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Fin Fish Diversity of Dholai Fishing Harbour, Gujarat, India

Princekumar D. Tandel [a], H. K. Kardani [b*], R. V. Borichagar [a], Gautam Bhatti [a] and C. Abhinesh [a]

[a] Department of Fisheries Resource Management, College of Fisheries Science, Kamdhenu University, Veraval, Gujarat, India.
[b] Fisheries Research Station, Kamdhenu University, Sikka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

This study aimed to assess the finfish diversity landed at Dholai Fishing Harbour, Gujarat, India, from September 2025 to April 2026. Fishery-independent data, including fish samples, landing observations and catch-related metrics, were gathered from trawlers and gillnetters using a randomised sampling strategy. To ensure data accuracy and establish a reliable average, approximately 10 boats were sampled per trip, with data collection conducted in three replications per month. Species identification was performed using morphometric, meristic and external diagnostic characters, supported by standard taxonomic keys and online databases. A few species were dissected for species confirmation. A total of 120 finfish species belonging to 96 genera, 60 families and 22 orders were recorded during the study period. The recorded diversity included 14 species of Elasmobranchii distributed across 13 genera, eight families and five orders, and 106 species of Teleostei distributed across 83 genera, 52 families and 17 orders. The trawl catch was grouped into 26 finfish categories, with mackerels, groupers, tongue soles, croakers, rays, seabreams, snappers, sharks, threadfin breams, catfishes, threadfins, flatheads, eels and barracudas forming important components. Small croaker

**Corresponding author: Email: hiteshkardani@gmail.com;*

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(≈897 kg/trip/boat), catfish (≈554 kg/trip/boat), miscellaneous species (≈530 kg/trip/boat) and big croaker (≈498 kg/trip/boat) were the dominant groups among the 26 major fish groups landed at Dholai. Gillnet landings included commercially important species such as *Tenualosa ilisha*, *Eleutheronema tetradactylum* and *Scomberomorus commerson*. Monthly Shannon diversity ranged from 1.737 in April 2026 to 2.273 in December 2025, while Margalef richness ranged from 1.890 in November 2025 to 2.359 in December 2025. Evenness varied from 0.584 in April 2026 to 0.763 in September 2025. Most fish landings are transported to fish processing units in Bombay or Veraval, while a proportion of the landing is sold locally in fresh or iced condition. The findings provide a baseline benchmark dataset on the composition and seasonal pattern of finfish landings and the family-wise contribution of various fish groups at Dholai Fishing Harbour. These data may support ecological monitoring and the formulation of sustainable, data-driven fisheries management policies along the Gujarat coast. The dominance of predatory fishes may help marine biologists monitor the health of the local food web and track shifting migration patterns along the Arabian Sea. The study may also help fisheries managers implement species-specific mesh-size regulations, particularly for gillnetters.

Keywords: Finfish diversity; Dholai Fishing Harbour; Gujarat coast; trawl catch; gillnet landings; relative abundance; species occurrence; Shannon diversity; Margalef richness; Pielou evenness; trophic status; conservation status.

1. Introduction

Biodiversity is broadly defined as the variety and abundance of life within a given area. The Indian peninsula is bounded by oceanic waters along more than half of its perimeter, with the Arabian Sea to the west, the Bay of Bengal to the east and the Indian Ocean to the south. This geographical configuration provides an extensive coastline of 11,098.81 km (SoI, 2025, 2024b), characterised by highly productive, nutrient-rich waters and heterogeneous ecosystems that support a wide range of marine micro- and macrofauna. Within these marine environments, thousands of fish species exhibit distinct morphological, behavioural and ecological traits. Investigation of ichthyofaunal diversity enables researchers to identify patterns in species richness, spatial distribution and overall ecosystem structure. Furthermore, biodiversity assessments facilitate the discovery of novel or poorly documented species, thereby expanding the fundamental understanding of marine biology.

Documenting marine fish diversity is vital for evaluating the composition, function and sustainability of marine food webs. Beyond ecological value, these resources have substantial socio-economic and cultural importance. A diverse array of fish species sustains both commercial and artisanal fisheries, secures the livelihoods of millions of coastal residents, supports regional nutritional security and preserves traditional coastal heritage. Consequently, a comprehensive understanding of species distribution patterns is a cornerstone for developing balanced policies that align ecological conservation with socio-economic requirements (FAO, 2020). Moreover, biodiversity research provides an empirical baseline for conservation and resource management. Under escalating anthropogenic threats, including overfishing, pollution, habitat degradation and climate change, species-richness and abundance datasets offer critical reference points for monitoring temporal shifts in community structure. These baseline metrics are therefore essential for identifying vulnerable or declining populations and designing robust conservation frameworks, such as marine protected areas and adaptive fisheries regulations (IUCN, 2026).

