Spatial mapping of important marine habitats of Malvan coast for re-organization of boundary of the Malvan Marine Sanctuary

Final Report

May 2023

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

महाराष्ट्र वन विभाग

MANGROVE FOUNDATION

Project Title:	Spatial mapping of important marine habitats of Malvan coast for reorganization of boundary of the Malvan Marine Sanctuary
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Funding Agency	Mangrove Cell, Maharashtra Forest Depart-
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Citation: Shinde, N., Bayana, S., Sarkar, D., Pande, A., Sivakumar, K., Talukdar, G. (2023). Spatial mapping of important marine habitats of Malvan coast for reorganization of boundary of the Malvan Marine Sanctuary. Technical report (TR no/2023/11), *Wildlife Institute of India.*

Foreword

"The sea, the great unifier, is man's only hope. Now, as never before, the old phrase has a literal meaning; we are all in the same boat."

~ Jacques Yves Cousteau.

The marine ecosystems around the world are in grave peril of complete degradation. A massive loss of marine biodiversity has been observed internationally and in our national waters. In lieu to this calamity, the Malvan Marine Sanctuary is an effort to conserve and protect our rich marine biodiversity for future generations to come. This project has helped in identifying and demarcating important marine habitats along the Malvan coast of Maharashtra. The protection of these habitats is of the utmost importance. It will be a stepping stone towards sustainable development of the region. The recommendations based on sound science will steer these globally important ecosystems towards a better future.

Sh. Virendra R. Tiwari
Director
Wildlife Institute of India

Acknowledgements

We thank the State Forest Department, Government of Maharashtra for funding this study. We would like to convey our sincere gratitude to Shri. Virendra Tiwari IFS, Additional Principal Chief Conservator of Forests & Executive Director of Mangrove Foundation and Smt. Neenu Somaraj, IFS Deputy Conservator of Forest, Mangrove Cell, Maharashtra State Forest Department for their support towards project implementation. We also express our gratitude to Dr. Manas Manjrekar for his assistance in initiating field activities.

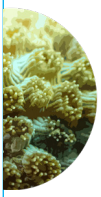
We thank Dr. SP Yadav, Director, Dr. YV Jhala, Dean and Dr. Ruchi Badola, Registrar, Wildlife Institute of India for their guidance and support to this project.

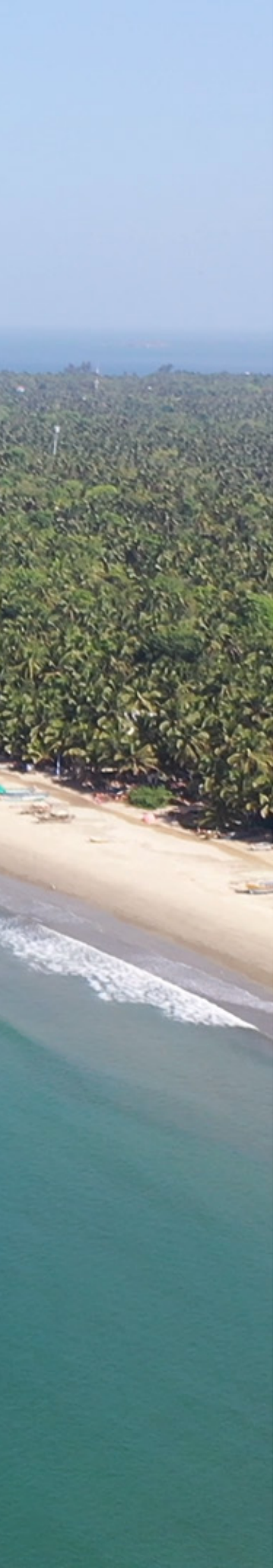
We would also like to acknowledge, Mr. Deepak Sonawane (Range Forest Officer), and Mr. Sanjeevan Shilvant (Forest Guard) of Mangrove Cell, Maharashtra State Forest Department for their help in the field work. Our gratitude goes to Ms. Durga Thigale, Biodiversity and Livelihood Specialist, Mangrove Foundation and Mr. Rohit Sawant, District Coordination Officer, UNDP India for helping manage field operations at the study area.

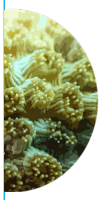
Special thanks to Mr. Govind Dhuri PADI IDC Staff Instructor, Gomantak Scuba, Boat masters Mr. Praveen Mankar and Mr. Dayal Achrekar for assistance in conducting underwater surveys.

Executive Summary

Malvan Marine Sanctuary is a Marine Protected Area located in the Sindhudurg district of Maharashtra state. Known for its rich biodiversity, it is grappling with increasing anthropogenic pressure necessitating a comprehensive study to assess its habitats and threats. Management Effectiveness Evaluation (MEE) of 2017-2018 team had suggested for boundary reorganization to exclude areas of human intervention and to include important habitats and areas with high biodiversity for the better management of biodiversity off the coast of Malvan. The project has undertaken because high tourism zone are areas with high anthropogenic pressure within the core zone of the sanctuary. Coral reefs and its associated fish fauna were surveyed at nine sampling sites. The total hard coral cover was observed to be 28% while the seagrass cover was observed to be 3% in 21 sampling sites. 19 genera of corals were identified. *Favites sp.* was observed to be the most abundant (19.18%). Within the sanctuary, Seagrass patches were identified at five sampling sites namely King's Garden 1, King's Garden 2, King's Garden 3, Dharan and Donor site. 122 species of fish belonging to 38 families were observed during underwater surveys. Fish-market surveys were conducted to study the species composition and size-class of fish species caught around the sanctuary. A total of 44 different fish species were observed during market surveys. Beach litter surveys were conducted to assess the anthropogenic stress along the Malvan coastline. Debris in the form of polythene was the major contributing litter type at all three sections of the beach. The rocky outcrops along the coast were observed to be roosting sites for avifaunal species namely, White-bellied Sea Eagles, Pigeons, Swiftlets, etc. Spatial prioritization of the marine habitats revealed potential PA's include Kawda, 7 rocks, Lighthouse area, covering an area of 29.07 sq.km; conservation priority areas comprising Chiwla, and Sargassm covering a total area of 19.21 sq. km and King's garden (3.534 sq km) as sensitive area. Strategies to conserve these areas for long term conservation should be planned.







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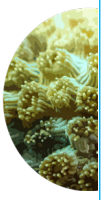


1. Introduction to Malvan Wildlife Sacntuary

Malvan Marine Sanctuary (MMS) is located in Malvan, a small coastal tourist town in the Sindhudurg district of Maharashtra state (Figure 1). It was notified as a sanctuary on 13th April 1987, with a total area of 29.122 square kilometre (which includes 3.182 km2 core zone and buffer of 25.94 km2). The core zone of the sanctuary is spread around the historic Sindhudurg Fort built by Chhatrapati Shivaji Maharaj which is recognised as a monument by the Archaeological Survey of India. Padmagad Island and the surrounding coral reefs also fall under the core zone of the sanctuary. The buffer zone of the sanctuary comprises of rocky outcrops namely Dharan, Ekicha Dhonda and underwater rock agglomerations (Mandal) namely bhootachi mandal and (Bhoothnath reef), Sath mandal (7 rocks). Various rocky outcrops and underwater habitats within the sanctuary harbour corals reefs, seagrasses, algal beds and numerous marine organisms (De, 2020; Shinde, 2020). Malvan coast harbours variety of coastal habitat such as mangroves mudflats, islands, rocky promontories, coral reefs and sandy beaches and was included in the list of 11 marine hotspots in India (ICMAM, 2001). There are 22 fishing villages in Malvan Taluk which is a major fish landing centre (Rajgopalan, 2008; Gupta et al., 2020) bordered by three creeks viz., Karali, Kolamb and Kalavai. It lies on the basement plate of basalt flows of the Deccan volcanic province (Kumaran et al., 2004). This region experiences three distinct seasons, the winters with cold and dry winds (November to February), hot dry summers (March to May) and rainy season with monsoon (June to October).

1. 1. Biodiversity

Malvan coast is known to have rich marine biodiversity with many taxa groups reported from the coast. A total of 367 species have been reported by different reports along the Malvan (Integrated Coastal and Marine Area Management, 2001) but recent studies and reports have observed lesser number of species. In early 1980's, Parulekar (1981) surveyed the area and reported 208 species of fauna (Porifera, Cnidaria, Annelida, Arthropoda, Mollusca, Echinodermata) while Pande (2005) reported 286 species from MMS. Overall known biodiversity of MMS consists of about 58 species of phytoplankton (ICMAM, 2016), 114 species of molluscs (Pande, 2005), 73 species of

Plate 1. An aerial photograph of the coral reef from Chiwla beach

polychaetes (Sukumaran, 2016), 17 species of corals (Shinde, 2020), (Poritidae, Faviide, Dendrophyllidae etc.). Malvan coast also hosts about 18 species of mangroves (ICMAM, 2001) 36 species of seaweeds (Valanju, 2020) and 73 species of marine algae (GOI-DOD, 2012). Survey by ICMAM found 51 species of fishes along the Malvan coast and 69 species of marine fishes were caught in a study related to fisheries along the Sindhudurg, Ratnagiri and Raigad coast (Tingote et al., 2015). Barman et al. (2007) reported 108 species of fishes in the Malvan sanctuary area. Congregation of whale sharks is also reported from Malvan waters (Premjothi et al., 2016). A total of 307 species of birds recorded along coastal talukas of Sindhudurg district, of these, 247 species observed from Malvan taluka (Rao et al., 2019). The waters off the Malvan coast are used by four species of sea turtles viz. Olive ridley, Green, Leatherback and Hawksbill. Seven species of sea snakes (*Acroprodus arafurae, Acroprodus granulatus, Hydrophis curtus, Hydrophis viperinus, Hydrophis schistosis, and Pelimas platura*) are known from the Malvan waters (Dsouza, 2020). Seven species of cetaceans (*Balaenoptera musculus, Balaenoptera edeni, Neophocaena phocaenoides, Physeter macrocephalus, Orcinus orca* and *Sousa plumbea*) are found off the coast of Malvan. Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) and Indian Ocean humpback dolphin (*Sousa plumbea*) are two common near shore cetaceans found along the Malvan coast (Jog et al., 2018). All these species of reptiles and dolphins are known to be caught in fishing gear and also regularly stranded along the Malvan coast (Dsouza et al., 2020; Jog et al., 2018).

Plate 2. Devil's whip coral (Ellisella sp) observed during dive surveys along the Malvan coast

Plate 3. Species of Hydroid observed during dive surveys along the Malvan coast

Studies conducted along Malvan coast have revealed many areas outside the MMS with good patches of coral reefs. Sarjikot, Rajkot and mouth of Kolamb creek were found to have corals by ICMAM (2001) while Shinde (2020) found many coral patches outside the protected area (Lighthouse complex and Sargassum complex). Study from Malvan coast have found up to 22 species of corals in and around the sanctuary area (Shinde, 2020). De (2020) found 19 species of corals within the MMS with biggest patches occurring around the Sindhudurg fort. Both studies have reported over 40 species of reef fishes in and around the protected areas (De, 2020; Shinde, 2020).

1. 2. Local Communities and their livelihood

Local community of Malvan is primarily dependent on fisheries and tourism for their livelihood. Fishing is operated using both mechanised trawlers (~ 80-100), gill-net boats (~ 600) and non-mechanised artisanal crafts operating shore seines or hook and line gears (Gupta et al., 2020). A survey reported over 2800 people directly involved in fishing and over 5700 individuals involved

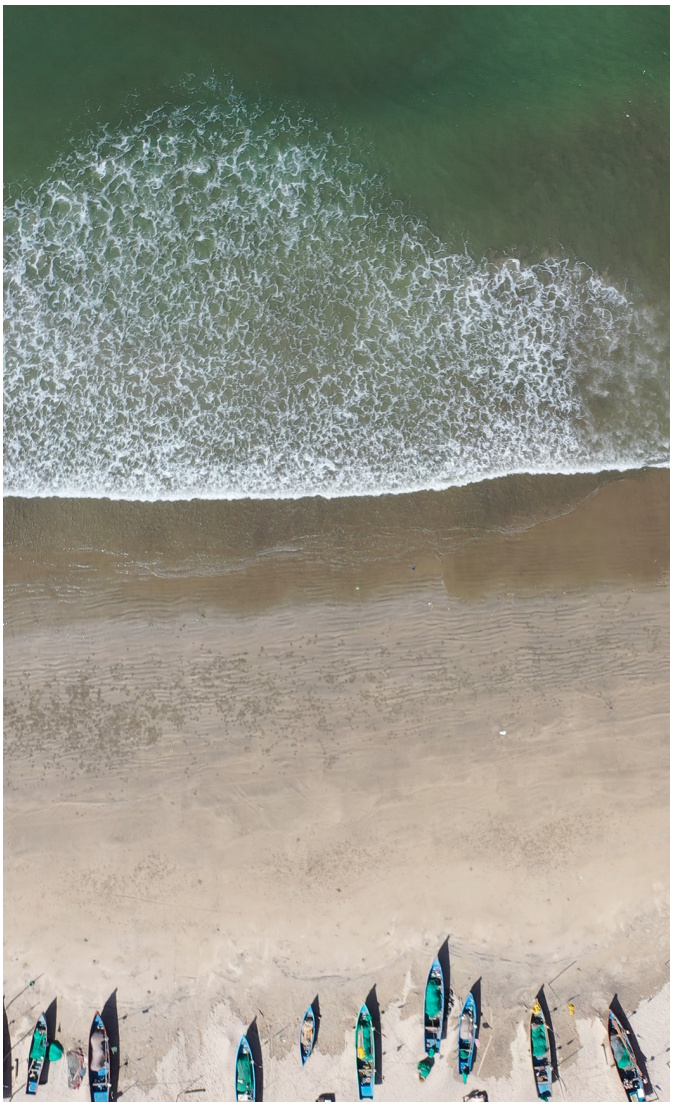


Plate 4. An aerial photograph of Dandi beach, Malvan

in other fisheries related activities such as fish processing and transport (UNDP, 2013). There is also a migrant fishermen population involved in fishing operations in the region (CMFRI, 2012).

