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Catch-based Marine Fish Abundance along the Maharashtra Coast of India

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Maharashtra, with its extensive 720 km coastline, encompasses seven maritime districts: Palghar, Thane, Mumbai City, Mumbai Suburban, Raigad, Ratnagiri, and Sindhudurg. This state is a major contributor to India's marine fisheries, supported by a significant fleet of approximately 12,946 mechanized and 2,272 non-mechanized fishing vessels. The study investigated catch-based marine fish abundance along the Maharashtra coast, focusing on data collected from 33 species and species groups. The analysis classified the status of fish stocks into categories such as abundant, less abundant, declining, depleted, or collapsed, based on the percentage of recent average catch relative to historical maximums. Findings indicated distinct regional variations: Mumbai region showed a relatively better situation in terms of the status of species abundance, with 63.64% of species categorized as abundant or less abundant. Conversely, the southern districts, particularly Ratnagiri and Sindhudurg, exhibit alarming declines, with significant proportions of species classified as depleted or collapsed. Historical studies and comparative analyses underscore the dynamic nature of fisheries and the need for adaptive management strategies. Regions like Ratnagiri, with only 3.03% of species classified as abundant, highlight the critical state of marine resources. The study emphasized the necessity for continuous monitoring, effective management interventions, and tailored conservation plans to sustain the marine fish populations across Maharashtra's diverse coastal regions. Urgent, targeted conservation efforts are particularly crucial in the southern districts, where the abundance of the number of species and species groups is declining rapidly.

(***Key words:*** *Abundance, Coastal Maharashtra, Marine fishes, Landings)*

Maharashtra is one of the important maritime states of India with 720 km of coastline extending from 20°08′0″ N, 72°44′0″ E to 15°43′3″ N, 73°40′3″ E. The total coastline of which Thane and Palghar together contribute 112 km, Mumbai 80 km, Raigad 240 km, Ratnagiri 167 km and Sindhudurg 121 km. The state has 1,12,512 km^2 of continental shelf area, facilitating vast fishing grounds for the fishermen to fish for their livelihood. The state has a total of 173 fish landing centres along the coast. The 46 landing centres are located in Ratnagiri district which is the maximum as compared to other districts in the state whereas, 19 fish landing centres are located in Greater Mumbai which is the minimum among all the districts. The state has one major fishing harbour at Sassoon Dock, Mumbai and two minor fishing harbours one at Mirkarwada in Ratnagiri and the other at Agro in Raigad district (DOF, 2023).

The state operates around 13172 mechanized fishing vessels and 2352 non-mechanized fishing vessels. There are 526 fisheries villages consisting of 364899 fisher folk population including 76928 active fishermen (DOF, 2022). Marine fisheries are crucial for Maharashtra, providing thousands of jobs directly and indirectly. This work force includes fishers, processors, packagers, distributors and those involved in the broader supply chain and export sectors. It also supports various ancillary industries, such as boat manufacturing, net making, and fish processing. These industries contribute to the overall economic impact of the fisheries sector. The economic impact of marine fisheries is substantial, contributing significantly to both domestic markets and international trade. Fishing practices in Maharashtra utilize a blend of traditional and modern techniques. Traditional methods, passed down through generations, involve artisanal approaches suited to local conditions. Modern techniques, particularly the use of mechanized boats, enhance fishing efficiency by allowing for greater catch volumes and improved navigation and processing

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capabilities. 13,172 mechanized fishing vessels are operating in the state which is a substantial number and plays a crucial role in increasing the efficiency and volume of fishing activity along the coast. These vessels are equipped with modern technology for better navigation and processing. Marine fisheries contribute significantly to the state's Gross Domestic Product (GDP) through both domestic consumption and exports. The sector's output enhances the economic value of coastal areas and supports local economies.

Maharashtra is a major player in the seafood export industry. The value generated from seafood export during the year 2021-22 was 5,878 thousand crores which was more than 10% of the total value generated by the national seafood export (MPEDA, 2023). This not only boosts the state's economy but also supports the national trade balance. The challenges to make the fisheries sustainable along the Maharashtra coast include enforcing regulations and addressing illegal, unreported, and unregulated (IUU) fishing. However, overfishing is a significant concern, leading to the depletion of various fish species and disrupting marine ecosystems and biodiversity. This issue underscores the need for sustainable fishing practices to maintain fish populations and ensure the industry's long-term viability. Historical and comparative studies supported the dynamic nature of fisheries and the necessity of adaptive and region-specific management strategies to ensure the sustainability of marine fish resources. Marine biodiversity is globally threatened and requires new management strategies to address the increasing challenges of biodiversity loss at genetic and special levels due to environmental and anthropogenic changes (Lakra *et al.,* 2021). Hence the present study was taken upto monitor the availability of fish stocks of various species or species groups along the coast of Maharashtra.