Recent fish-diversity assessments also indicate that local inventories can be strengthened when species lists are linked with abundance, occurrence and ecological-index data. For example, Patel et al. (2025) documented ichthyofaunal diversity from Gavier Lake in Surat, whereas Ndiaye et al. (2026) applied species richness, relative abundance, frequency of occurrence, Shannon-Weaver diversity and Pielou evenness to evaluate lake fish assemblages.

Finfish documentation on the southern coasts of Oman, bordering the north-western coast of the Arabian Sea and the Indian Ocean, recorded a total of 1,016 shore and deep-sea fish species representing three classes and 30 orders, belonging to 507 genera within 161 families (Jawad et al., 2021).

Landing-based fishery assessment of Indian fishery stocks is carried out by ICAR-CMFRI. As per FRAEED-CMFRI -2025, the resource assessment estimated landings at 3.45 million tonnes (t) in 2024, reflecting a 2% decline from 3.53 million t in 2023. Gujarat retained its top position in fish landings with 7.54 lakh t, despite an

8% decline, contributing approximately 22% of total landings. Tamil Nadu, West Bengal and Maharashtra recorded notable increases, with Maharashtra experiencing the highest growth of 47% compared with the previous year. The valuation of these landings reached ₹62,702 crores at landing centres and ₹90,104 crores at retail markets, indicating notable growth from the previous year (FRAEED-CMFRI -2025).

Kosygin et al. (2024) reported that India hosts 3,523 fish species spanning 1,097 taxa, 272 families and 55 orders, representing approximately 9.7% of global ichthyofaunal diversity. Within this assemblage, roughly 2,443 species are marine fishes, accounting for 75.6% of the nation's total fish diversity. More recently, Sreeraj et al. (2025) documented an updated checklist comprising 3,967 fish species belonging to 1,197 genera, 287 families and 60 orders. Regionally, Tamil Nadu exhibits the highest fish diversity, with 1,919 species, followed by the Andaman and Nicobar Islands (1,544 species) and Kerala (1,202 species). Notably, of the total species recorded in this recent inventory, 2,173 are restricted exclusively to marine environments.

Taxon-focused syntheses further support the need for updated order-level and habitat-linked checklists, including recent reviews of Indian flatfishes and clupeiform fishes that emphasise distribution, conservation status and fishery relevance across Indian waters (Pillai & Dutta, 2024; Pillai et al., 2026).

Singh et al. (2021) investigated the ichthyofaunal diversity of Sutrapada, Gir Somnath district, Gujarat, for three years, from June 2015 to June 2018, through the analysis of fish catch data from trawl fisheries and archives of the Fisheries Department, Central Institute of Fisheries Technology-Central Marine Fisheries Research Institute (ICAR-CMFRI), Marine Products Export Development Authority and the Fisheries Department, Veraval, Gujarat. During the study period, 114 fish species belonging to 55 families and 93 genera were identified.

In the Gulf of Kachchh, Gujarat, Parmar et al. (2023) documented the marine ichthyofaunal diversity along the Sikka coast, located on the northern coast of the Gulf of Kachchh. During the study, a total of 102 fish species belonging to two classes, 22 orders, 53 families and 72 genera were recorded from November 2021 to April 2022. The highest number of species was recorded from the family Carangidae, followed by Mugilidae and Sparidae. Of the 102 species, 97 were classified as Least Concern or Data Deficient in the IUCN Red List, three were Vulnerable and two were Near Threatened. Among the recorded species, 64% were carnivores, 21% were herbivores or planktivores and the remaining species were omnivores.