Trawler fishing, gill-netting and purse seine fishing takes place in the deeper offshore seas while the artisanal fishing activities such as the shore seines and hook and line fishing is limited to near shore waters. The fish catch is brought to the landing site at Dandi beach by smaller vessels locally known as *Paat,* which remain anchored around the Sindhudurg fort area. Mechanised fishing activities are banned during the monsoon when only dried fish sale

Plate 5. Tourists at Dandi beach, Malvan come for Watersports activities

happens (Gupta et al., 2020).

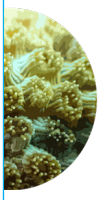
The taluk development council of Malvan undertook the promotion of Malvan as a tourism town in 2007 (Rajgopalan, 2008). Today, the tourism sector is one of the fastest growing economic activities in Malvan. The locals of Malvan are primary beneficiaries of tourism and about 3000 individuals are directly or indirectly involved in ecotourism activity (UNDP, 2013).

1.3. Tourism activities and their impacts

Malvan is a popular water sports driven tourist destination site. Major water sports attractions include SCUBA diving, snorkelling, boat pulled parasailing, high-speed boating etc. These activities are centred around the Sindhudurg fort area which is also the core zone of the MMS. The number of tourists visiting Sindhudurg district are expected to increase by 6% every year with Malvan expecting to receive ~6,40,000 tourists in 2021-2022 (Munjal, 2019).

Unregulated recreational diving in the Malvan area is considered as one the main threats to coral reefs in the region (De et al., 2020). Physical contact, anchoring of boats and fish feeding is observed by the tourists in the sanctuary region and is a major concern. Increased tourism combined with absence of proper waste and sewage disposal also poses a risk to the marine ecosystem of Malvan coastline (ZSI, 2015).

Plate 6. An aerial photograph of Malvan jetty and Padmagad Island



2. Background and project objectives

Since being declared as a Wildlife (Marine) Sanctuary in 1987, the local fishing communities have opposed its formation and demanded some areas to be kept out of the restriction zone. The core zone of the sanctuary comprises Sindhudurg Fort under the management of the Archaeological Survey of India (ASI) and is a tourist attraction. Moreover, the land within the fort is privately owned and thus does not help in effective management of biodiversity for which the sanctuary was created. The perception of the sanctuary as a breeding ground of many commercial fishes' and providing alternate livelihood options are not yet effectively communicated to the communities, resulting in resentment against its formation. Adequate measures need to be taken to protect the occupational interest of the local fishers and settlement of rights, if any (Vasudevan & Fernandes, 2014). The Management Effectiveness Evaluation (MEE) of MMS had suggested for reorganization of its boundaries to exclude areas of human intervention and to include important habitats and areas with high biodiversity for the better management of biodiversity off the coast of Malvan.

In this context, State Forest Department of Maharashtra vide their letter no. 344/2020-21 dated 04.08.2020 (Annexure) had approached the Wildlife Institute of India to identify the important biodiversity areas and advise reorganization of the Malvan Marine Sanctuary. In this connection, this report summarising the results

Plate 7. Goniopora coral at the sampling site

Plate 8. An underwater photograph of a research diver exploring the reef

of the surveys undertaken from April 2021- January 2022.

The objectives of this project were to,

1. Conduct a rapid assessment of the current status of marine biodiversity of MMS through a multi-seasonal survey.
2. Identify and demarcate high priority habitats within and around the sanctuary to advise management interventions.
3. Build capacity of the frontline forest personnel and local communities to monitor marine biodiversity and generate conservation awareness.

3. Methodology

Various methodologies were employed to collect data on biodiversity during the field work of the project. These methodologies were tested for limitations during the pilot survey in April, 2021. For underwater data collection, surveys were conducted using SCUBA as a tool, where teams of 2 dive buddies each would dive at a sampling site. One buddy would collect data on coral while the other would collect data on fish. Total 21 sites were sampled (Table 1). In the results, Chiwla and Anchor point data are clubbed togather as they are in close proximity.

3.1. Coral survey

Quadrat method (Rogers et. al 1994) was used to assess the coral diversity and benthic percentage cover underwater at a sampling site. The sampling points used for coral quadrats overlap with fish point counts locations to increase efficiency of data collection. The observer placed a 1x1 meter quadrat at the chosen point and noted the species of coral observed, the number of grid each species covered, and other components of the benthos. A minimum distance of 8-10 fin kicks was maintained between every sampling point.

Plate 9. Research diver conducting coral quadrat and fish point count surveys

3.2. Fish survey

Stationary point count method with variable radius (Samoilys and Carlos 2000) was used to assess the fish biodiversity and abundance underwater at a sampling site. The points to be surveyed were chosen randomly after descending underwater to negate any bias. After a point is chosen the observer remained neutrally buoyant over the point while observing and recording the fish fauna around 360 degrees of the point. The species, number of fish, distance of the fish from the point and visibility was noted. A minimum distance of 8-10 fin kicks was maintained between every point.

3.3. Beach litter survey

Belt transect method (Rogers et. al 1994) was used to collect data on beach litter, random points were placed along the Malvan coast at a distance of 300 meters at the low tide line. The beach was divided into three zones namely intertidal zone, above high tide line and low tide zone. The observer would walk perpendicular to the beach collecting data on litter based on various categories in each zone. The belt size was 1 meter on each side of the observer along the entire length.

3.4. Fish market survey

Fish market surveys were conducted to check for the age and size-class of different fishes caught around the sanctuary, at the Malvan fish market, Dandi beach. Surveys were done during early evening hours (1600 – 1800 hrs). Fish market surveys were conducted twice every week with randomly selecting vendors and collecting the data on fish species available with them along with the numbers and their size class. Pictures and counts of species were recorded manually using a digital camera and approximate size (length) of the individuals of a species was estimated visually. The data was analysed and compiled to find the total number of individual species catch, the size (Length) of individuals of particular species. The data here only represents the species caught pre-monsoon. Commercial fish catch assessment was conducted using a methodology formulated to suit the fishing or market timings. Observers collected data on species, number of fish, size class in cm and weight.

Plate 10. Research diver conducting coral quadrat and fish point count surveys

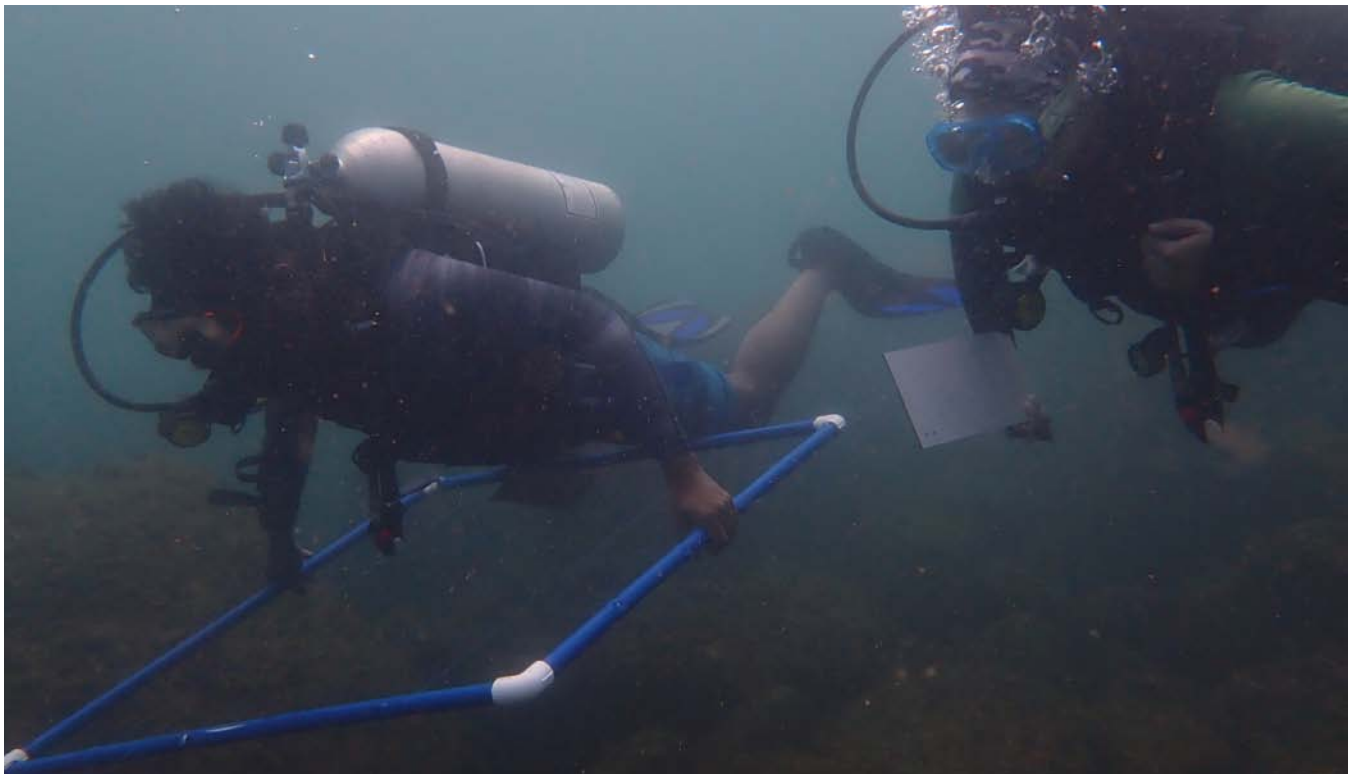


Plate 11. Research divers conducting coral quadrat and fish point count surveys

3.5. Rampan survey

Rampan is a traditional beach seine fishing practice observed in the Sindhudurg district, Maharashtra. The fisherfolk of Malvan participate in this artisanal fishing technique for both their personal sustenance and sale at the fish market. Anywhere between 10 to 50 people are involved in pulling the rampan net. Rampan operation can be done at any time during the day as wind direction is the key factor for getting a good catch. North winds are preferred as they bring the potential catch towards the shore. The rampan surveys were conducted arbitrarily during morning (0500-1000 hrs), afternoon (1400-1600hrs) and evening time (1700-2000hrs). These surveys were conducted to check for the age and size-class of different fish species caught around the sanctuary. Pictures of each fish species caught were taken through a digital camera on a blank white paper with a steel scale to estimate the size. The average weight of all fish species group was also recorded, giving a total estimate of fish landings.

3.6. Estimating Biodiversity and threat scores for spatial prioritization

A combination of species richness and threat score was used for spatial prioritization of the Malvan marine sanctuary. The scores were calculated based on the survey data. A combination of coral and fish richness was used for richness score, where Coral richness were given double weightage. For threat scores, active boats were taken as a measure for threats to a sampling site with following order of weightage, i.e. motorized boats (3), dive boats (2) and row boats(1). The information on boats were collected through questionnaire surveys.

Table 1: Sampling sites along the Malvan coast, Maharashtra. In the results, Chiwla and Anchor points data were clubbed togather becasue these sites are in close proximity
(marked are not a part of any complex)*

Complex name	Sites Within (Total sites=21)
I. Kawda Complex	Kawda, Swarnakada
II. Chiwla Complex	Chiwla, Anchor point
III. King's Garden Complex	King's garden 1, 2, 3, Dharan, Donor site
IV. 7 Rocks Complex	Ekicha dhonda, 7 Rocks, Bhootnath
V. Sargassum Complex	Sargassum, Shengale mandal, Ghode mandal
VI. Lighthouse Complex	Old lighthouse, New lighthouse, Fansa, Classroom, Middle rock
	*Purse seine shipwreck

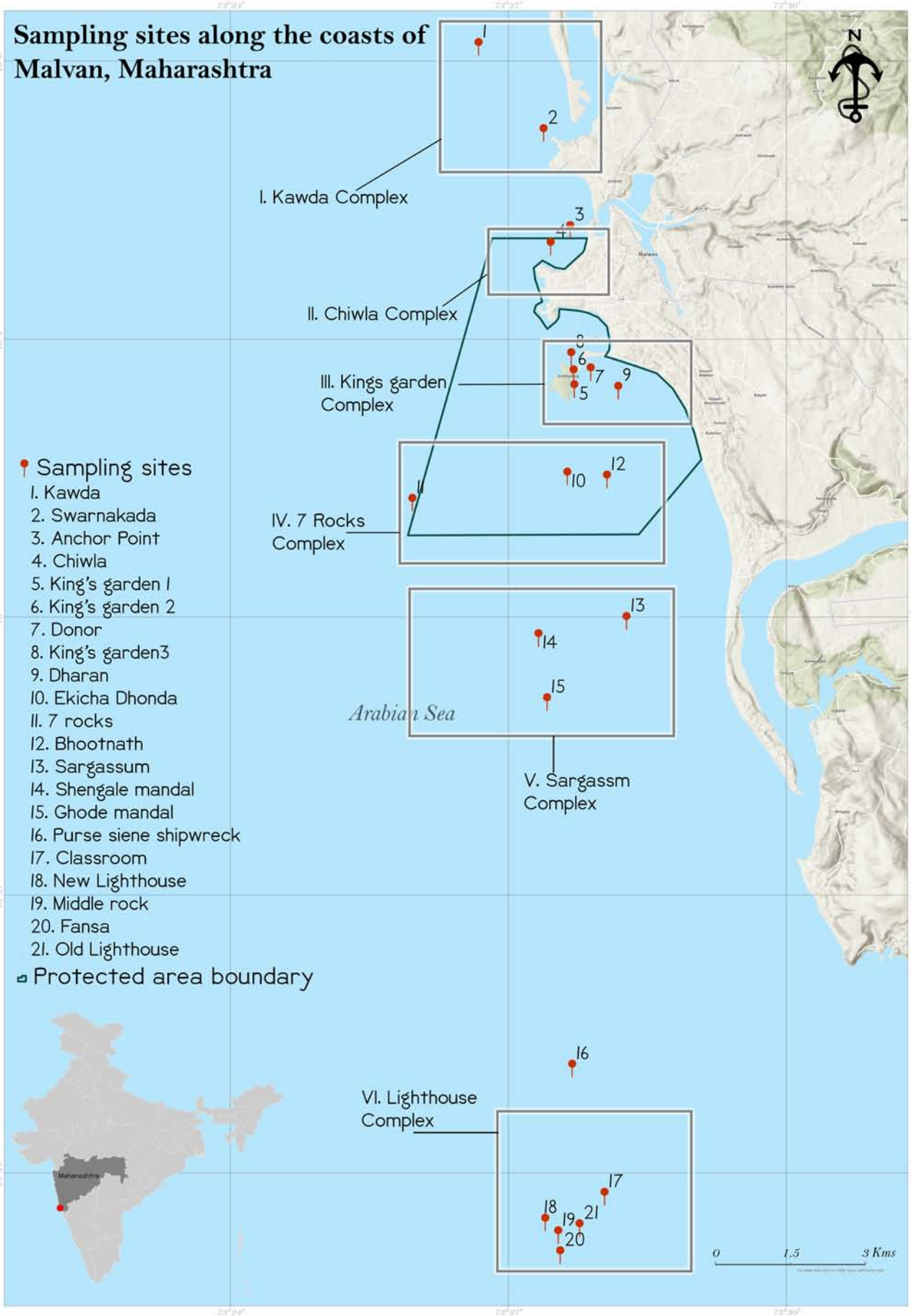


Figure 1. Sampling locations in and around the Malvan Marine Sanctuary, Maharashtra where underwater assessment surveys was undertaken between April 2021-January 2022.