MATERIALS AND METHODS

The present study on marine fish abundance was carried out in different districts of Maharashtra (Fig. 1). The Department of Fisheries, Government of Maharashtra collects the marine fish landing data for 33 species and species groups from 26 different zones along the coast of Maharashtra. Earlier, marine fish landing for Mumbai region was collected together from

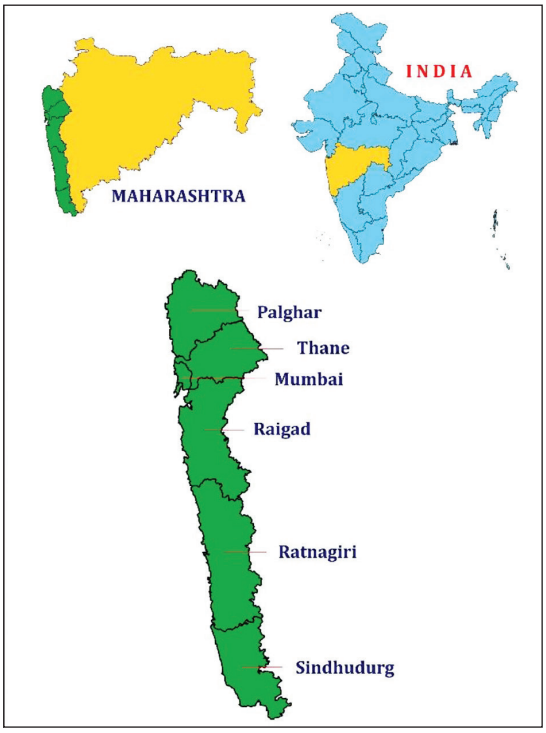

Fig. 1. *Study Area*

Table 1. *Criteria used for fish stock classification*

Stock Status	Percentage of recent average catch to the historical maximum catch
Abundant	> 70
Less Abundant	50 – 69
Declining	11 – 49
Depleted	06 – 10
Collapsed	< 5

Mumbai city and Mumbai suburban. Since 2012-13, separate data was given for Mumbai city and Mumbai sub-urban region. For this present study, the combined data was used to have uniformity in the data for the Mumbai region. The Thane district was split into two separate districts Thane and Palghar. Though these are two separate districts, the data was published together under the Thane district. Hence, there were no separate estimations for Palghar district but it is included in Thane only.

The marine fish production data for the Maharashtra state for 42 years from 1978 -79 to 2020 - 21 was used to classify the catch-based fish stock status whereas 24 years data from 1997 - 98 to 2020 - 21 was used for district-wise estimations. To investigate the stock abundance status, the historical maximum catch records for each species and/or species group and the recent average catch for the last three years were taken to calculate the recent average catch percentage to its historical maximum recorded catch. The status of catch-based fish stock abundance was classified as 'abundant', 'less abundant', 'declining', 'depleted' or 'collapsed' on the basis of the percentage of recent average catch to the historical maximum annual catch as per Mohamed *et al.* (2010) given in Table 1. While applying the criteria for the classification in the different stock status, the recent average catch for a species just more than 11% of its historical maximum, would still be categorized as 'declining', even though it is near the 'depleted' threshold. Likewise, if the recent catch is more than 70% of the historical maximum, it could be considered 'abundant', but the species is likely to be entered into the 'less abundant' status in the near future. The graphical representation of the exact percentage of recent average catch to the historical maximum catch is used which gives an idea about the species on the edge of the class borders. This will clarify the strength and adherence of the species or species group to its stock status class.

RESULTS AND DISCUSSION

Marine fish availability classification on catch-based data was analysed for the entire Maharashtra coast as well as district-wise landings. The results obtained in this study are given below explaining the scenario of overall Maharashtra coast landings and the availability of marine fishes for every district along the coast on the basis of historical catch data recorded.

Fish availability classification of marine fishes along Maharashtra coast

Out of 33 species and species groups, 33.33% species were categorised under the abundant category which included anchovies, perches, polynemids, croakers, caranx, seerfish, tunnies, sole fish, penaeid shrimp and cephalopods. The less abundant class consisted 30.30% of species or species groups and comprised elasmobranch, catfishes, dorab wolf-herring, hilsa shad, thrissocles, pomfrets, black pomfret, mackerel, goatfish and lobsters. The eels, sardines, other clupeids, Bombay-duck, red snapper, sciaenids, ribbonfish, barracuda, ponyfish and non-penaeid shrimp were observed declining whereas other clupeids landings were observed depleted from their historical maximum catches. The catch of Unicorn cod was observed to have collapsed in recent years. Among all 33 species or species groups, the percentage of depleted and collapsed

groups was 3.03% each while 30.30% of species groups were classified as declining. The detailed classification of the fish species according to their availability is depicted in Fig. 2 and Table 2.

Fish availability classification of marine fishes along Thane-Palghar coast

The classification based on marine fish species available along the Thane-Palghar coast was analysed