Borichangar et al. (2022) documented 136 finfish and shellfish species belonging to 63 families and 23 orders from Dholai Fishing Harbour during 2016-2020. In their study, the order Acanthuriformes (33 species) outnumbered all other orders, followed by Carangiformes (26 species), Decapoda (17 species), Clupeiformes (11 species), Perciformes (9 species) and Scombriformes (7 species). Additionally, they recorded Siluriformes and Tetraodontiformes (four species each), Beloniformes (three species), Carcharhiniformes, Myliobatiformes, Anguilliformes, Atheriniformes, Aulopiformes, Centrarchiformes, Elopiformes and Syngnathiformes (two species each), while the remaining orders were represented by a single species each. Reports from this harbour also include *Sphyraena fosteri*, *Rhizoprionodon acutus*, *Chiloscyllium arabicum*, *Mierspenaeopsis hardwicki* and *Chiloscyllium griseum* (Borichangar et al., 2023; Parmar et al., 2023; Bharda et al., 2024; Borichangar et al., 2024a, 2024b). Additional reports include *Roa jayakari*, *Muraenesox bagio*, *Parapenaeopsis coromandelica* and *Paraplagusia bilineata* from Dholai Fishing Harbour (Borichangar et al., 2024c,2025; Borichangar et al., 2024).

Kuhada et al. (2025) documented 75 species belonging to 20 orders and 50 families from Veraval, including 62 species of finfish, 11 species of crustaceans and two species of cephalopods. Carangidae, Sciaenidae and Penaeidae were the dominant families.

Khilchi and Raval (2025) reported 113 fish species belonging to 60 families and 25 orders from different fish landing sites of the Mangrol fish landing centre, Gujarat, India, from September 2022 to March 2023. The checklist comprised three Critically Endangered, seven Near Threatened, 10 Data Deficient, six Endangered, 66 Least Concern, seven Vulnerable and 10 Not Evaluated species.

Bengani et al. (2025) compared variations in fish landing patterns, market operations, traded species and daily volume at Dholai fish harbour and Kakwadi-Danti fish landing station. Insufficient infrastructural amenities, including sanitation, cold storage and drainage, were highlighted as critical issues at both landing points. The research emphasised infrastructural upgrading, policy support and formalisation to ensure maximum efficiency and resilience in Gujarat's fish marketing systems.

Climate change, reflected in significant environmental changes such as warming, sea-level rise and shifts in salinity, oxygen and other ocean conditions, is expected to affect marine organisms and associated fisheries. A study by Wabnitz et al. (2018) suggests that up to 35% of initial species richness could disappear by 2090, with the greatest decline projected in the south-western Gulf (Saudi Arabia, Qatar and the UAE). It also projects that fish catch potential on the western side of the Gulf will decline, severely affecting Qatar and the UAE with declines exceeding 26%, while socio-economic data indicate that the fisheries of Bahrain and Iran are the most vulnerable to these climatic shifts.

A study on the Arabian Sea Large Marine Ecosystem (Palomares et al., 2021) suggests that industrial fisheries development in surrounding countries should not be promoted at the expense of small-scale, food-security and livelihood fisheries. Serious consideration should be given by all these countries to reducing and tightly controlling industrial fishing, both domestic and foreign, with particular emphasis on reducing or banning wasteful bottom trawl fisheries and assisting and empowering well-managed small-scale fisheries.

Recent evidence from the east coast of India also indicates that regional marine-fish inventories are useful for connecting biodiversity documentation with conservation and fisheries-management needs (Rout & Behera, 2025).

The industrial and artisanal sectors were equally important in India between 2000 and 2015. The main taxa recorded during this period were *Sardinella longiceps*, Sciaenidae, Carangidae and Trichiuridae. For such baseline data, fish fauna landed at various ports, their fishing grounds, seasonal availability and occurrence- or abundance-related data are crucial. Therefore, the present work was carried out.

1.1 Research Gap

Although previous studies have documented marine fish assemblages from Dholai and other Gujarat landing centres, available information remains insufficient for an updated, season-specific assessment of finfish landings that separately considers trawl and gillnet contributions, relative abundance, occurrence patterns, diversity indices, trophic structure and conservation status for the current fishing season.

1.2 Objectives

The objective of the present study was to document the finfish diversity landed at Dholai Fishing Harbour, Gujarat, during September 2025 to April 2026, to analyse monthly catch composition, relative abundance and occurrence patterns, and to generate baseline information on diversity indices, trophic status and conservation status to support future monitoring and fisheries-management studies.

2. Materials and Methods

2.1 Location of Research Work

This study was carried out at Dholai Fishing Harbour (20°44′20″N, 72°53′50″E), located at the mouth of the Ambika River estuary where it meets the Arabian Sea in Navsari district, Gujarat (Figure 1). As South Gujarat's largest operational fishing harbour, this major landing centre hosts a fleet of approximately 250 registered and actively operating fishing vessels.