4. Results

Sampling for the project was carried out between April 2021 to January 2022 with assessments done for the areas within and outside the boundary of the sanctuary. Seasonal replicates were taken for the sites within the sanctuary. Priority was given to areas with highest tourist influx and known coral reefs present along the Malvan coast. Parallel assessment of corals, fishes and anthropogenic threats were done at 20 dive sites (Table 1). Along with the offshore sampling area, the beach within the sanctuary area was assessed for anthropogenic waste.

4.1 Coral habitat mapping

Coral reefs at MMS were studied using quadrates to collect data for benthic cover and species composition estimation of reefs (Rogers et. al 1994). A total of 20 dive sites were selected for sampling including the nine previously identified coral reef sites (Shinde, 2020) were selected within the MMS for habitat assessment. Random points on the reef were selected for quadrat sampling during SCUBA diving. Quadrats of 1m x 1m were used for assessment and 10- 13 sampling points were taken depending on feasibility. Substrate composition and percentage cover were

Plate 13. Table coral in the sampling sites

visually estimated using photo-quadrates and species identification was conducted at all sites.

The benthic substrate was categorised into 11 groups namely, Hard Coral, Soft Coral, Bleaching Coral, Dead Coral, Sponges, Algae, Rock, Sand, Rubble, Zooanthid and Seagrass (supplementary table 6). Total benthic composition of all sites are given in Figure 2 and Figure 3. The highest live coral percentage cover was observed at Donor site (42%) followed by King's Garden 2 (38%), Middle Rock (32%), Dharan (30%), Sargassum (28%), King's Garden 1 (27%) and 7 Rock (24%) while the lowest was observed at Fansa (0%) (Supplementary table 6). Total nineteen genera of coral were observed at the sampling sites (Supplementary table 1). The coral diversity was higher at far-shore sites than near-shore sites.

Plate 14. Porites coral at the sampling site

4.2. Coral diversity and species richness

Coral diversity (Table 2) was low at Fansa (H`= 0) whereas the highest diversity was observed at 7 Rocks (H`= 2.061). Highest genera richness were found in 7 Rocks and Sargassm (Figure 4). The value of equitability varied from 0-1. It is equal to 1 when all the species have the same abundance and tends to zero when the near total fauna is concentrated on only one species. Sites with the highest score of Equitability were Bhootnath (0.9141) and 7 Rock (0.8951). Diversity indices were calculated using PAST software. The sites 7 Rock and Sargassum were observed to have the highest coral genera richness of 10 and 9 respectively. The Evenness index values varied from 0 at Fansa and 0.5086 at Old Lighthouse to 0.9898 at New Lighthouse (Figure 5). New Lighthouse, Purse seine shipwreck and Bhootnath showed the maximum evenness values of 0.9898, 0.9184 and 0.9099 respectively. The highest diversity values (Shannon- Weaver's index) (Rogers et. al 1994) were observed at 7 Rock (2.061) and Sargassum (1.736) (Figure 6). On the basis of the analysis done during this survey, the sites Sargassum, Bhoothnath Reef, 7 Rock, Kings' Garden 2, Donor site, Middle rock and Dharan can be categorised as important coral habitats.

Plate 15. Squid eggs

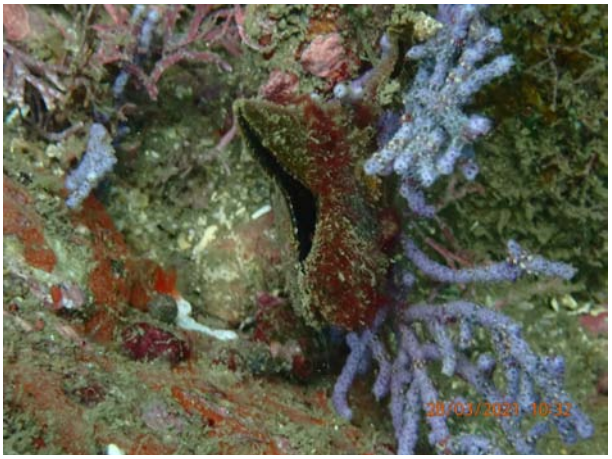


Plate 16. Corals documented from the sampling sites

Table 2: Coral biodiversity values by biodiversity index and static parameters for sampled sites at Malvan Marine Sanctuary, Maharashtra between April 2021-January 2022.

Zone	Sampling sites	No of Genera	Individuals	Dominance	Simpson's index	Shannon-Weaver's index
Tourism Zone	7 rocks	10	63	0.16	0.84	2.061
	Bhootnath	3	7	0.388	0.612	1.004
	Donor	3	52	0.640	0.360	0.632
	Ghode mandal	6	101	0.231	0.769	1.563
	Purse seine shipwreck	3	16	0.390	0.610	1.013
	Shengale mandal	5	37	0.295	0.705	1.353
	Swarnakada	3	27	0.446	0.554	0.920
Non Tourism Zone	Chiwla+Anchor point	7	64	0.207	0.793	1.708
	Classroom	3	29	0.534	0.466	0.787
	Dharan	3	52	0.640	0.360	0.632
	Ekicha Dhonda	4	15	0.367	0.633	1.091
	Fansa	1	1	1	0	0
	Kawda	2	25	0.962	0.038	0.096
	King's garden 1	5	42	0.315	0.685	1.279
	King's garden 2	3	63	0.634	0.366	0.671
	King's garden3	2	33	0.888	0.112	0.226
	Middle rock	4	49	0.679	0.322	0.672
	New Lighthouse	2	3	0.510	0.490	0.683
	Old Lighthouse	7	51	0.375	0.625	1.27
	Sargassum	9	330	0.213	0.787	1.736

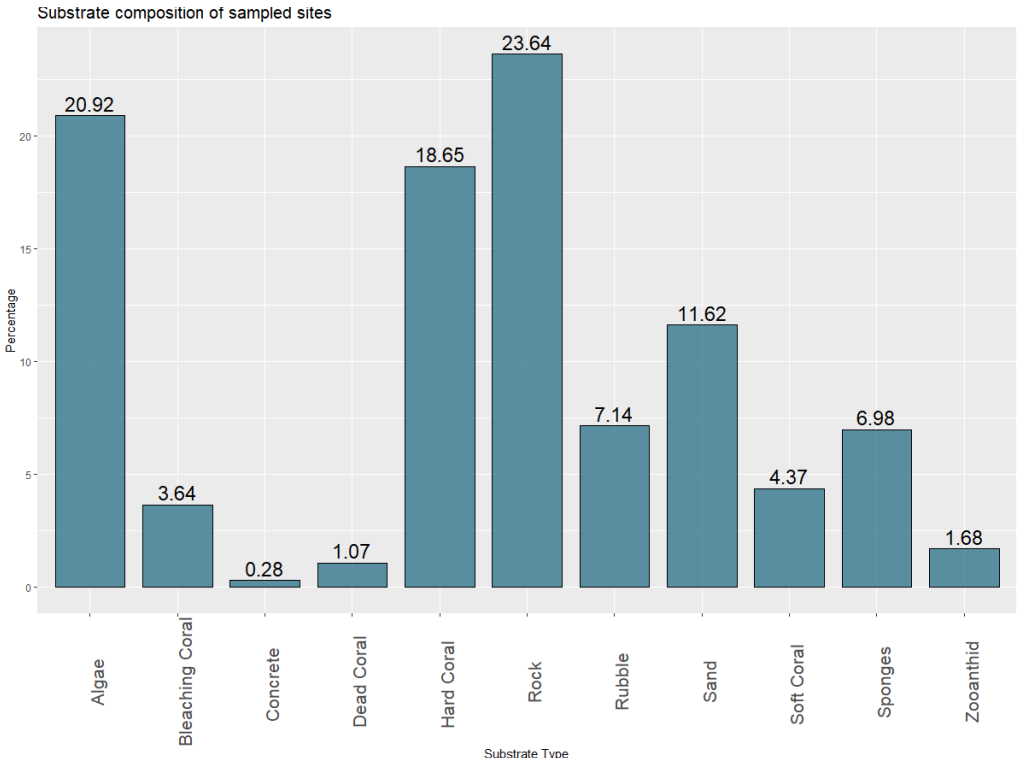


Figure 2: Substrate composition of sampled sites in Malvan Marine Sanctuary, Maharashtra between April 2021-January 2022.

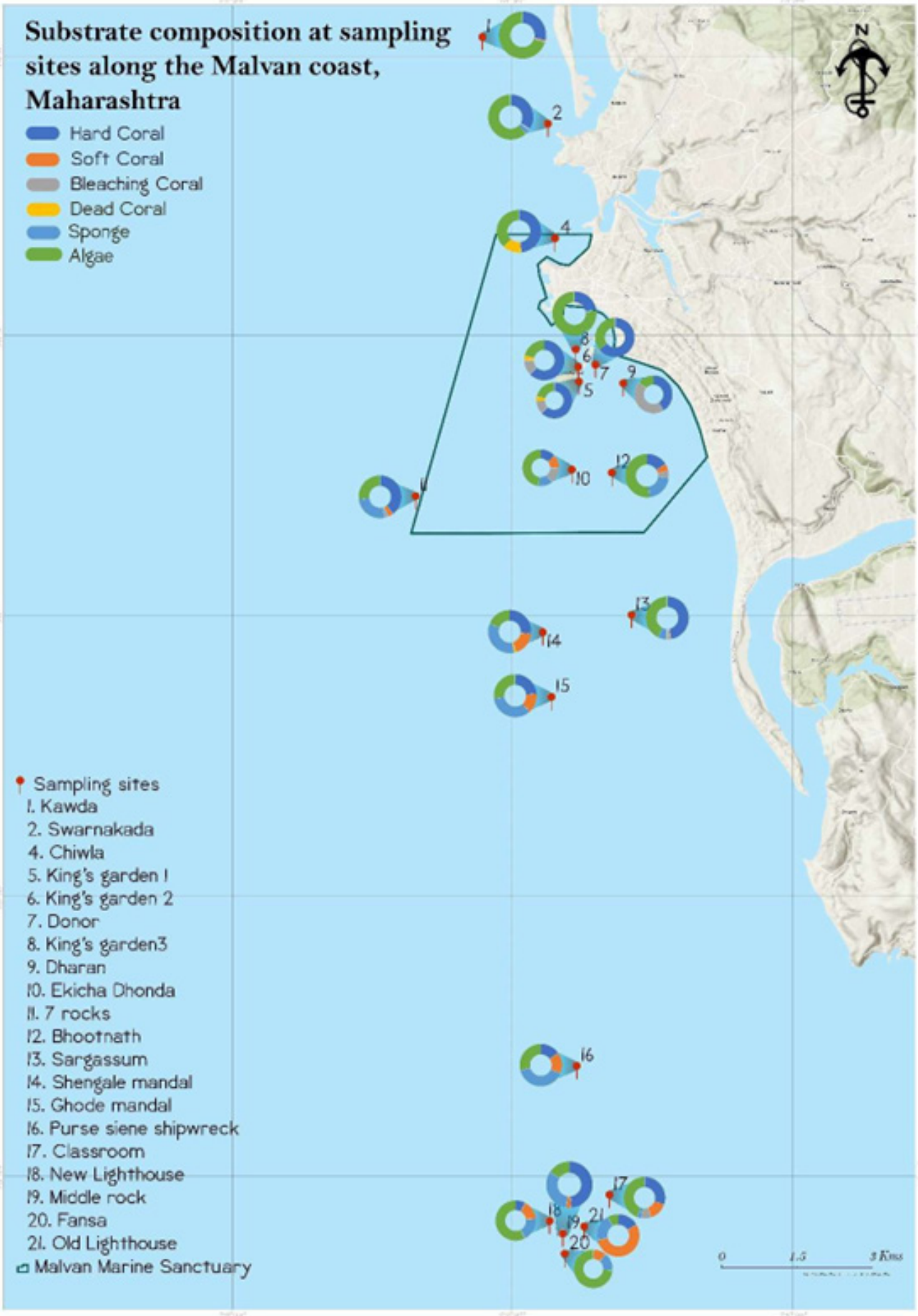


Figure 3. Substrate composition at sampling sites within Malvan Marine Sanctuary, Maharashtra