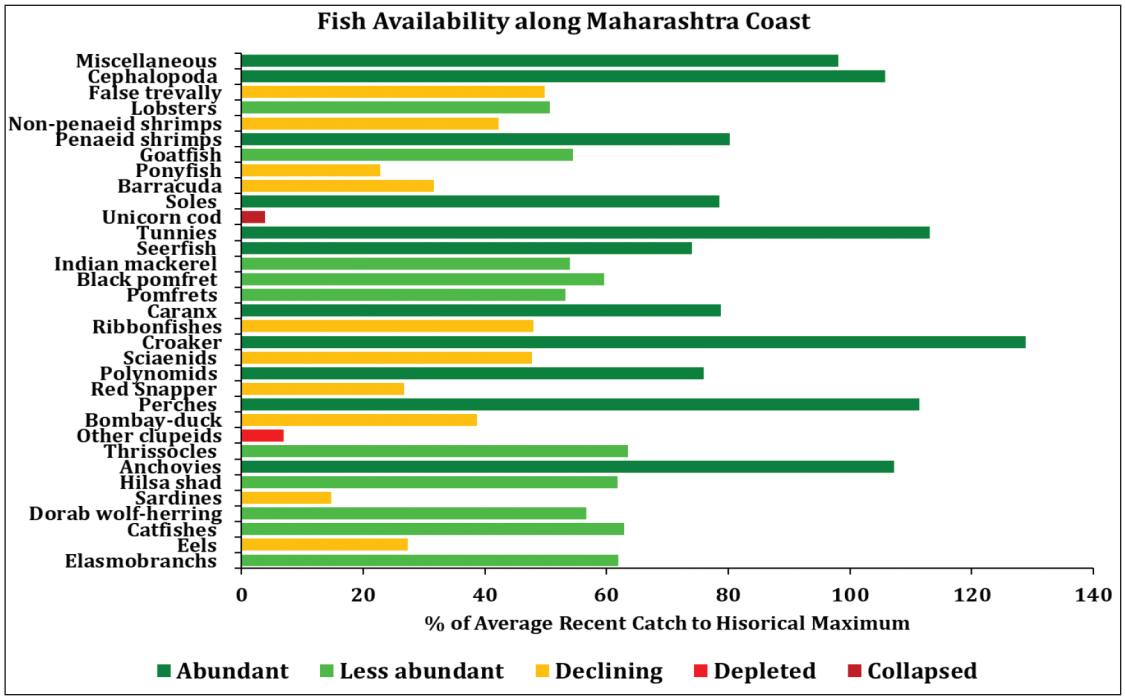

Fig. 2. *Fish availability classification along Maharashtra coast*

Table 2. *Fish availability classification along Maharashtra state*

Sr. No.	Species/variety	Historical maximum (Excluding last 3 years)	Average for recent 3 years (t)	% of Average catch to historical maximum (t)	Abundance
1	Elasmobranchs	11,381	7,050	61.95	Less Abundant
2	Eels	11,190	3,052	27.27	Declining
3	Catfishes	15,876	9,977	62.84	Less Abundant
4	Dorab wolf-herring	6,385	3,619	56.68	Less Abundant
5	Sardines	67,132	9,879	14.72	Declining
6	Hilsa shad	4,929	3,044	61.76	Less Abundant
7	Anchovies	24,997	26,817	107.28	Abundant
8	Thrissocles	9,119	5,792	63.52	Less Abundant
9	Other clupeids	6,736	469	6.96	Depleted
10	Bombay-duck	81,327	31,420	38.63	Declining
11	Perches	1,138	1,267	111.34	Abundant
12	Red Snapper	1,352	361	26.70	Declining
13	Polynemids	2,668	2,026	75.94	Abundant
14	Sciaenids	8,403	4,008	47.70	Declining
15	Croaker	25,747	33,192	128.92	Abundant
16	Ribbonfishes	53,569	25,682	47.94	Declining

17	Caranx	14,959	11,778	78.74	Abundant
18	Pomfrets	29,514	15,695	53.18	Less Abundant
19	Black pomfret	3,665	2,184	59.59	Less Abundant
20	Indian mackerel	50,379	27,161	53.91	Less Abundant
21	Seerfish	14,657	10,847	74.01	Abundant
22	Tunnies	9,562	10,817	113.12	Abundant
23	Unicorn cod	2,737	107	3.91	Collapsed
24	Soles	9,876	7,753	78.50	Abundant
25	Barracuda	11,112	3,517	31.65	Declining
26	Ponyfish	9,818	2,243	22.85	Declining
27	Goatfish	24,353	13,264	54.47	Less Abundant
28	Penaeid shrimps	56,235	45,103	80.20	Abundant
29	Non-penaeid shrimps	1,15,895	48,941	42.23	Declining
30	Lobsters	1,488	753	50.60	Less Abundant
31	False trevally	6,338	3,155	49.78	Declining
32	Cephalopods	26,643	28,188	105.80	Abundant
33	Miscellaneous	37,997	37,283	98.12	Abundant

according to the recent average catch with its historical maximum. The result showed that only four species/groups were under the abundant class having more than 70% score. The species falling under the less abundant category were eels, thrissocles, polynemids, pomfrets, soles, ponyfish, goatfish, penaeid shrimps and cephalopods. Four species namely caranx, unicorn cod, barracuda and false trevally were observed as collapsed whereas, sardines were classified under the depleted class. The remaining species groups were categorized as declining species or species groups because of less than 50% score of recent average catch to the respective historical maximum catches (Fig. 3).