2.2 Method Used

This finfish biodiversity assessment used a simple random sampling design. Specimen samples, catch data and visual observations were gathered from trawlers and gillnetters operating at Dholai Fishing Harbour. To ensure data accuracy and establish a reliable average, approximately 10 boats were sampled per trip. Sampling was conducted at 10-day intervals to comprehensively cover monthly landings, resulting in three trips and 30 sampled boats per month. On average, two to three groups of 30-35 trawler boats visit the harbour each week for landing. Hence, approximately 240-420 boats per month approach the harbour to unload catches and carry ice, fuel and other essential items. During the present study, approximately 30 boats/month (≈10% of total boats) were surveyed.

Fig. 1. Satellite View of Dholai Fishing Harbour

Gear selection depended on the vessel's dimensions, the season and the fishers' local ecological knowledge regarding species availability. Trawlers with an overall length of 15 metres deployed trawl gear. In contrast, gillnetters ranging from 7 to 13 metres in length used drift gillnets and bottom-set gillnets. These gillnets were constructed from polyamide nylon, either monofilament or multifilament, with mesh sizes ranging from 50 mm to 220 mm. In the case of trawl nets, fishing trip durations generally remain 12-13 days, compared with 1-3 days for gillnetters. Collected species were subsequently identified using morphometric and meristic characteristics, along with phenotypic attributes such as body shape, colouration and fin dimensions. Each species was photographed properly to show all key characteristics for identification and was grouped into specific fish groups (Fig. 2).

Taxonomic sorting relied on standard keys and databases, including the FAO Species Identification Sheets (Fischer & Bianchi, 1984), Commercial Sea Fishes of India (Talwar & Kacker, 1984), FishBase (Froese & Pauly, 2026) and WoRMS (WoRMS Editorial Board, 2026). For structured catch monitoring, species were classified into 26 representative finfish groups.

The relative abundance (RA) of each species and the probability of occurrence were calculated based on its contribution to the respective group for each month.

$$\text{Relative abudnace} = \frac{\text{Total No of individual of a specific specis group}}{\text{Total No of all individual group}} \times 100$$

The probability of occurrence was calculated using the following formula:

$$\text{Probability of occurrence} = p(A) = \frac{n(A)}{n(S)}$$

p(A) = probability of event A occurring
n(A) = number of successful outcomes (the number of ways the event can occur)
n(S) = total number of possible outcomes in the sample space

Various ecological indices were also calculated by considering all species groups, which included the different species landed at Dholai Fishing Harbour in different months, following the methods described by Shannon (1948), Pielou (1966) and Margalef (1958).

$$\text{Shannon} - \text{Diversity index (H')} = -\sum_{i-1}^{S} pi\ ln\ pi$$

Where;

H'= The Shannon Diversity Index value.
S = total number of fish species groups in the catch or community (species richness).
pi = proportion of individuals belonging to the i-th species group relative to the total population (pi = ni/N, where ni is the number of individuals in species group i, and N is the total number of individuals in all species groups).
ln = The natural logarithm (log base *e*).

$$\text{The Margalef Richness Index (d)} = \frac{S-1}{\ln(N)}$$

Where:

d = The Margalef Richness Index value.
S = total number of unique species groups identified in the sample.
N = total number of individual organisms collected across all species groups.
ln = The natural logarithm (log base *e*).

$$\text{Pielou's Eveneness index (J)} = \frac{H'}{H'_{max}} = \frac{H'}{\ln(S)}$$

Where:

J' = Pielou's Evenness Index value.
H' = The calculated Shannon Diversity Index value for the sample.
ln = The natural logarithm (log base e).
S = total number of unique species groups in the sample (species richness).

3. Results and Discussion

During the present study, a total of 120 species belonging to 22 orders, 60 families and 96 genera were documented. Among these, the class Elasmobranchii was represented by five orders, eight families, 13 genera and 14 species. Within Elasmobranchii, the order Myliobatiformes dominated with two families and six species, followed by Carcharhiniformes (two families and three species), Rhinopristiformes and Torpediniformes (two families and two species each), and Orectolobiformes (one family and one species).