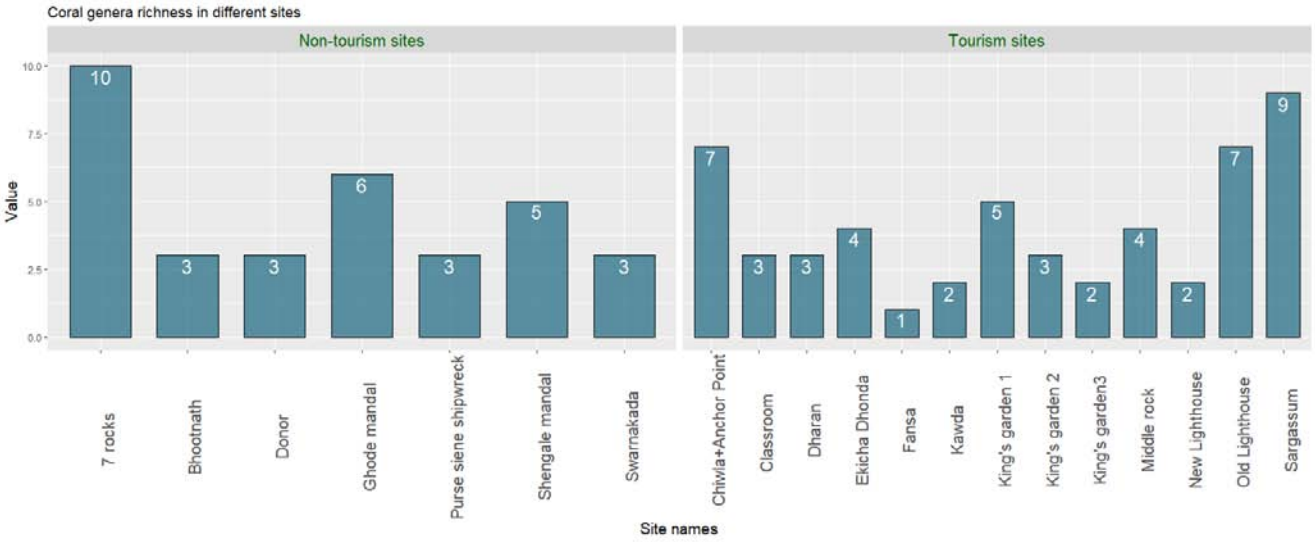


Figure 4. Genera richness observed for corals at sampling sites in Malvan Marine Sanctuary during the survey conducted from April 2021-January 2022.

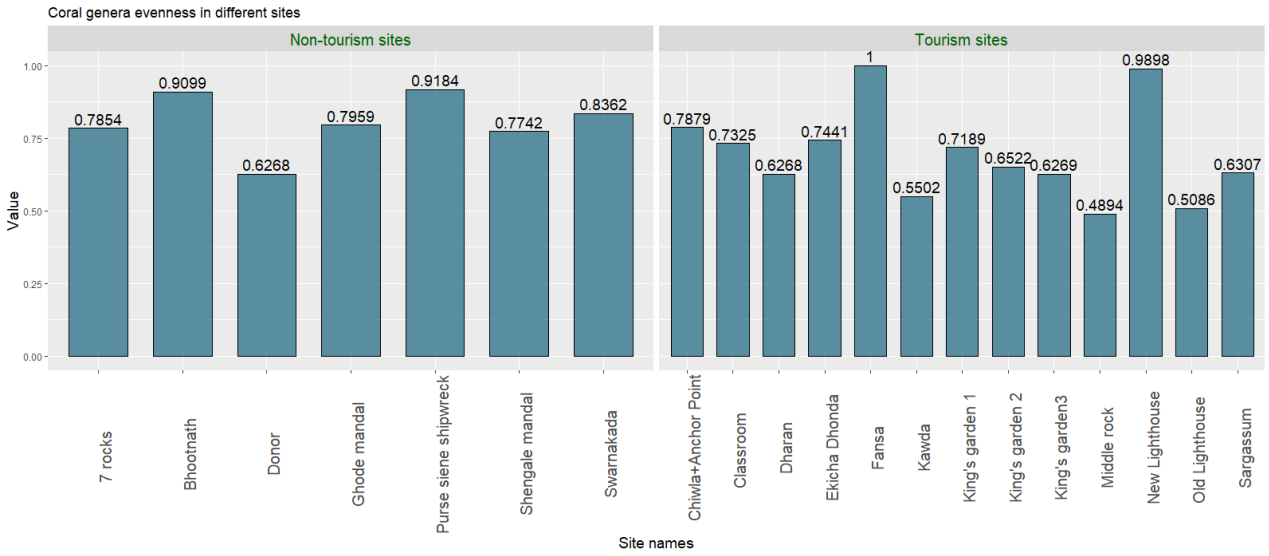


Figure 5. Evenness of coral genera distribution among sampling sites at Malvan Marine Sanctuary during the surveys conducted from April 2021-January 2022.

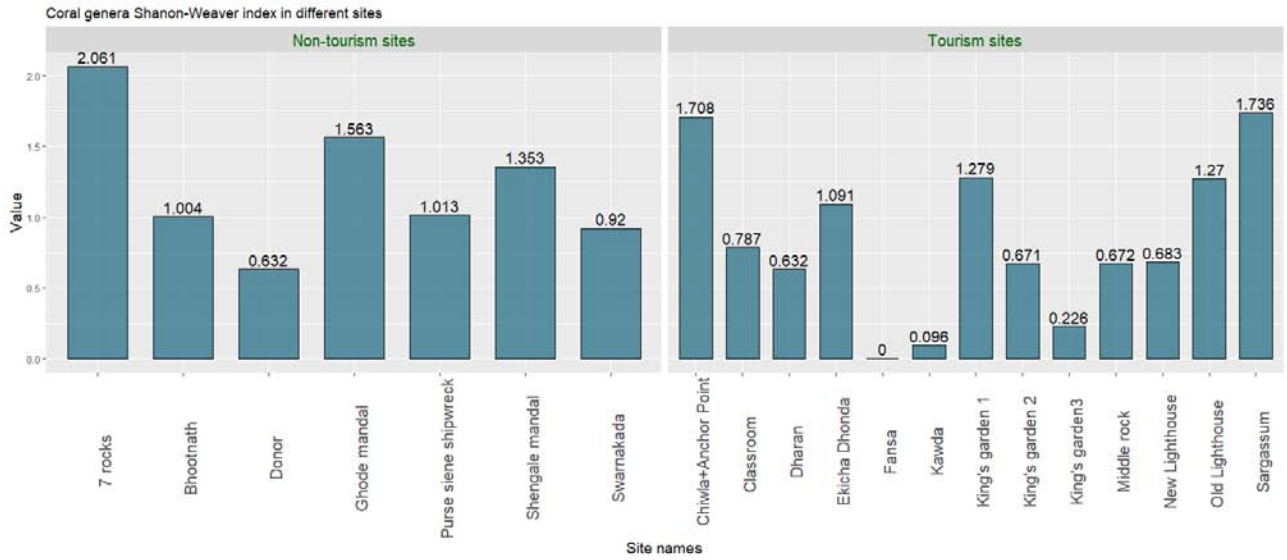


Figure 6. Shannon-Weaver's diversity index across sampling sites at Malvan Marine Sanctuary, Maharashtra during the surveys conducted from April 2021-January 2022.

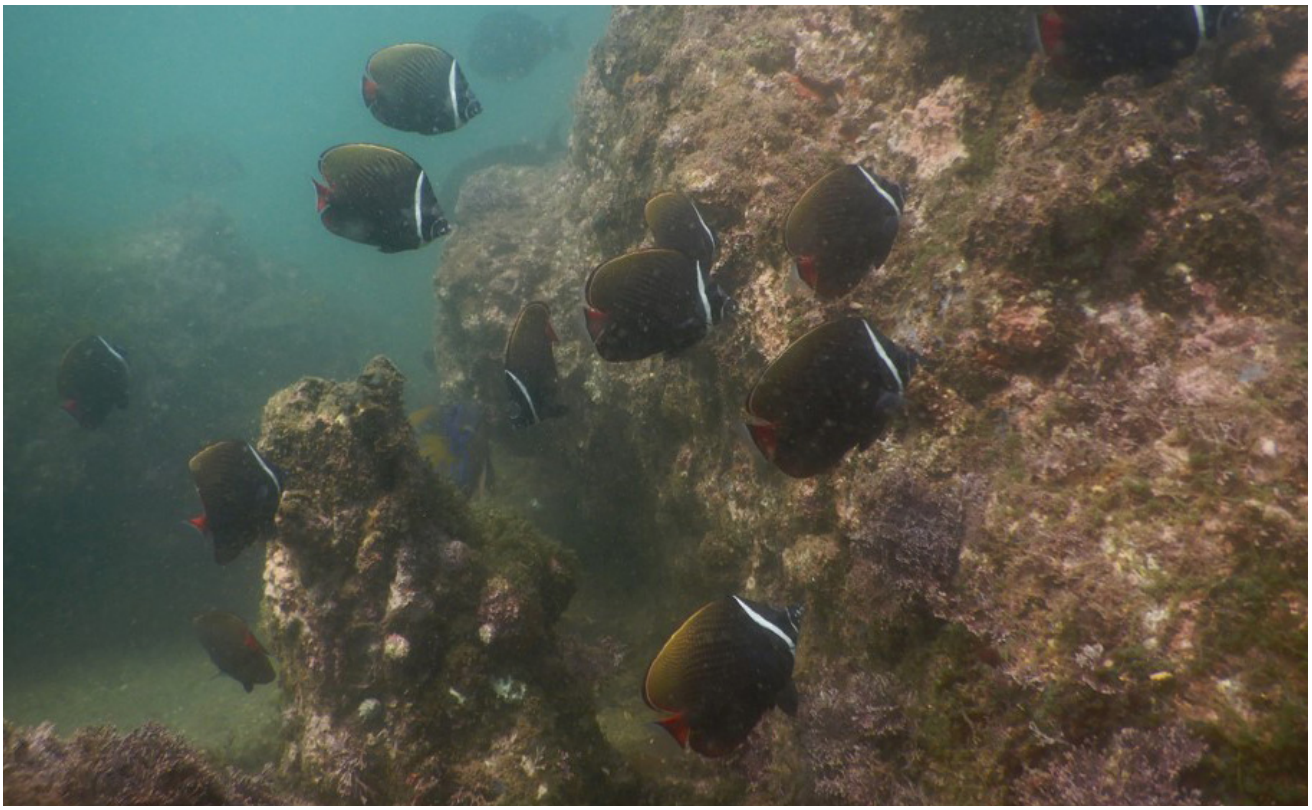


Plate 18. A school of white collared butterflyfish

4.3. Fish diversity and abundance

MMS area is known to have high diversity of fishes along with the diverse coral reefs (Shinde 2020). Some of these areas experience huge footfall of tourist and artificial feeding in these areas. To understand the differences in fish diversity and density, we conducted point counts for fishes at different reefs present within the protected area.

A total of 21 sites were sampled to understand the diversity of fishes associated with coral reefs by using the stationary point count technique with a variable radius (Samoilys and Carlos 2000). The points were selected randomly while SCUBA diving over a coral reef. Fish diversity estimation was carried out for 10 minutes by hovering approximately 1m above the quadrate. Fish species, number of individuals, distance from the centre of quadrate was recorded by the observer. Parameters such as horizontal visibility and depth were also noted by visual estimation. 7 to 13 point counts were taken per site depending on the feasibility, visibility and currents. Exploratory analysis was carried out using Microsoft Excel. Diversity indices were calculated using PAST v 4.03. Fish density estimation was done using the Distance software v 7. To estimate densities, we clubbed the sites which were in close proximity. Out of the 20 sampled sites, 13 were identified to be tourism zones- where recreational activities like SCUBA diving and snorkelling were carried out regularly. Rest of the 7 sites were not used for tourism.

We found 122 species belonging to 38 families at the surveyed sites within the MMS (Supplementary table 2). Out of these, *Chiloscyllium punctatum* (Brown banded Bamboo Shark) is found to be 'Near Threatened' according to IUCN red list, while most of the other species are 'Least Concerned'.

Plate 19. Mombassa lionfish resting on a sandy patch

High species richness and diversity was found at 7 rocks (n= 49, Shannon-weaver index= 3.257) (Table 3, Figure 7, 8, 9). Lowest species richness was found at Swarnakada with 9 species, and this site also recorded the highest evenness 0.77 (Figure 8). Highest fish density (Individual/ sq. m) was found in Lighthouse complex (Figure 10).

Plate 20. Camouflaged Scorpionfish resting on a rock

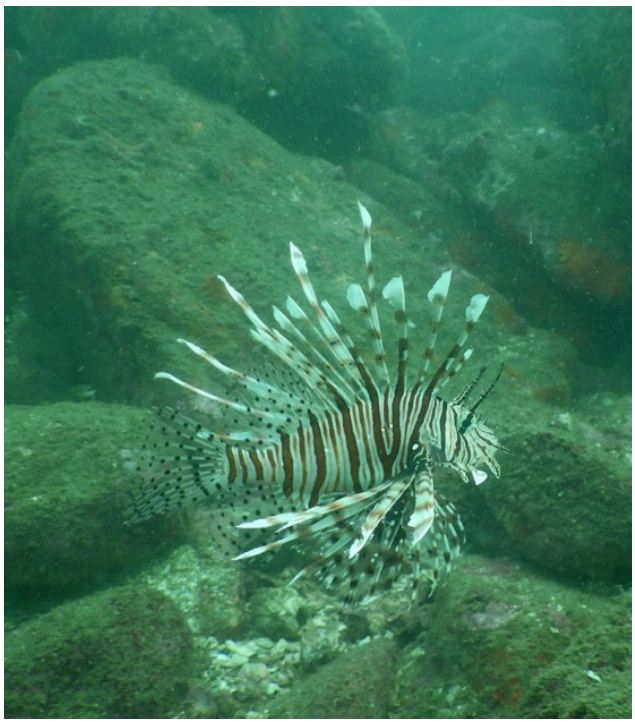


Plate 21. Indian lionfish with flared supraorbital tentacle

Table 3: Fish density and diversity indices values at Malvan Marine Sanctuary, Maharashtra during the survey conducted from April 2021-January 2022.