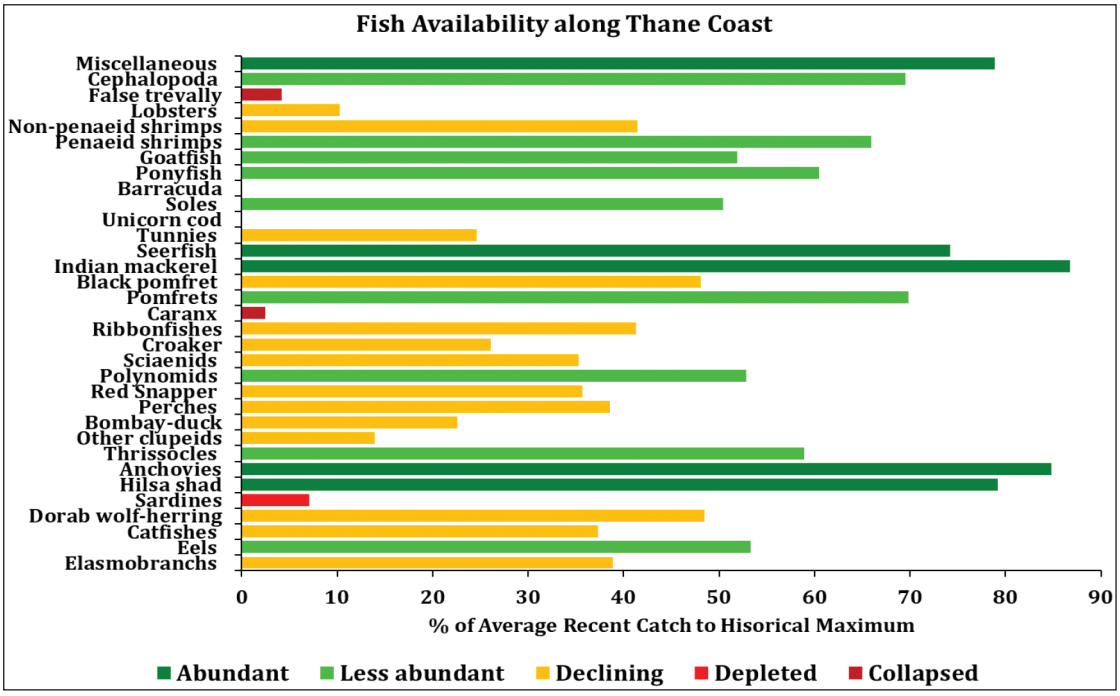

Fig. 3. *Fish availability classification along Thane-Palghar coast*

Fish availability classification of marine fishes along Mumbai coast

The fish catch availability classification of the marine fishes along the Mumbai coast is given in Fig. 4. As per the analysis, the anchovies, croaker, ribbonfish, caranx, barracuda and false trevally were observed abundant during the last three years whereas, catches of perches and unicorn cod observed collapse. The catches of eels, dorab wolf hearing, sardines, other clupeids, red snapper, sciaenid, black pomfret, Indian mackerel, pony fish, non-penaeid shrimps and lobsters were declining during the past three years. The remaining species groups were less abundant as their average last three years catch was between 50 to 70% of their respective historical maximum.

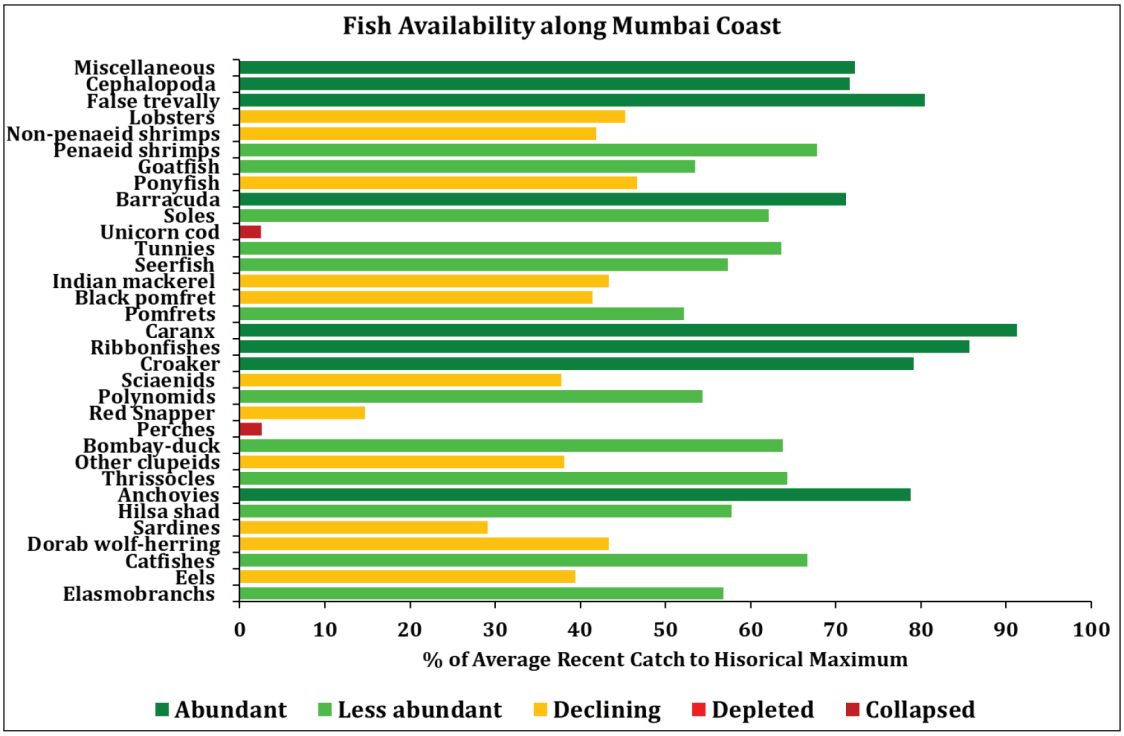

Fig. 4. *Fish availability classification along Mumbai coast*

Fish availability classification of marine fishes along Raigad coast

Along the Raigad coast, the availability of marine fishes was classified based on the percentage of recent average catch to the historical maximum of that particular species or species group. The analysis showed that the four species groups were clustered in the collapsed category namely eels, thrissocle, unicorn cod and barracuda as their recent average annual landing was less than 5% of their annual historical maximum catch. The availability of hilsa shad, croaker, black pomfret, tunnies, penaeid shrimps and cephalopods along the coast was abundant followed by less abundant class which included ribbon-fish, pomfrets, Indian mackerel, seerfish, soles and goatfish. The remaining species and species groups were observed declining in their annual landings along the Raigad coast. The detailed classification of the fish availability along the Raigad coast is depicted in Fig. 5.