The class Teleostei represented the highest species diversity, comprising 17 orders, 52 families, 83 genera and 106 species. Within Teleostei, the order Perciformes dominated with 14 families and 38 species, followed by Carangiformes (four families, 18 species), Scombriformes (four families, nine species), Clupeiformes (five families, eight species) and Pleuronectiformes (four families, six species). Additionally, Acanthuriformes and Tetraodontiformes were represented by five and four families, respectively, with five species each; Beloniformes and Siluriformes included three and one family, respectively, with three species each; Anguilliformes, Aulopiformes and Centrarchiformes each consisted of one family and two species; and

Apogoniformes, Elopiformes, Mugiliformes, Mulliformes and Ophidiiformes each comprised one family and one species.

Previously, finfish documentation at Dholai Fishing Harbour was carried out by Borichangar et al. (2022) over a five-year period from January 2016 to December 2020 using a random sampling method. They reported a total of 136 finfish and shellfish species belonging to 23 orders and 63 families. In their study, the order Acanthuriformes (33 species) outnumbered all other orders, followed by Carangiformes (26 species), Decapoda (17 species), Clupeiformes (11 species), Perciformes (9 species) and Scombriformes (7 species). Additionally, they recorded Siluriformes and Tetraodontiformes (four species each), Beloniformes (three species), Carcharhiniformes, Myliobatiformes, Anguilliformes, Atheriniformes, Aulopiformes, Centrarchiformes, Elopiformes and Syngnathiformes (two species each), while the remaining orders were represented by a single species each.

During the current study, the whole catch was divided into two types: (i) trawl catch composition and (ii) gillnetter catch composition. Monthly catch composition was recorded with biomass (catch).

3.1 Trawl Catch-composition

The composition of the catch landed by trawlers at Dholai Fishing Harbour was grouped into around 26 groups, consisting of more than 120 fish species and other catches, including shrimps, crabs, cephalopods and molluscs. These groups included mackerels (14), groupers (7), tongue soles (6), big/small croakers (6), rays (6), seabreams (5), snappers (4), sharks (4), threadfin breams (3), catfishes (3), threadfins (3), flatheads (2), eels (2), barracudas (2), and single species of ribbonfish (*Lepturacanthus savala*), Bombay duck (*Harpadon nehereus*), lizardfish (*Saurida tumbil*), silver pomfret (*Pampus argenteus*), black pomfret (*Parastromateus niger*), goatfish (*Upeneus moluccensis*), tiger-toothed croaker (*Otolithoides biauritus*), gold-spotted anchovy (*Coilia dussumieri*), lunar-tail bigeye (*Priacanthus hamrur*) and Coromandel ribbonfish (*Lepturacanthus pantului*).

3.2 Gill-netter Catch-composition

The gillnetter catch included 12 species, namely *Tenualosa ilisha*, *Eleutheronema tetradactylum*, *Scomberomorus commerson*, *Scomberomorus koreanus*, *Harpadon nehereus*, *Scoliodon laticaudus*, *Thryssa mystax*, *Pellona ditchela*, *Leptomelanosoma indicum*, *Chirocentrus nudus*, *Chirocentrus dorab* and *Pampus argenteus*, along with other miscellaneous catches, including shrimps, crabs, cephalopods and molluscs.