Sr. no	Sites	Tourism (T)/ Non tourism (NT)	Taxa	Individuals	Dominance	Simpson's index	Shan-non-Weaver's index
1	7 rocks	NT	49	782	0.054	0.947	3.257
2	Bhootnath	NT	28	276	0.082	0.918	2.784
3	Donor	NT	24	176	0.097	0.903	2.634
4	Ghode mandal	NT	28	524	0.203	0.797	2.066
5	Purse seine shipwreck	NT	23	182	0.127	0.873	2.397
6	Shengale mandal	NT	33	563	0.096	0.904	2.774
7	Swarnakada	NT	9	42	0.176	0.824	1.931
8	Chiwla+Anchor point	T	30	199	0.097	0.904	2.75
9	Classroom	T	35	924	0.243	0.758	2.055
10	Dharan	T	25	188	0.108	0.892	2.586
11	Ekicha dhonda	T	27	348	0.250	0.750	2.161
12	Fansa	T	31	1549	0.375	0.626	1.555
13	Kawda	T	32	410	0.077	0.923	2.879
14	King's garden 1	T	10	100	0.295	0.705	1.54
15	King's garden 2	T	21	261	0.124	0.876	2.517
16	King's garden 3	T	15	119	0.194	0.806	2.085
17	Middle rock	T	31	526	0.257	0.743	2.087
18	New lighthouse	T	31	819	0.320	0.680	1.843
19	Old lighthouse	T	26	208	0.284	0.716	2.066
20	Sargassum	T	44	946	0.086	0.914	2.844

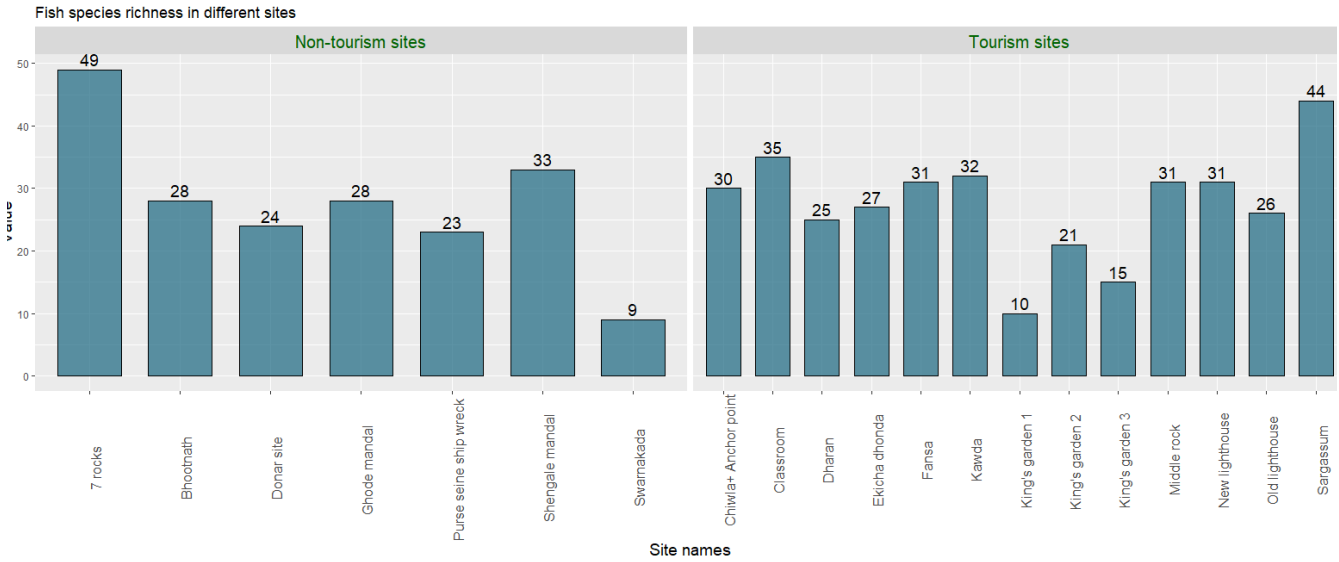


Figure 7. Fish species richness across sampled sites in Malvan Marine Sanctuary, Maharashtra during the surveys conducted from April 2021-January 2022.

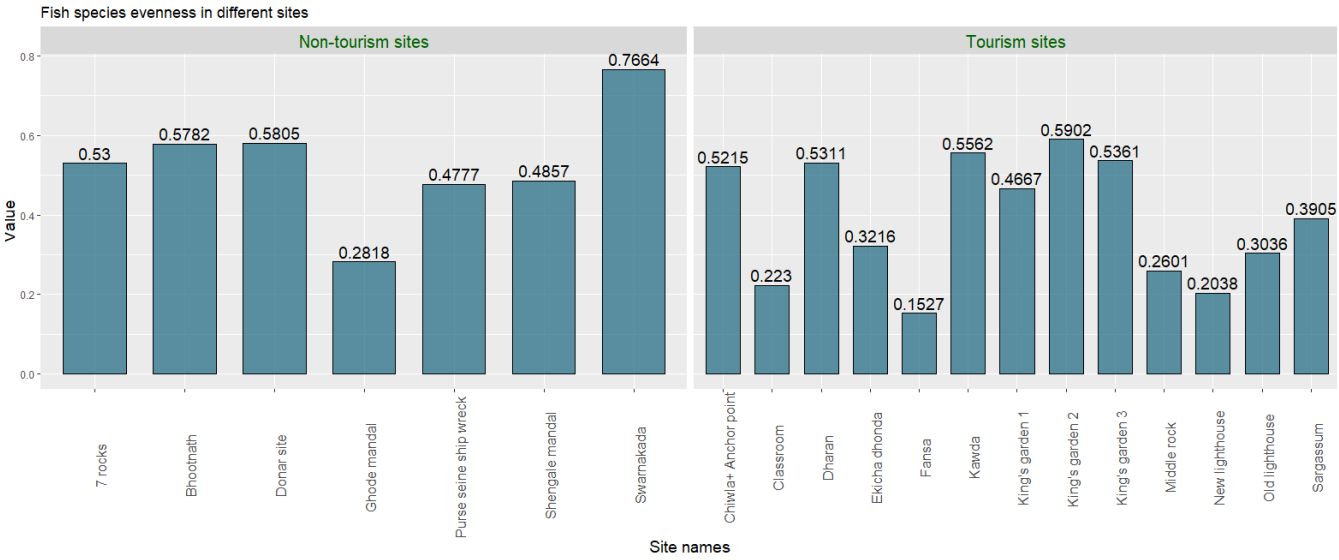


Figure 8. Evenness of distribution of fish species across study sites at Malvan Marine Sanctuary, Maharashtra during the surveys conducted from April 2021-January 2022.

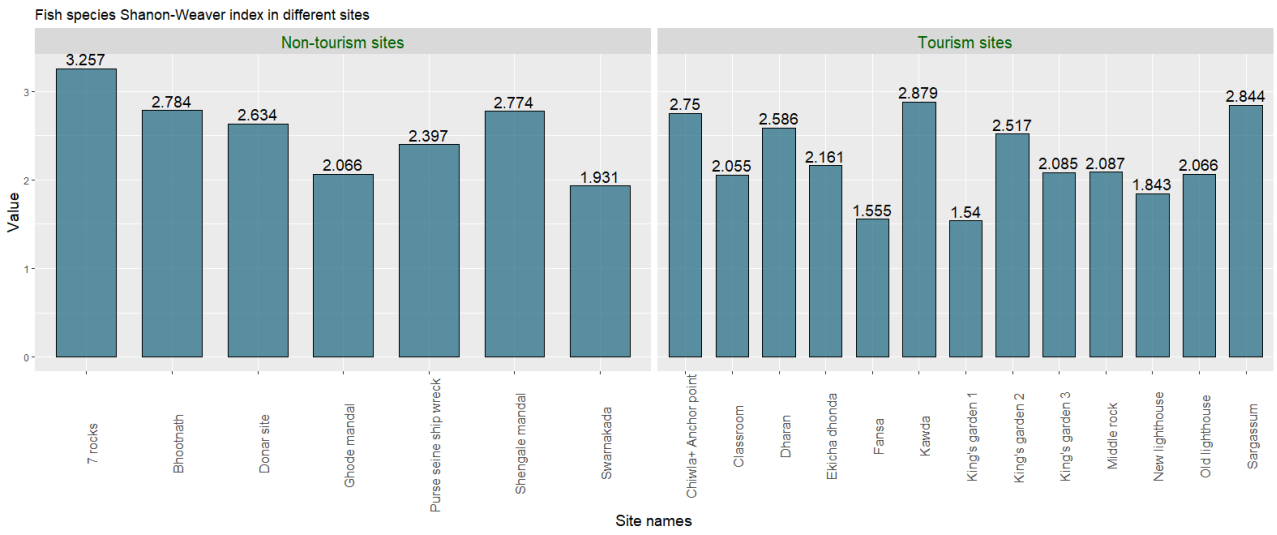


Figure 9. Shannon-Weaver's diversity index of fish species across study sites at Malvan Marine Sanctuary, Maharashtra during the surveys conducted from April 2021-January 2022.

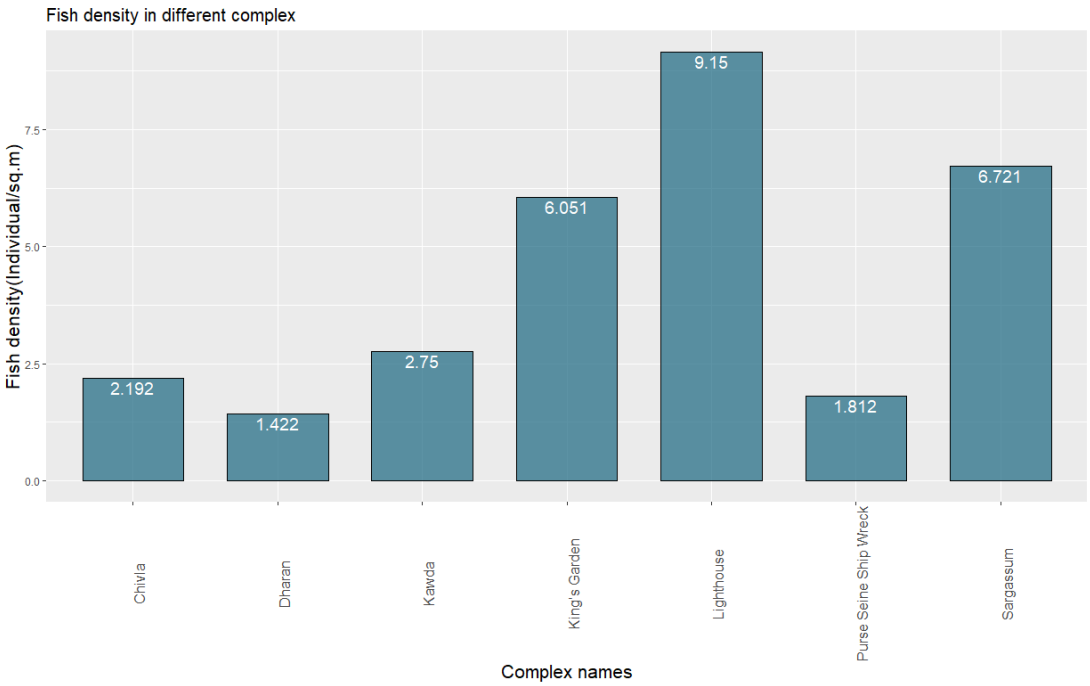


Figure 10. Fish density in different complexes along Malvan coast, Maharashtra during the surveys conducted from April 2021-January 2022.

4. 4. Commercial fish catch assessment

a) Malvan fish market:

A total of 44 different fish species were observed during the market surveys (Supplementary table 3). Fishes such as the Silver pomfret, Black pomfret, Indian mackerel, King mackerel were the most common fishes observed.

The species with outliers in the figure 11 have lower median values which represents smaller size class. Species with a higher median value represent an observation with larger size class.

Figure 11 represents the total number of fish observed by family as per their size. The size class of fishes observed in the market throughout the survey were skewed towards smaller sized fish (0 – 30 cm). The larger sized fish species were of the family Muraenidae (Eels) and Serranidae (Groupers).