Fish availability classification of marine fishes along Ratnagiri coast

Along the Ratnagiri coast, only cephalopods were found abundant among all the listed species and species groups of marine fishes. Other less abundant species were thrissocles, polynomids, pomfrets, tunnies and soles. The status of elasmobranchs, eels, red snapper and lobster was observed depleted whereas landings of sardines, other clupids,

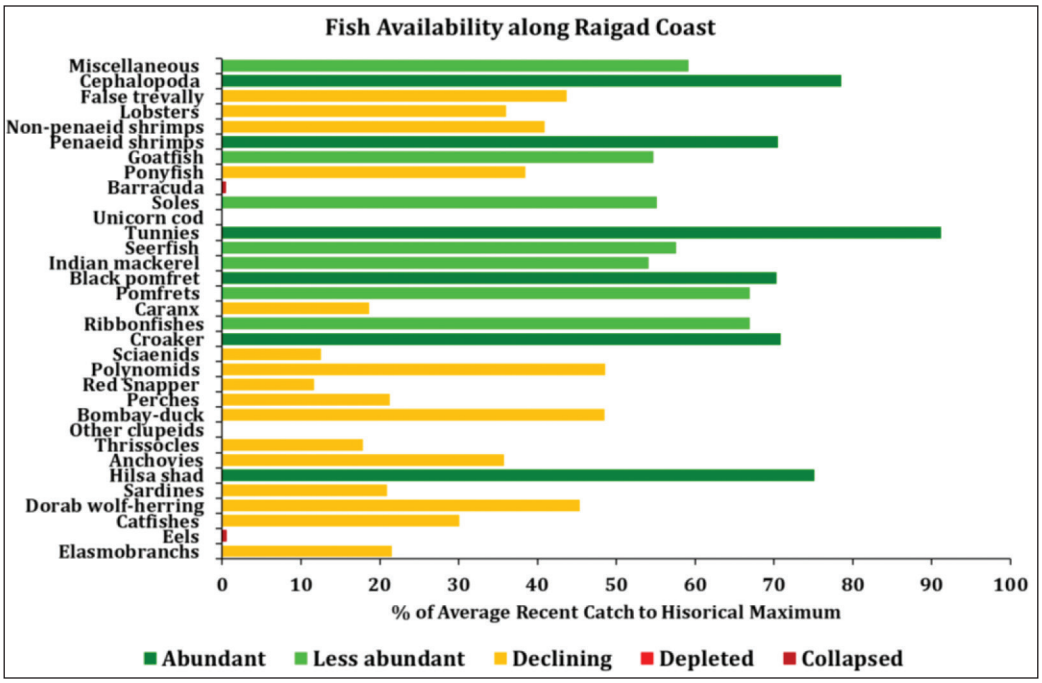

Fig. 5. *Fish availability classification along Raigad coast*

sciaenids and unicorn cod were collapsed during the past three years. All other species and species groups were grouped under the declining class because their average annual landings for the last three years were between 11 and 49% of respective annual historical maximum landings. The detailed classification of the fish availability along the Ratnagiri coast is depicted in Fig. 6.

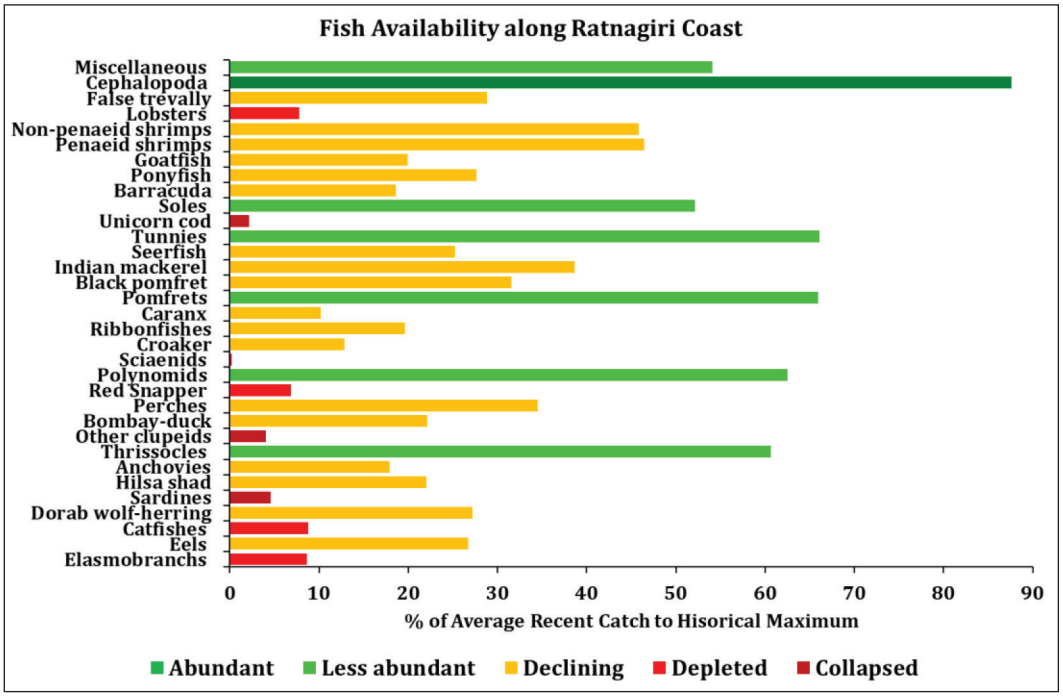

Fig. 6. *Fish availability classification along Ratnagiri coast*

Fish availability classification of marine fishes along Sindhudurg coast

The classification of fishes on the basis of their availability along the Sindhudurg coast during the last three years showed that a total of nine species groups were clustered under either collapsed or depleted classes. Under the collapsed category, anchovies, thrissocles, perches, tunnies, goatfish and non-penaeid shrimps were classified. Whereas dorab wolf hearing, ribbonfish and lobsters were observed to be depleted. Remaining all the groups were classified as declining because of their reduced recent annual catches. The detailed classification of the fish availability along the Sindhudurg coast is depicted in Fig. 7.

