a complex phenomenon and may be impacted and shaped by many natural and anthropogenic factors. Safeguarding Olive Ridley turtle nesting along the Ratnagiri coast requires controlled tourism zonation, alternatives to beach stone armoring, and stringent regulations on sewage and non-degradable solid waste management along the beach.

Acknowledgements:
We thank the **Principal Chief Conservator of Forest (Wildlife Wing)** & **Forest Department of Maharashtra** for granting the necessary fieldwork permissions. We would also like to thank **Mangrove Foundation, Government of Maharashtra** for necessary permissions and support for fieldwork. We thank **Ph.D. Department of K.T.H.M College, Nashik** for providing all the resources for the successful completion of the work. We would like to thank **Mahatma Jyotiba Phule Research & Training Institute (MAHAJYOTI) for the research fellowship for the study.** We would also like to thank **UGC STRIDE Scheme** for partial financial support for the study. We would also like to thank respected **Dr. V. B. Gaikwad, former Principal of K.T.H.M College, Nashik** for all the support & help. We would also like to sincerely thank **Mr. Mohan Upadhye, Mr. Abhinay Kelaskar** from Mangrove Foundation & all the patrolling team members of selected study beaches for their valuable input and support for fieldwork.

Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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