Plate 22. Species of flower pot coral in Malvan

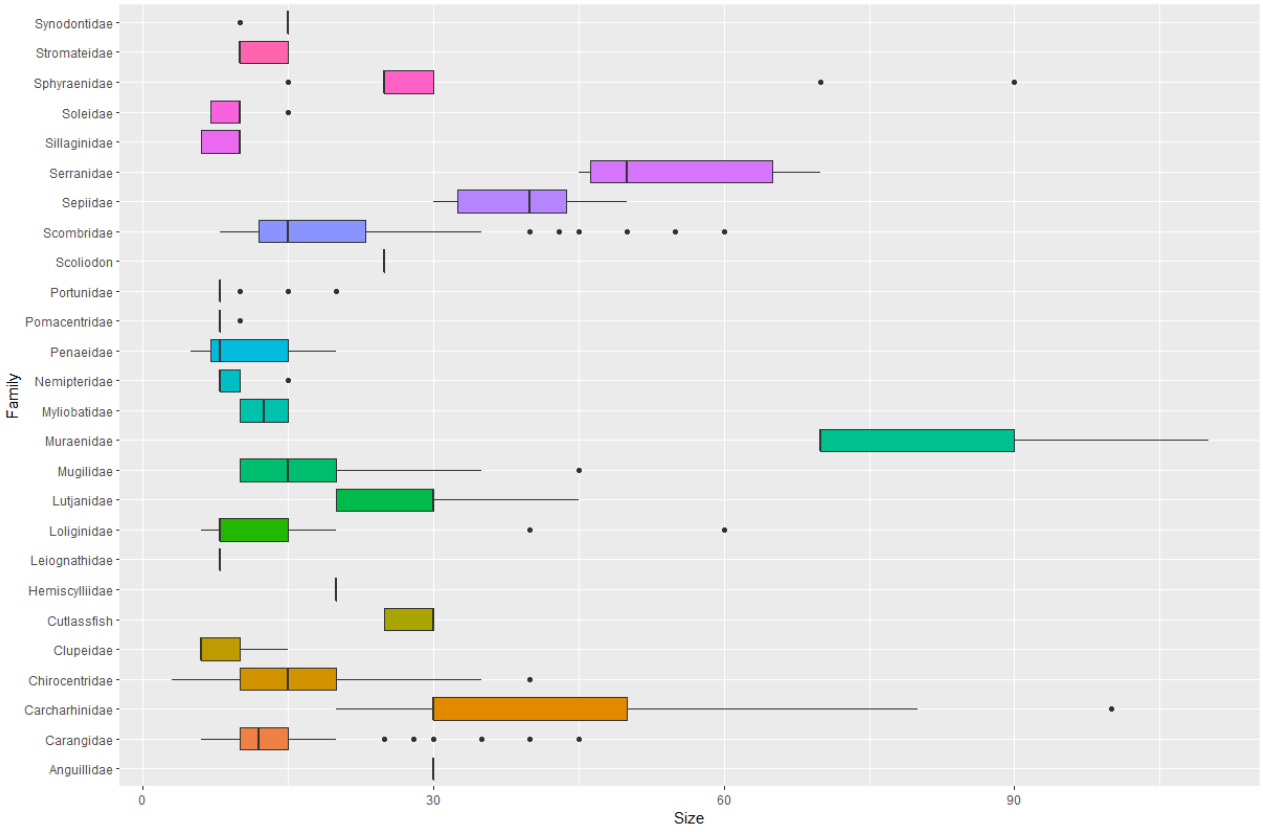


Figure 11. Boxplot representing the family-wise size distribution of fish species observed in Malvan, Maharashtra during the surveys conducted from April 2021-January 2022

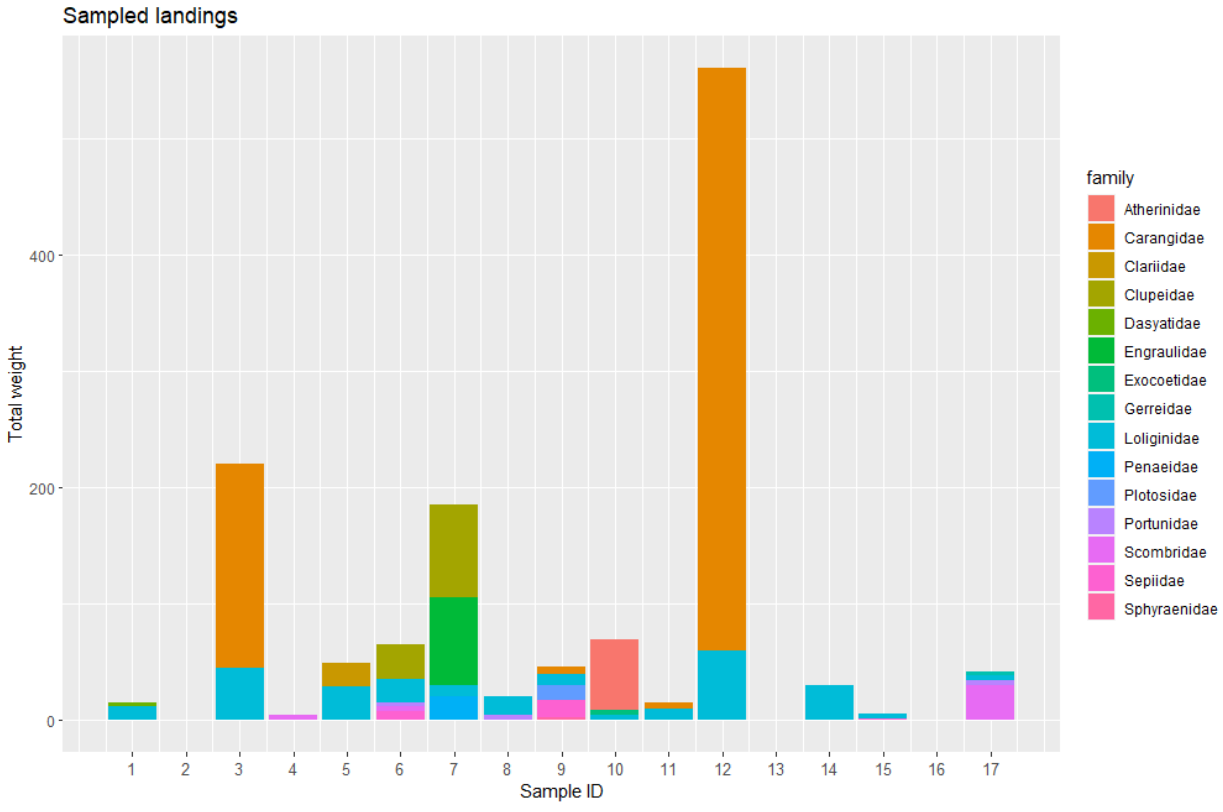


Figure 12. Total family-wise fish landings observed during rampan net survey along Malvan coast, Maharashtra during the surveys conducted from April 2021-January 2022.

Plate 23. School of trevallies swimming

b) Rampan surveys:

A total of 43 consumable/commercial fish species were observed in rampan during the surveys (Supplementary table 4). Along with the 43 species, some were bycatch namely, Jellyfish, Box puffer fish, Eel catfish, Sea snake, Needlefish and Eels. Catch of small-sized Stingrays, along with Eel, Catfish and other small-sized juvenile fish such as Groupers were sold as fishmeal for Rs 15 per kg. In one of the samplings, a total of 22 sub-adult Bamboo sharks were caught.

Major fish landings occurred in the month of October in which fish species of family Engraulidae, which consists of species of Anchovies, was the highest catch. No species had significant weight to be occurring as catch in all three months during which the survey took place. The least catch was of Sphyraenidae in the month of November (Figure 13), which consists of species like barracudas.

4.5. Estimation of beach litter

The solid waste observed in beach litter surveys mostly composed of plastic bottles, polythene materials, and Styrofoam, with higher volumes in areas within the Malvan Marine Sanctuary core zone. Littering of these areas can be attributed to the absence of a waste management/disposal plan and high influx of tourists. Owing to the prevailing monsoon winds, a deposition of tar was observed washed onto the beach. Litter surveys at dive sites and at sea surface were not able to provide sufficient data to make a strong assertion owing to the changing physical conditions. Discarded ghost nets and plastic products were observed at some sites.

In the survey, a total of 3346 debris were encountered for 4157.7 meters of belt transect. The total average debris present per square meter of the beach for pre, and post monsoon

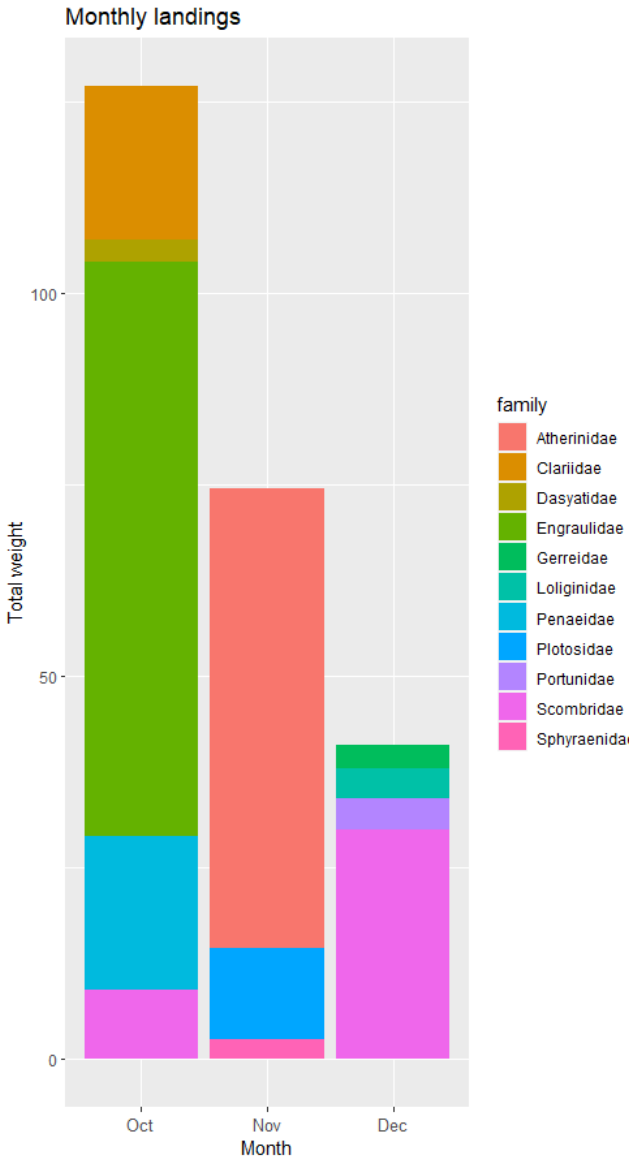


Figure 13. Family-wise fish species during the Rampan survey (October to December, 2021) along the Malvan coast, Maharashtra.

data was found to be 2.01, which is an exponential rise when compared to the post monsoon average i.e., 0.05.

Plastic waste was the dominant litter type followed by anthropogenic wastes (Figure 14). Plastic wrappers were the dominant type of plastic waste found throughout the survey, followed by plastic bottles (Figure 15).

Figure 16 shows comparative boxplots of the four key debris types highlighting the range of total litter type encountered as per their size. The debris type with outliers in the plot have lower median values which represents smaller size class. Debris with a higher median value represent an observation with larger size class. Debris type of a single observation of a specific size class is shown by the whisker (black line) in the figure 16.

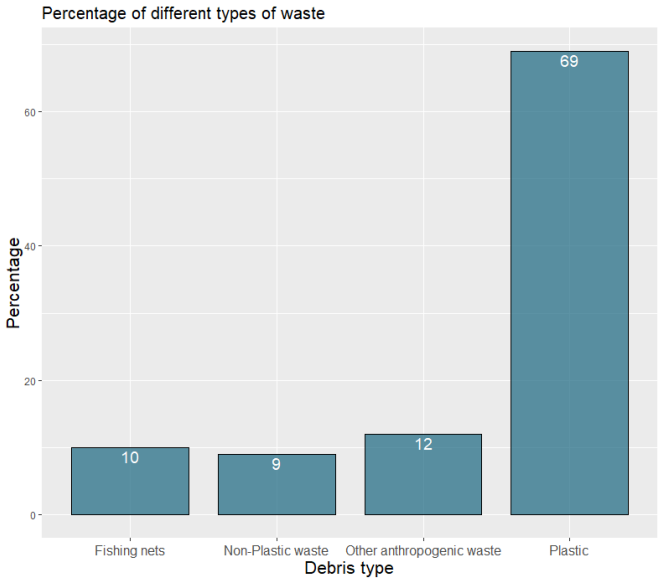


Figure 14. Percentage cover of debris type along the Malvan coast, Maharashtra

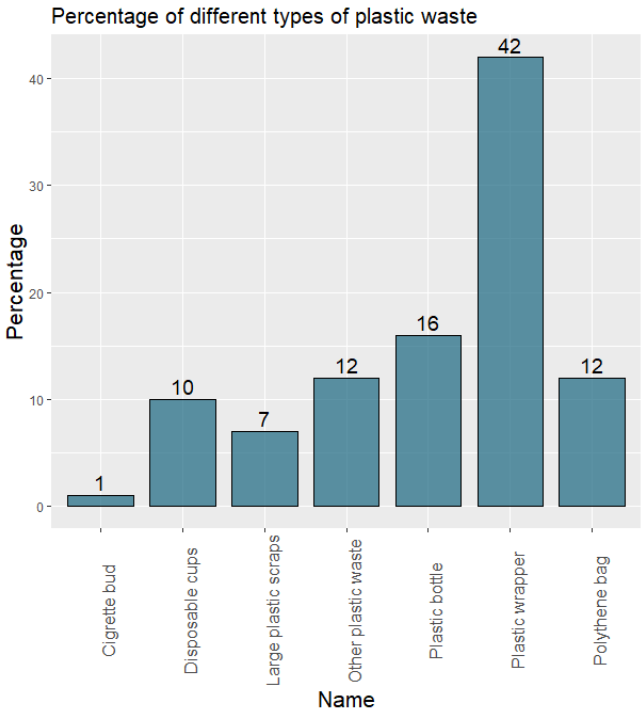


Figure 15. Percentage cover of various plastic waste along the Malvan coast, Maharashtra