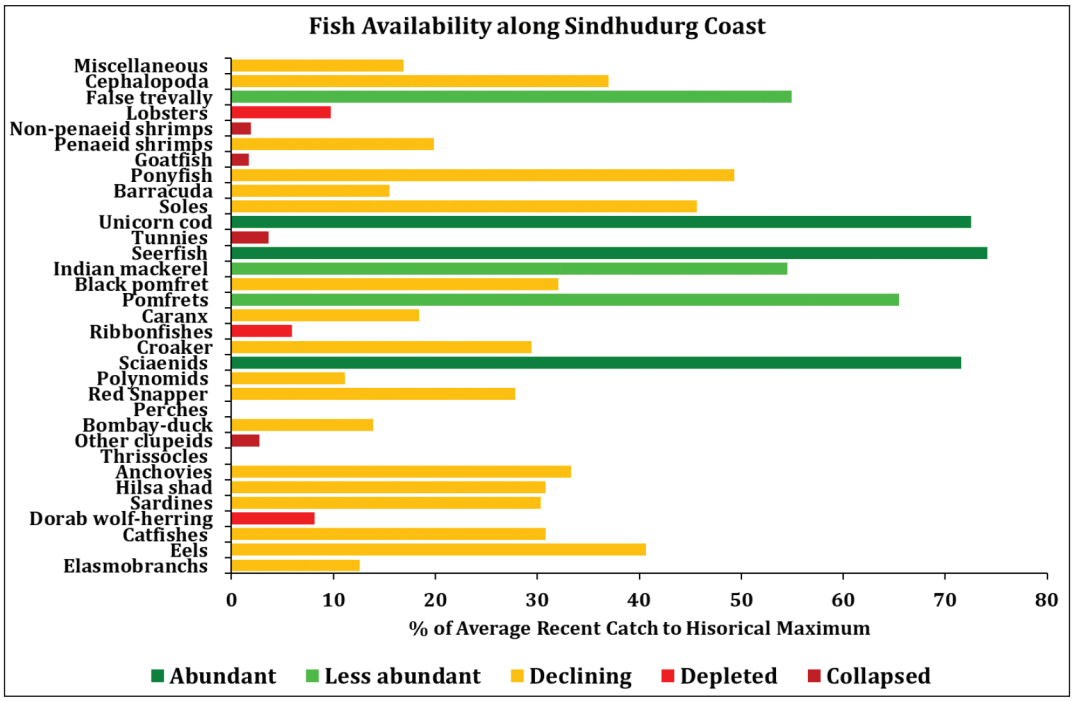

Fig. 7. *Fish availability classification along Sindhudurg coast*

The analysis of marine fish species across the districts of Maharashtra reveals crucial findings about the regional variations in species abundance and depletion (Tables 3, 4 and Fig. 8.). Among the 33 recorded species or species groups, Mumbai stands out with 63.64% of species categorized as abundant or less abundant, indicating a relatively healthier marine ecosystem. Conversely, the Thane-Palghar region has a lower proportion of species in these categories (42.42%), suggesting a less stable environment. The situation worsens further south, with Raigad, Ratnagiri, and Sindhudurg showing progressively fewer abundant or less abundant species at 39.39%, 21.21%, and 18.18%, respectively. Being the lowest among districts, the situation in Ratnagiri is particularly concerning, with only 3.03% of species falling under the abundant class. Additionally, both Ratnagiri and Sindhudurg have the highest percentages of species in the declining category at 54.55%, followed by Raigad (48.48%), Thane-Palghar (42.42%), and Mumbai (33.33%). This indicates a significant trend of declining marine fish populations across these regions. The southern districts are in a critical state, with Sindhudurg showing 27.27% of species as depleted or collapsed and Ratnagiri at 24.24%. These percentages were notably lower in the northern districts, with Thane-Palghar at 15.15%, Raigad at 12.12%, and Mumbai at 6.06%. This stark contrast highlights the urgent need for targeted conservation efforts, especially in the southern regions where marine ecosystems are under severe stress.