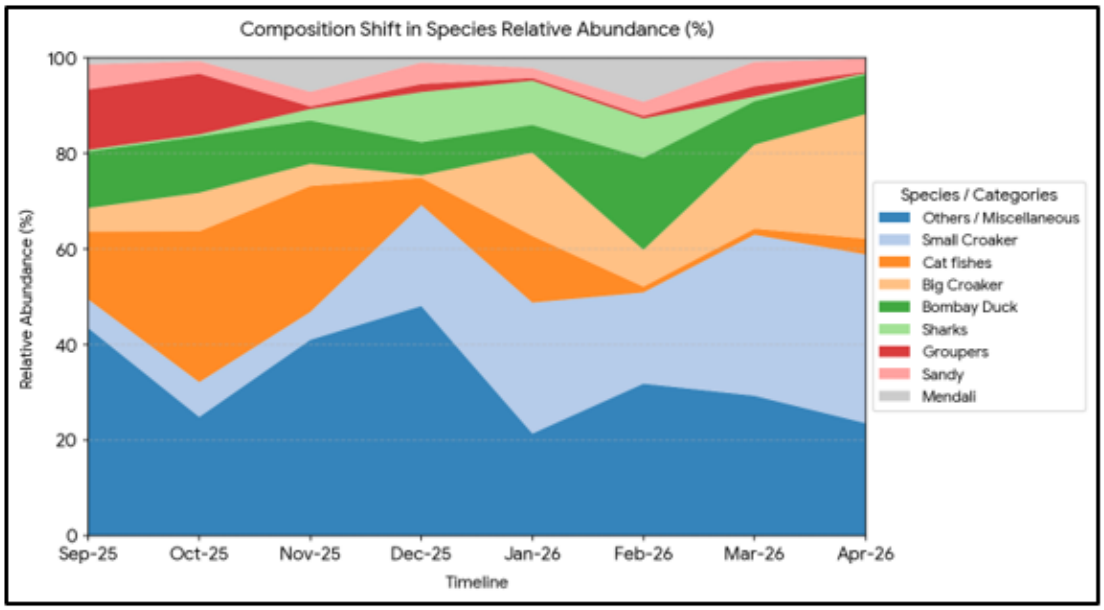

Chart 1. Composition shift in Relative Abundance (RA%) of Species/Categories

Table 1. Relative abundance (RA %) of fish groups contribution to total fish catch

Fish group	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26	Apr-26
Sharks	0.37	0.42	2.40	10.50	9.28	8.23	0.95	0.32
Rays	1.23	0.19	1.55	1.86	0.81	2.77	0.83	0.26
Groupers	12.64	12.75	0.54	1.68	0.53	0.54	2.16	0.26
Big Croakers	4.92	8.07	4.65	0.54	17.43	7.72	17.62	26.09
Small Croaker	6.01	7.30	5.83	21.15	27.43	19.10	33.73	35.33
Eels	4.78	2.03	3.63	4.40	1.28	0.99	0.65	0.36
Cat fishes	14.21	31.60	26.39	5.68	13.98	1.21	1.26	3.31
Snapper	0.30	0.12	0.20	0.22	0.44	0.59	0.34	0.26
Mackerel	0.94	0.32	0.04	4.73	0.54	0.12	2.27	0.94
Ribbon Fish	1.88	1.14	0.68	4.51	1.54	1.31	1.58	3.99
Bombay Duck	11.84	11.79	9.07	6.94	5.82	19.27	9.10	8.28
Flatheads	2.44	4.30	3.48	3.73	0.60	0.25	2.82	1.85
Threadfin bream	2.46	2.34	0.35	0.95	0.16	0.44	0.46	0.53
Tongue sole	5.57	3.55	1.51	0.77	0.26	0.34	0.50	0.73
Barracuda	2.82	0.12	0.09	0.94	1.08	0.15	0.15	0.49
Lizard fish	1.06	0.37	0.21	0.54	0.72	0.25	1.32	1.17
Pomfret	0.16	0.09	0.43	0.16	0.08	0.20	0.04	0.08
Black pomfret	0.06	0.05	0.04	0.04	0.04	0.05	0.10	0.04
Goat fish	1.78	0.13	0.06	1.79	0.58	1.90	0.96	0.62
Tiger toothed/Pama Croaker	5.58	4.33	6.07	2.05	1.17	6.57	0.60	0.14
Sea bream	0.20	0.15	0.16	0.64	0.04	0.33	0.12	0.04
Gold spotted anchovy	1.33	0.63	7.06	0.93	2.07	9.15	0.78	0.15
Lunar tail bigeye	1.01	0.38	5.96	3.63	0.47	0.86	1.32	0.31
Coromandel ribbonfish	2.01	0.03	0.13	0.25	1.45	2.88	3.04	0.21
Threadfins	5.23	2.62	3.07	4.51	2.11	2.97	5.13	2.73
Miscellaneous	9.17	5.18	16.40	16.86	10.10	11.82	12.18	11.52