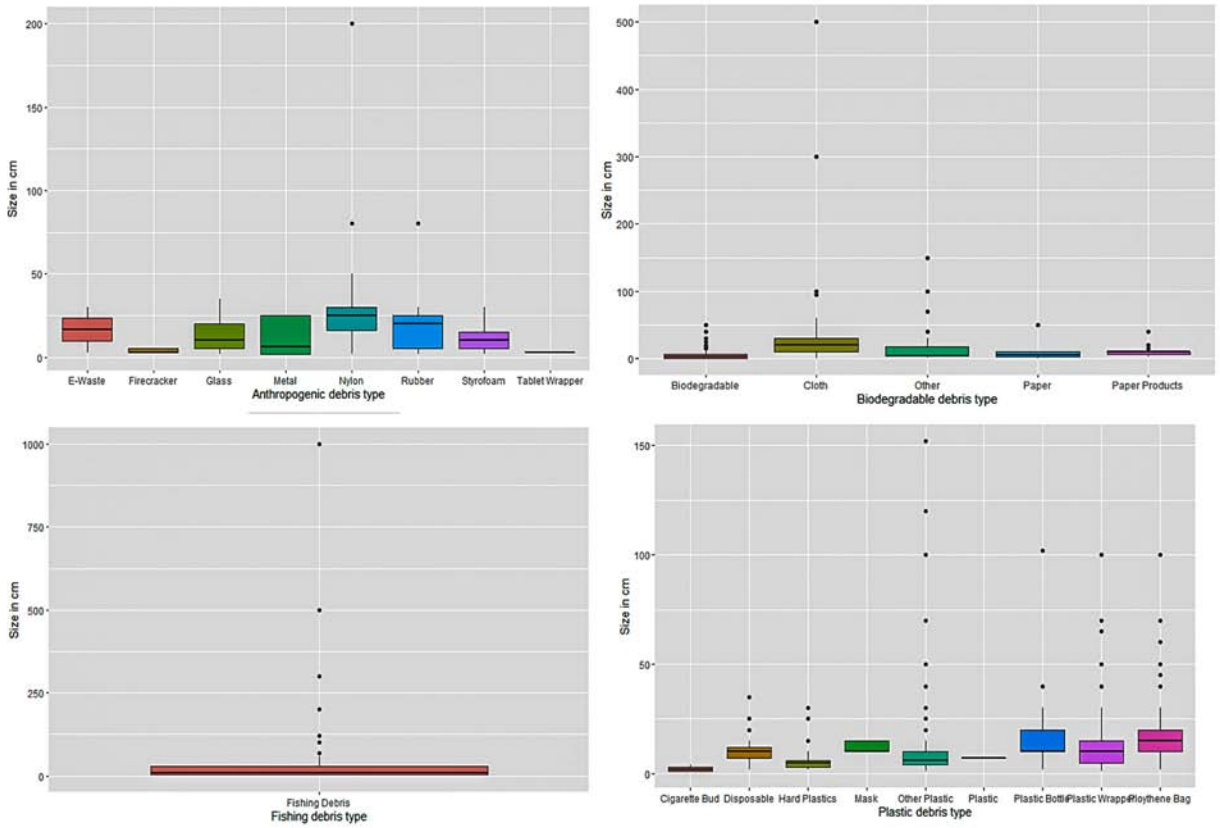


Figure 16. Boxplots of different waste types along the Malvan coast, Maharashtra during the surveys conducted from April 2021-January 2022

4.6. Coastal bird diversity

Previously published information lists 370 species of birds along the coastal talukas of Devgad, Malvan and Vengurla (Babu Rao et al. 2019). This includes 136 shorebirds or seabird species (Supplementary table 5). Since many of these birds are dependent on the adjoining creeks, and the near coast regions for feeding, this adds up to the overall ecological importance of this region.

Plate 24. Little egret

Plate 25. Brahminy kite

Plate 26. Heron and Egrets

Plate 27. Sargassum cinerium algae species

4.7. Estimating Species Richness and threat scores for spatial prioritization

The sampling sites surveyed along the Malvan coast represent a mosaic of multiple habitats like coral reefs, rocky outcrops and sandy patches with seagrass beds. The bubble chart (Figure 17) indicates that sites namely 7 Rocks, Bhootnath, Classroom, Sargassum, Middle rock, Old and New Light house, Chiwla, Shengale Mandal, Ghode Mandal, Ekicha Dhonda and Kawda are critical habitats with higher biodiversity and lower threat in comparison to the others. It is also evident that the sites (King's Garden 1, 2 and 3) within the core zone of the Malvan marine sanctuary now have low biodiversity attributing to the high anthropogenic stress.

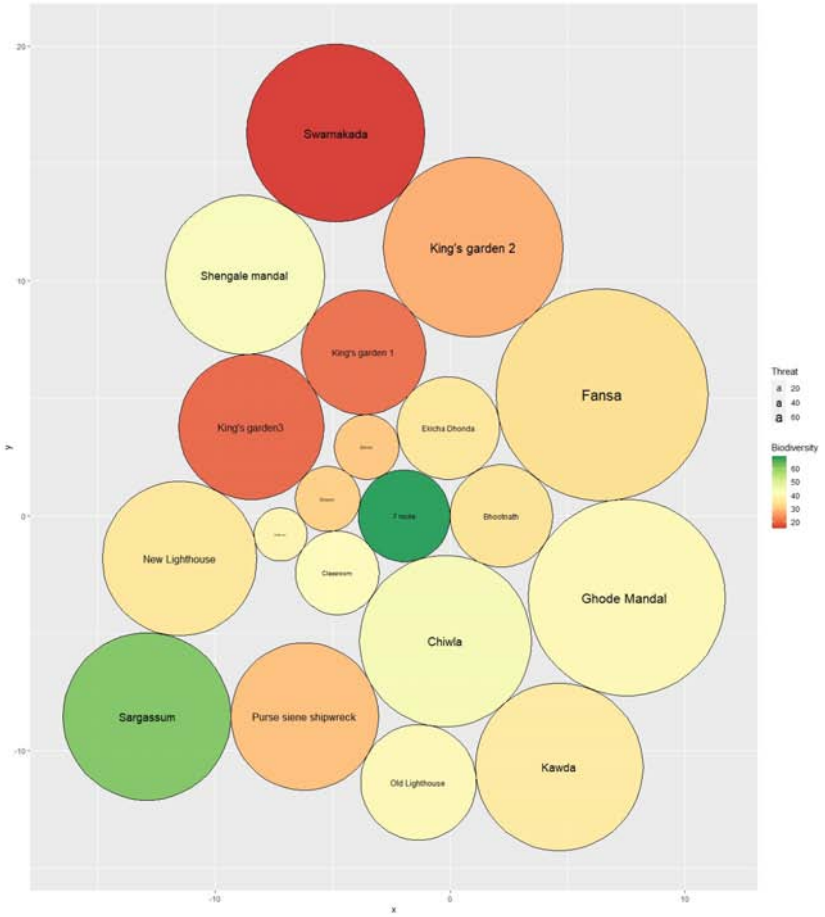


Figure 17: Bubble chart representing threat range with bubble size and biodiversity range with colour along the Malvan coast of Maharashtra. A bigger bubble size means higher threat score, where red to green means lower to higher species richness (Fish+Coral) score.

Plate 28. New lighthouse

5. Spatial prioritization

A matrix (Figure 18) was used to prioritise sites with respect to biodiversity (The species richness of coral and ichthyofauna) and threats (diving, motorised fishing boats and non-motorised fishing boats).

The sites surveyed were clubbed into complexes for management ease. A total of six complexes were formed namely Kawda, Chiwla, King's Garden, 7 Rocks, Sargassum and Lighthouse. Prioritized areas along the coast of Malvan (Figure 19) were clubbed in 3 categories viz. Potential PA, Conservation Priority areas & Sensitive Areas based on the conceptual framework (Figure 18) and table 4. The details are given below

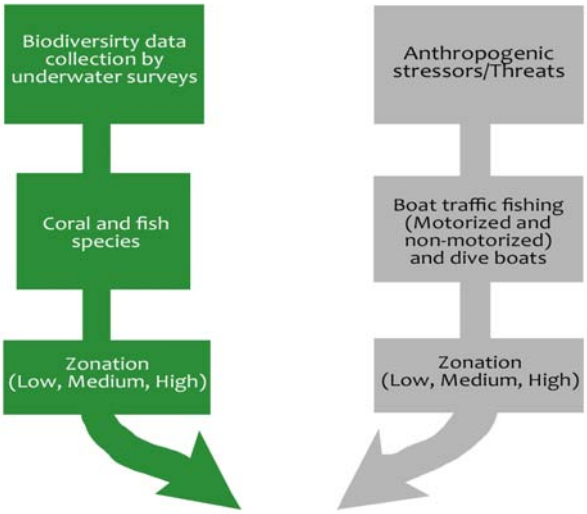
a. Potential Protected Areas

Potential PAs (Table 5) are areas with medium to high species richness and and low to medium threat score scores. Total area of the Potential Protected area is 29.07 sq.kms. These sites are as follows.

Kawda Complex (Figure 19) is the Northern most com-

Threat score= (Motorized fishing boats*3) +(Dive boats*2) +(Row boats*1)
Biodiversity score= (Coral genera richness*2) +(Fish species richness*1)

Class Interval	Low	Medium	High
Richness score	0-31	33-39	40-69
Threat score	0-15	19-40	42-64



Spatial Prioritization		Comparative Matrix		
		Threat		
		Low	Medium	High
Species richness	Low	LL	LM	LH
	Medium	ML	MM	MH
	High	HL	HM	HH

Figure 18. Conceptual framework for spatial prioritisation of sites/complex

Plate 29. Malvan beach

plex off the coast from Talashi beach. It comprises of the area around Kawda Island and Swarnakada. The Kawda Island has high fish diversity and richness. The Talashi beach is also a known Olive Ridley turtle nesting site. Swarnakada is a dive site along the cliff adjoining Sarjekot jetty. The sites Kawda Island and Swarnakada have a species and genera richness score of 36 and 15 respectively and a threat score of 40 and 45 respectively.

7 Rocks Complex (Figure 19) comprises of the sites 7 Rocks, Bhoothnath reef and Ekicha Dhonda. These sites have low pressure from diving tourism. These sites have large rocks underwater that provide shelter for fish owing to the high fish diversity and richness found in this region. Ekicha Dhonda is a large outcrop that also is a nesting site for Sea eagles. The sites 7 Rocks, Bhoothnath reef and Ekicha Dhonda have a species and genera richness score of 69, 34 and 35 respectively and a threat score of 12, 15 and 15 respectively.

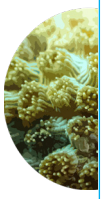
Lighthouse Complex (Figure 19) is the southern most complex. It comprises of the sites Classroom, Old and New Lighthouse, Fansa and Middle rock. These sites are a group of large outcrops off the coast of Niviti and Vengurla. This complex was observed to have high fish diversity along with coral percentage cover and genera richness. These outcrops are also nesting sites for multiple avifaunal species including the Indian swiftlet. The sites Classroom, Old and New Lighthouse, Fansa and Middle rock have a species and genera richness score of 41, 40, 35, 33 and 39 respectively and a threat score of 10, 19, 34, 64 and 4 respectively.

b. Conservation priority areas

Conservation priority areas (Table 6) are complexes with medium to high species richness and high threats. Total area of the conservation priority area is 19.21 sq.kms. Total two complexes comes under this conservation priority areas.

Chiwla Complex (Figure 19) is located offshore from Chiwla beach. It comprises of the dive sites Chiwla and Anchor point. The sites are high in coral genera rich-

Plate 30. Malvan during the sunset



ness. But under high stress from diving tourism and fishing. 6% of dead coral cover was observed at this complex, predominantly in boulder corals (*Porites sp.*) The sites Chiwla and Anchor point combined have a species and genera richness score of 44 respectively and a threat score of 42 respectively.

Sargassum Complex (Figure 19) is a located off shore from the Bhogwe coast. The sites Ghode Mandal, Shengale Mandal and Sargassum Forest are known fishing areas. Diving tourism was observed at Sargassum Forest and has seasonal presence of *Sargassum cinerium*. The sites Ghode Mandal, Shengale Mandal and Sargassum Forest have a species and genera richness score of 40, 43 and 62 respectively and a threat score of 55, 36, and 40 respectively.

c. Sensitive areas

Sensitive areas are areas with low species richness and low to high threats depicted in orange in Figure 19 and table 4. Total area of the Potential Protected area is 3.72 sq.kms. These are sensitive as they are areas with small patches of seagrass which is not frequently seen elsewhere.

King's Garden Complex is the area around the Sindhudurg fort. It comprises of the sites King's Garden 1, 2, and 3, Dharan and Donor. This region is currently a part of the core zone of the Malvan Marine Sanctuary. This complex has a very high tourism pressure of diving tourism and a heavy boat traffic and parking including recreational boats i.e. jet skis and parasailing boats. The coral health in the region has deteriorated with 12% and 3% dead coral cover at the sites King's Garden 1 and 2 respectively. Among the dead coral remains Brain coral skeletons were identified. All the sites in this complex were observed to have seasonal patches of seagrass (*Halophila decipiens*). Seagrasses serve as nursing for commercially important fishes and invertebrates (Gillanders, 2007) and provide forage to endangered species such as green sea turtles and dugongs (Valentina, 2007). The sites Dharan, Donor, Kings' Garden 1, Kings' Garden 2 and Kings' Garden 3 have a species and genera richness score of 31, 30, 20, 27, and 19 respectivelyy and a threat score of 6, 6, 22, 46, and 30 respectively. This complex has been categorised as "Sensitive" owing to the presence of coral species and seagrass (*Halophila decipiens*).