The historical references regarding catch-based fish stock status are also available. Alagaraja *et al.*

Table 3. *District-wise and overall fish availability classification along Maharashtra coast*

Sr. No.	Species/Species group	Thane-Palghar	Mumbai	Raigad	Ratnagiri	Sindhudurg	Overall Maharashtra
1	Elasmobranchs						
2	Eels						
3	Catfishes						
4	Dorab wolf-herring						
5	Sardines						
6	Hilsa shad						
7	Anchovies						
8	Thrissocles						
9	Other clupeids						
10	Bombay-duck						
11	Perches						
12	Red Snapper						
13	Polynemids						
14	Sciaenids						
15	Croaker						
16	Ribbonfishes						
17	Caranx						
18	Pomfrets						
19	Black pomfret						
20	Indian mackerel						
21	Seerfish						
22	Tunnies						
23	Unicorn cod						
24	Soles						
25	Barracuda						
26	Ponyfish						
27	Goatfish						
28	Penaeid shrimps						
29	Non-penaeid shrimps						
30	Lobsters						
31	False trevally						
32	Cephalopods						
33	Miscellaneous						

Category	Abundant	Less Abundant	Declining	Depleted	Collapsed
Colour Code					

Table 4. *Percentage share of fish species/species groups along Maharashtra coast in different abundance classes*

Region	Species / Species group percentage				
	Abundant	Less abundant	Declining	Depleted	Collapsed
Maharashtra	33.33	30.30	30.30	3.03	3.03
Thane-Palghar	15.15	27.27	42.42	3.03	12.12
Mumbai	24.24	36.36	33.33	0.00	6.06
Raigad	18.18	21.21	48.48	0.00	12.12
Ratnagiri	3.03	18.18	54.55	12.12	12.12
Sindhudurg	9.09	9.09	54.55	9.09	18.18

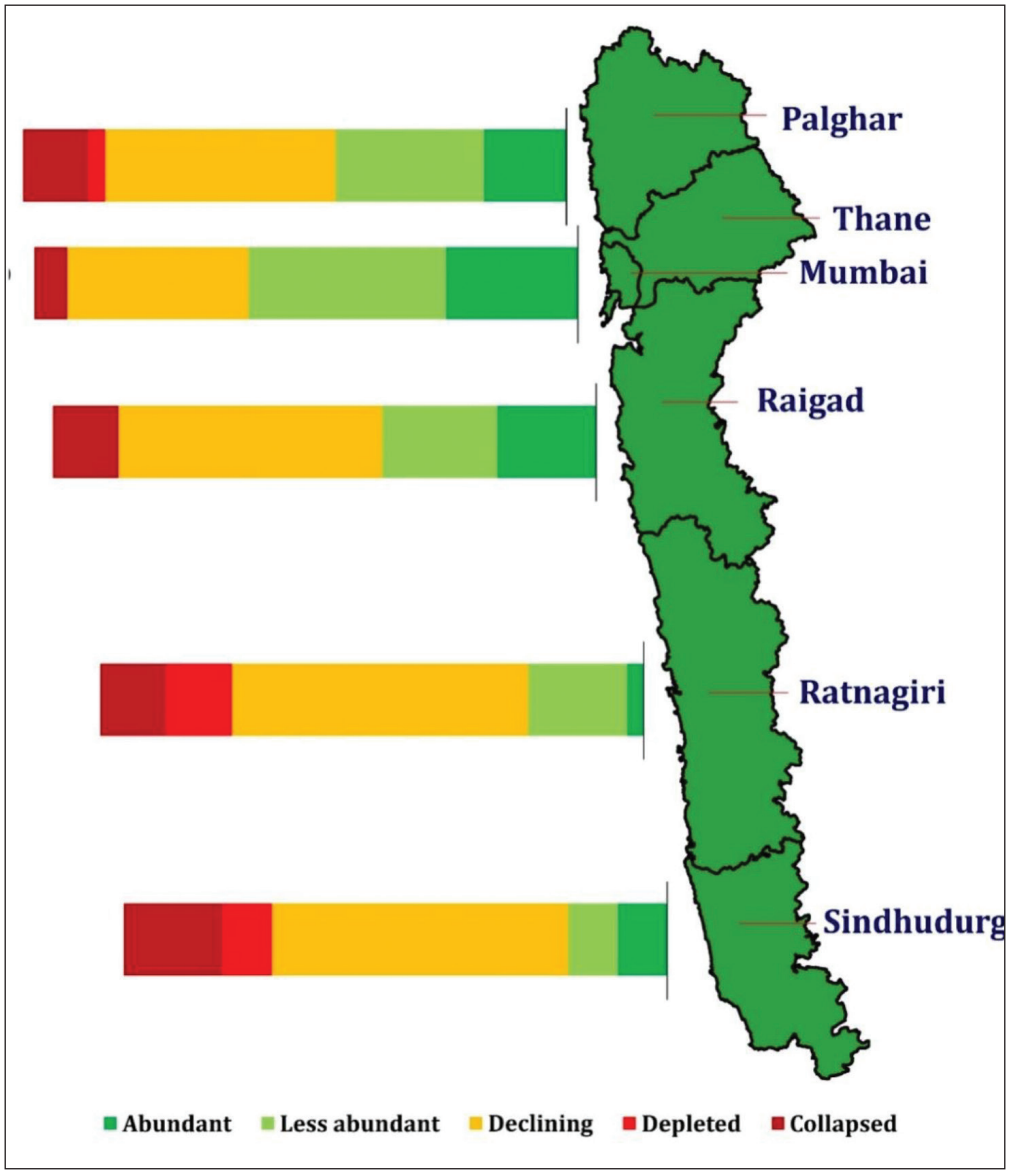

Fig. 8. *Percentage contribution of different abundant classes of marine fish landings along Maharashtra coast*