Table 2. Group and month- wise occurrence (in %) at Dholai Fishing Harbour

Fish group/species	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26	Apr-26
Sharks	30	90	90	100	90	100	90	40
Rays	100	90	100	100	80	100	100	70
Groupers	100	90	70	50	70	40	70	50
Big Croakers	50	50	40	50	70	80	100	90
Small Croaker	40	40	40	40	70	60	100	80
Eels	100	80	90	100	100	100	100	100
Cat fishes	100	100	100	100	80	60	70	90
Snapper	100	60	100	100	60	100	90	100
Mackeral	40	80	60	50	70	40	70	60
Ribbon Fish	40	60	40	50	50	60	50	80
Bombay Duck	100	100	90	100	100	80	100	100
Flatheads	50	90	70	80	50	30	80	70
Threadfin bream	30	70	40	90	60	50	80	90
Tonguesole	60	90	60	100	80	80	90	80
Barracuda	50	20	40	100	80	40	40	80
Lizard fish	60	90	50	80	80	30	70	100
Pomfret	40	80	50	40	40	50	40	70
Black pomfret	60	70	70	70	20	30	30	80
Goat fish	70	30	30	90	90	90	90	80
Tiger toothed/Pama Croaker	60	100	90	80	50	100	70	70
Sea bream	40	30	50	60	40	30	50	20
Gold spotted anchovy	50	80	90	60	60	50	50	60
Lunar tail bigeye	50	60	40	100	100	70	90	60
Coromandel ribbonfish	70	30	30	50	60	40	60	60
Threadfins	100	100	100	100	90	80	70	100
Miscellaneous	100	100	100	100	100	100	100	100