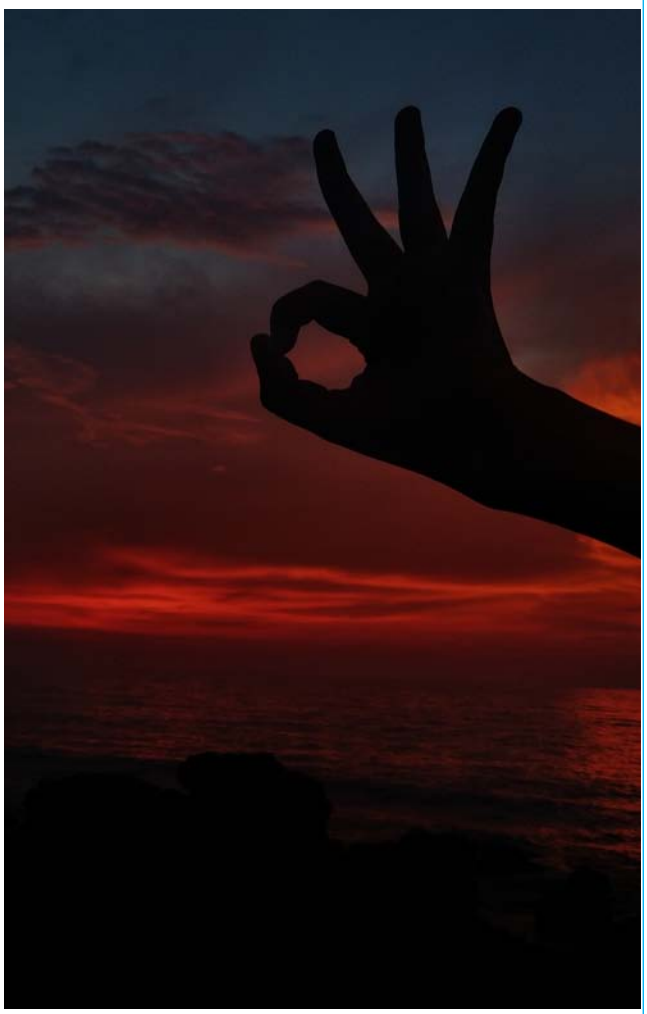
Table4. Threat and species/genera richness score used for prioritisation of sampling sites

S. No.	Complex	Site names	Biodiversity score	Threat score	Biodiversity and threat category	Conservation areas
1	Lighthouse	Classroom	41	10	HL	Potential protected area
1	Lighthouse	Fansa	33	64	MH	Potential protected area
1	Lighthouse	Middle rock	39	4	ML	Potential protected area
1	Lighthouse	New Lighthouse	35	34	MM	Potential protected area
1	Lighthouse	Old Lighthouse	40	19	HM	Potential protected area
2	Sargassum	Ghode Mandal	40	55	HH	Conservation priority area
2	Sargassum	Sargassum	62	40	HM	Conservation priority area
2	Sargassum	Shengale mandal	43	36	HM	Conservation priority area
3	7 rocks	7 rocks	69	12	HL	Potential protected area
3	7 rocks	Bhootnath	34	15	ML	Potential protected area
3	7 rocks	Ekicha Dhonda	35	15	ML	Potential protected area
4	King's garden	Dharan	31	6	LL	Sensitive area
4	King's garden	Donor	30	6	LL	Sensitive area
4	King's garden	King's garden 1	20	22	LM	Sensitive area
4	King's garden	King's garden 2	27	46	LH	Sensitive area
4	King's garden	King's garden3	19	30	LM	Sensitive area
5	Chiwla	Chiwla+Anchor point	44	42	HH	Conservation priority area
6	Kawda	Kawda	36	40	MM	Potential protected area
6	Kawda	Swarnakada	15	45	LH	Sensitive areas
7	No Complex	Purse seine shipwreck	29	31	LM	Sensitive area

Plate 31. Middle rock and Old lighthouse

High species richness of coral and fish coupled with lower anthropogenic stressors was observed at 7 Rocks complex, Kawda, and Lighthouse complex indicating these areas are ideal for being demarcated as Protected. The areas namely Sargassum complex and Chiwla complex were observed to have good biodiversity but a higher range of anthropogenic stressors (fishing in Sargassum complex and diving in Chiwla complex) High Priority Areas, these sites may be included into the buffer area or eco-sensitive zone to the recommended Potential Protected Areas. Evidences of fragmentation and other physical harm point towards disturbances arising from tourism activities or other anthropogenic threats such as SCUBA diving, anchoring or fishing. Physical damage to corals such as breakage, holding or use for tying buoys should be avoided. It is recommended that recreational activities such as SCUBA diving, snorkelling and other motorised water sports that are carried out in the Malvan region be regulated and monitored in the High Priority Areas and Potential Protected Areas to avoid the further deterioration of the marine habitats.

The Sensitive Areas have had past records of high marine faunal diversity (Parulekar, 1981). These areas discernibly cover a large portion of the current Malvan Marine Sanctuary including the core zone indicating the deleterious effect of unchecked anthropogenic stressors. The above zonation (Figure 21) may be used to regulate seasonal access to critical areas for fishing activities thereby allowing the habitats time to recover in coral health and fish abundance. This might help in achieving an equilibrium in this vital marine ecosystem along the Malvan coast.



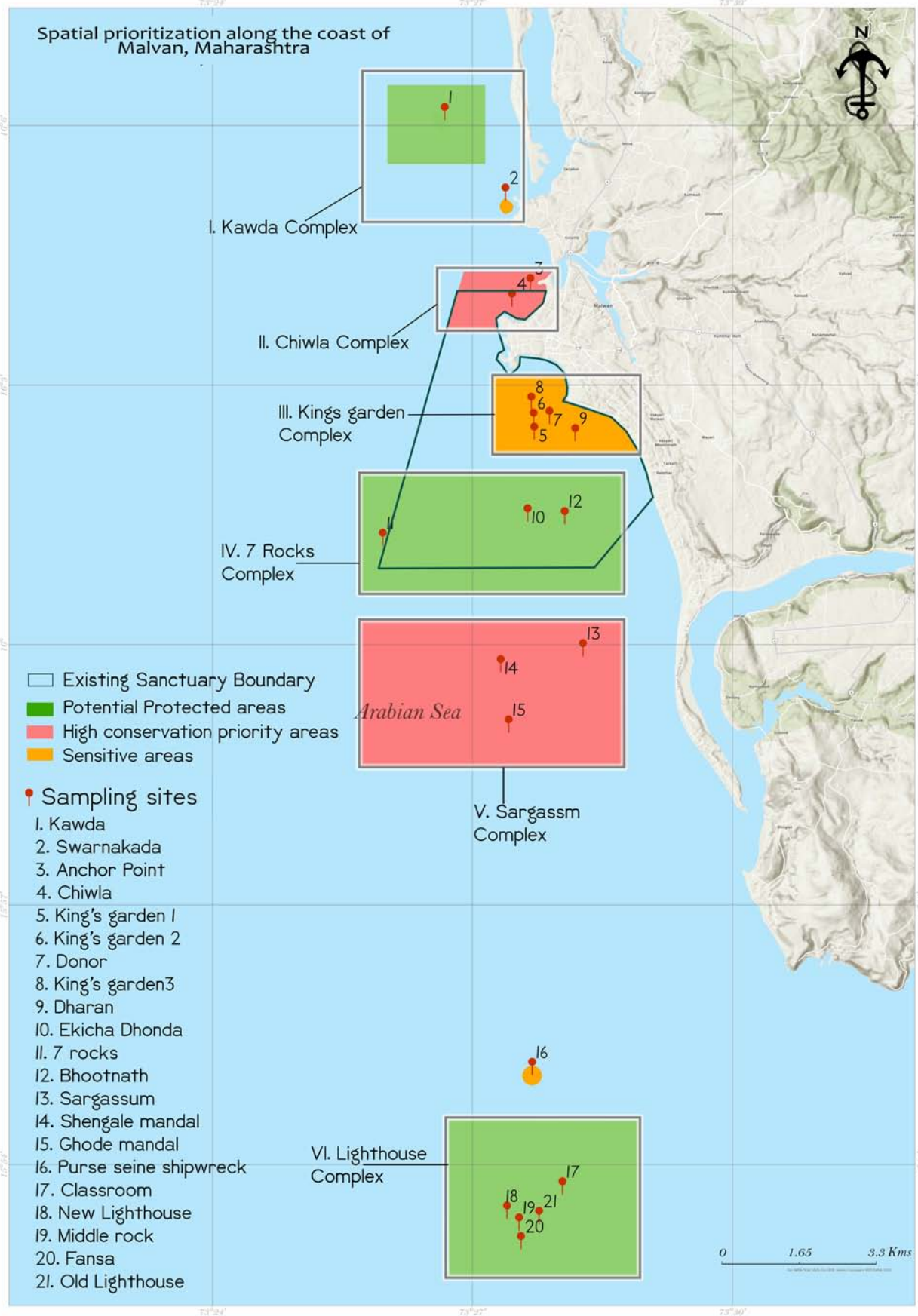


Figure 19. Map indicating high biodiversity areas along the coast of Malvan, Maharashtra during the surveys conducted from April 2021-January 2022.

Table 5. GPS coordinates of complexes prioritised as Potential Protected Areas along the Malvan coast, Maharashtra.

Potential Protected Area	Kawda Complex	7 Rocks Complex	Lighthouse Complex
Top Left	16° 6' 27.992" N	16° 1' 58.082" N	15° 54' 31.041" N
	73° 26' 1.039" E	73° 25' 41.263" E	73° 26' 43.102" E
Top Right	16° 6' 27.992" N	16° 1' 57.739" N	15° 54' 30.697" N
	73° 27' 8.826" E	73° 28' 46.017" E	73° 28' 56.766" E
Bottom Right	16° 5' 33.240" N	16° 0' 45.110" N	15° 52' 41.509" N
	73° 27' 8.826" E	73° 28' 46.022" E	73° 28' 56.464" E
Bottom Left	16° 5' 33.240" N	16° 0' 44.422" N	15° 52' 41.498" N
	73° 26' 1.039" E	73° 25' 41.261" E	73° 26' 43.413" E
Area in sq. km.	3.3899 sq. km	12.3477 sq. km	13.3343 sq. km

Table 6. GPS coordinates of complexes prioritised as Conservation Priority Areas along the Malvan coast, Maharashtra.

High Conservation Area	Chiwla Complex	Sargassum Complex
Top Left	16° 4' 18.533" N	16° 0' 16.881" N
	73° 26' 53.973" E	73° 25' 41.263" E
Top Right	16° 4' 18.533" N	16° 0' 16.881" N
	73° 27' 55.143" E	73° 28' 46.017" E
Bottom Right	16° 3' 38.754" N	15° 58' 34.684" N
	73° 27' 17.326" E	73° 28' 46.911" E
	16° 3' 38.754" N	
	73° 27' 17.326" E	
Bottom Left	16° 3' 38.835" N	15° 58' 34.662" N
	73° 26' 42.031" E	73° 25' 41.729" E
Area in sq. km.	1.9382 sq. km	17.2763 sq. km

Table 7. GPS coordinates of complex prioritised as Sensitive Area along the Malvan coast, Maharashtra

Sensitive Area	Kings Garden Complex
Top Left	16° 3' 5.658" N
	73° 27' 14.368" E
Top Right	16° 3' 6.074" N
	73° 28' 3.376" E
Bottom Right	16° 2' 13.283" N
	73° 28' 56.049" E
	16° 2' 13.283" N
	73° 28' 56.049" E
Bottom Left	16° 2' 13.021" N
	73° 27' 14.661" E
Area in sq. km.	3.5249 sq. km

6. Training workshop and local community discussions

Drone Training Workshop

Venue: Malvan Range Office (Malvan, Sindhudurg)
Date: 8th January, 2022

A Drone handling and hands on training workshop was conducted on the topic- "Using Unmanned Aerial Vehicles for marine conservation" under the project 'Spatial mapping of critical marine habitats of Malvan for re-organization of boundary of the Malvan Marine Sanctuary' for the frontline staff of Malvan Range of Mangrove Cell, Maharashtra Forest Department on 8th January, 2022. The workshop was attended by the staff members of Mangrove Foundation and Maharashtra Forest Department Mr. Sonawane Forest Range Officer, Mr. Sawant District Coordination Officer, UNDP, Mrs. Thigale Biodiversity and Liveihood Specialist, Mangrove Foundation. It included introduction to UAVs, UAVs in Marine Research and an outdoor demonstration session, hands on training for each participant, scan sampling and focal sampling exercises. The aim of the course was to teach the participants the necessary skills and knowledge to use a Drone for monitoring and research in the Malvan Marine Sanctuary.

SCUBA Diving Training Workshop

Venue: Divers of Vingoria (Bhogwe)
Date: 6th-11th February, 2023

Wildlife Institute of India organized a SCUBA Diving training workshop for the frontline staff of the Mangrove Foundation and Maharashtra Forest Department under the project 'Spatial mapping of critical marine habitats of Malvan for re-organization of boundary of the Malvan Marine Sanctuary' between 6th -11th February, 2023. The objective of the workshop was to train members of the forest department to dive underwater using SCUBA for better monitoring of the coral reefs in the Malvan Marine Sanctuary. The workshop was attended by the staff members of Mangrove Foundation and Maharashtra Forest Department Mr. Jayesh Vishwakarma, Mr. Abhinay Kelaskar, Mr. Sharad Kamble and Mr. Avinash Rathod. The scuba diving training workshop was a PADI Open Water Diver certification course conducted for 4 participants of the frontline staff of the Maharashtra Forest Department over a period of 4 days. The aim of the course was to teach the participants the necessary skills and knowledge to become certified scuba divers for underwater research and monitoring of the Malvan Marine Sanctuary.

Discussion-meeting with the local community in Malvan

Venue- Malvan Range Office (Malvan, Sindhudurg)
Date- 10th April, 2023

The Mangrove Foundation had requested the Wildlife Institute of India (WII) to advise on the reorganization of the Malvan Marine Sanctuary (MMS). In January 2023, WII submitted a draft report that identified the important biodiversity areas and advised on the boundaries of the MMS. The representatives from the fishing community and tourism sector in Malvan requested that the findings of the study be shared with them. A meeting was held on 10th April 2023, where the attendees were given a background of the subject, and WII representative presented the findings. The said meeting was chaired by Mr. Adarsh Reddy, Deputy Conservator of Forests, Mangrove Cell and the other officials present for the said meeting were Mr. Pradeep Patil, Range Forest Officer, Mangrove Cell-Malvan, Dr. Manas Manjrekar, Deputy Director, Research & Capacity Building, Mangrove Foundation, Mr. Shridhar Algiri, Asst. Commissioner of Fisheries, Malvan and Mr. Noah Shinde, Researcher, WII.
The complexes categorised as Potential Protected areas were considered for recommendation to the State Govt as reorganised areas and boundaries of MMS. This would mean that the existing boundaries of the MMS would cease to exist and the boundaries of these three separate complexes would form the new boundaries of MMS, covering an area of 29 sq.km. During the meeting, the attendees had various questions, doubts, fears and demands regarding the matter, which were related to their livelihoods and the implications for fishing and tourism activities in the new proposed areas of MMS, as well as the core and buffer zones, implications for fishing boats entering the boundaries of MMS, and guarantees that no land/sea area would be acquired by the Forest Dept. between the Kawada complex till the Lighthouse complex of the proposed new boundaries of Malvan Marine Sanctuary.

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A Tubastrea coral at Malvan marine WLS

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Spatial mapping of important marine habitats of Malvan coast for re-organization of boundary of the Malvan Marine Sanctuary

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