(1982) provided a historical perspective on marine fish landings in India, highlighting the multispecies nature of Indian fisheries and the varying trends between shrimp, pelagic, and demersal fisheries. Their analysis from 1969 to 1977 revealed a significant increase in shrimp landings, which contrasted with a decline in pelagic fish landings. This study emphasizes the dynamic nature of fishery resources and the need for adaptive management strategies. Sathianandan *et al.* (2011) further categorize Indian marine fishery resources into five groups: abundant, less abundant, declining, depleted, and collapsed. Their study, based on data from 1950 to 2010, revealed that a majority (73%) of the assessed resources are in a healthy state, but also identified critical groups that require management interventions. For instance, elasmobranchs, threadfins, and ribbon fishes were less abundant, while whitefish and unicorn cod were in declining and collapsed states, respectively. This highlights the importance of continuous monitoring and tailored conservation measures. Sathianandan *et al.* (2021) assessed the status of marine fish stocks in India, revealing that only five stocks were sustainable, one was experiencing overfishing, nine were in recovery, and 13 were overfished along the Maharashtra coast. The overfished species included black pomfret, catfishes, crabs, Indian mackerel, little tunny, lizardfishes, oil sardine, other clupeids, other perches, penaeid prawns, scads, soles, and thryssa along the Maharashtra coast. The findings of the current study are also consistent with those of Sathianandan *et al.* (2021), showing that species like black pomfret, catfishes, Indian mackerel and thrissocles are less abundant, while Indian oil sardine catches are declining and fish from the 'other clupeids' group are found to be depleted. The Unicorn cod is classified under the collapsed category. Prathibha *et al.* (2024) also mentioned that the Unicorn cod landings were primarily confined to Maharashtra, with some also occurring in Gujarat. As is common with small pelagic species, the landings have shown significant fluctuations over the years, with a sharp decline observed since 2012. Mohamed *et al.* (2010) focussed on the southwest coast of India, analysing species-wise and gear-wise catch data from Kerala and Karnataka. They highlighted that 37% of species in Kerala were abundant or less abundant, while 47% were in a declining state. Similarly, in Karnataka, 32% of species are healthy, but 55% are declining. Specific species such as whitefish, silver pomfret, and catfish are identified as depleted or collapsed, indicating significant regional declines. The study emphasised the importance of region-specific management plans to sustain the fishery in the area. Kolhe (2018) provides a detailed analysis of marine fish landings at Mirkarwada landing center in Ratnagiri from 1999 to 2017. His findings reveal that 60% of species in Ratnagiri were in a critical state, with significant portions in the declining, depleted, or collapsed categories. Species such as hilsa, perches, and red snapper were among those most affected. This detailed regional study sheds light on the alarming situation in Ratnagiri and the need for immediate conservation action.

Overall, the analysis of marine fish species in Maharashtra reveals a pressing need for targeted conservation efforts, particularly in the southern districts. Historical and comparative studies reinforce the dynamic nature of fisheries and the necessity of adaptive and region-specific management strategies to ensure the sustainability of marine fish resources. Continuous monitoring, effective management interventions, and tailored conservation plans are crucial to addressing the challenges faced by these marine ecosystems.

Ensuring the sustainability of species-specific marine fisheries along the Maharashtra coast requires a comprehensive strategy that integrates biological, socio-economic, and regulatory measures. Setting size and catch limits for key species can help prevent overfishing and allow fish populations to recover. Seasonal fishing bans and the establishment of marine protected areas (MPAs), especially in breeding and nursery zones, can further support the regeneration of depleted stocks. Gear restrictions, such as prohibiting harmful trawl nets in certain areas and encouraging sustainable fishing methods like hook-and-line or gillnet fishing, can minimize by catch and protect habitats. Community-based co-management practices that involve local fishers in resource management are crucial for ensuring compliance and tailoring management strategies to regional ecological and social conditions. Continuous monitoring through fishery-independent surveys and analysis of catch data is vital for adaptive management, enabling rapid adjustments to regulations based on the condition of fish stocks. Educating fishers

and building their capacity can also promote sustainable fishing practices. Combining traditional knowledge with scientific insights can improve the understanding of ecosystem changes and guide decision-making. Technological tools such as satellite tracking for migratory species and electronic logbooks for data collection can enhance enforcement and resource management. Support from governmental and non-governmental organizations in research, funding, and policy development is also key to implementing effective conservation initiatives. Adopting this comprehensive approach is critical for achieving long-term sustainability of marine fisheries in Maharashtra.

As suggested by Anulekshmi *et al.* (2018), monitoring and recognising the catch as juvenile fishing or below MLS specifically forspecies which are declining, depleted or collapsed category at sea or in the landing centre requires urgent attention. The fishers are to be encouraged for participatory research and fisheries management responsibilities where they must share information with researchers about the regions of high juvenile fish aggregations on a temporal and spatial scale. This will help in protecting such fishing grounds which will ensure the recovery of the fish belonging to declining, depleted or collapsed status.

CONCLUSION

In conclusion, the comprehensive analysis of marine fish availability along the Maharashtra coast emphasized significant regional disparities in species abundance and depletion. While Mumbai showed a relatively healthier situation with a higher percentage of species categorized as abundant or less abundant, the southern districts, particularly Ratnagiri and Sindhudurg, were in a critical state with a high proportion of species in declining, depleted, or collapsed categories. Historical data and comparative studies highlighted the dynamic nature of fishery resources and the necessity for adaptive management strategies tailored to specific regional needs. The significant declines in fish populations, particularly in the southern regions, signal an urgent need for targeted conservation efforts. Continuous monitoring, effective management interventions, and tailored conservation plans are essential to restore and sustain the marine ecosystems along the Maharashtra coast. These efforts are crucial to mitigate the adverse effects of over fishing and environmental changes, ensuring the long-term sustainability of marine fish resources for future generations.

CONFLICTS OF INTEREST

We declare that the authors do not have any conflict of interest.

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