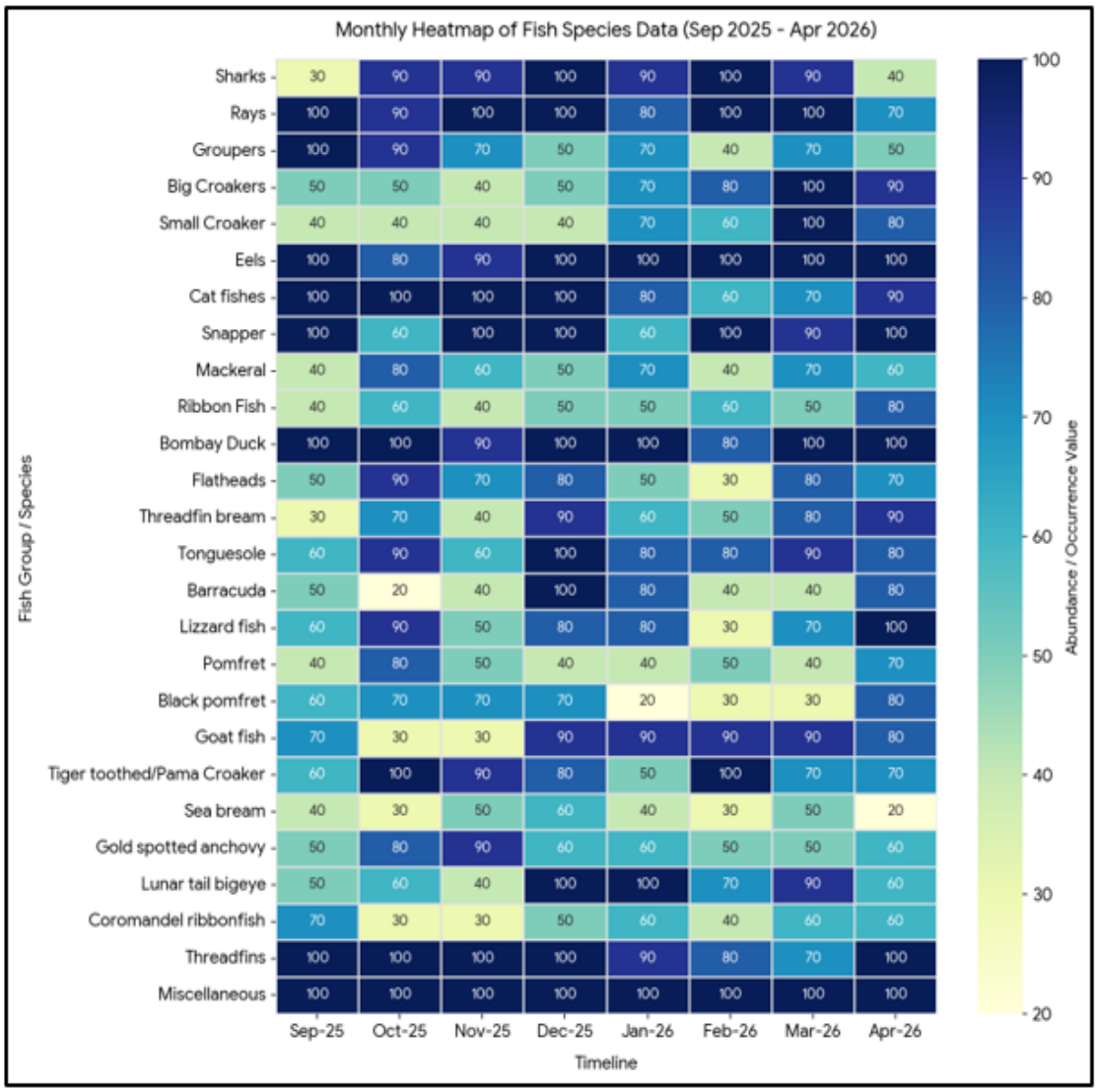

Chart 2. Monthly occurrence of Species/ Category

The relative abundance (RA %) of each species was calculated according to its contribution to the respective groups, combining landing data from both trawl and gillnetter catches. Changes in RA are described in Table 1, and the pictorial representation is depicted in Chart 1.

The occurrence of each fish group was analysed at monthly intervals and is represented in Table 2, with a pictorial representation depicted in Chart 2.

Different diversity indices, such as the Shannon diversity index, equitability and Margalef richness index, were also calculated by considering all species groups, including all different species landed by trawlers and gillnetters at Dholai Fishing Harbour in different months (Table 3).

The Shannon diversity index for the entire study period (September 2025 to April 2026) ranged between 1.737 (April 2026) and 2.273 (December 2025), and Margalef's species richness index varied between 1.890 (November 2025) and 2.359 (December 2025) throughout the fishing season. Similarly, monthly species evenness during the study period varied between 0.584 (April 2026) and 0.763 (September 2025).

The trophic level of all reported fish species was noted using FishBase (Table 4). The results show dominance of higher trophic levels (carnivores and predators: 112 species) (Chart 3).

Table 3. Diversity, Abundance, Evenness indices at Dholai Fishing Harbour

Month	Taxa	Individual	Shannon Diversity Index	Equitability	Margalef richness
Sep.-25	16.9	2218.1	2.141	0.763	2.076
Oct.-25	18.8	3794	1.928	0.659	2.179
Nov.-25	17.3	5761.8	1.899	0.674	1.890
Dec.-25	20.4	5778.6	2.273	0.757	2.359
Jan.-26	18.4	5846.8	1.772	0.609	2.050
Feb.-26	16.9	2014.1	1.893	0.678	2.169
Mar.-26	19.5	3835.9	1.876	0.632	2.312
Apr.-26	19.8	5464	1.737	0.584	2.232

The following observations were made from the study:

The trophic status of the recorded fish describes a distinct aquatic community characterised by an inverted trophic structure, where the ecosystem is dominated by top-level consumers. Of the 120 total species documented, apex predators with trophic levels between 4.0 and 4.5+ make up the largest portion of finfish diversity, accounting for approximately 45% of the community. When apex predators are combined with mid-level and top-level carnivores, the system shows a high carnivorous representation of 112 species, indicating that roughly 93.3% of the recorded fish diversity relies on a meat-based diet.

In contrast, the lower levels of the food web are sparsely represented within this finfish community. Primary consumers operating at trophic levels of 2.0 to 2.49 and secondary consumers at levels of 2.5 to 2.99 were represented by only four species in each category. Together, these lower-trophic groups accounted for 6.7% of total species diversity, indicating a top-heavy trophic pattern in the landed catch.

The community exhibited a progressive increase in species richness at higher levels of the food chain, creating an inverted diversity pyramid. This top-heavy structure is reflected by the increasing number of species at each ascending trophic tier. Specifically, the ecosystem transitions from four primary consumer species and four secondary consumer species to 24 mid-level carnivores, ultimately peaking at 34 top-level predator species.

Diversity indices show that December 2025 represented the most diverse and evenly distributed month of the study period. During this period, the ecosystem recorded its highest taxonomic count (20.4), highest Shannon diversity (2.273) and highest Margalef richness (2.359). This peak was also supported by high equitability (0.757), indicating that individuals were well distributed among the available taxa rather than concentrated in a few species. Although the high-density winter months of November and January each exceeded 5,700 individuals, February 2026 marked a community contraction. Total individuals decreased by more than 65% to a period low of 2,014.1, accompanied by a decrease in taxonomic richness to 16.9. Despite this decrease, the remaining community maintained relatively stable equitability (0.678), suggesting that the population reduction affected most species groups relatively evenly rather than removing specific groups. As the study transitioned into spring, a clear ecological shift occurred. By April 2026, total abundance increased to 5,464 individuals across a high number of taxa (19.8). However, this population increase coincided with the lowest Shannon diversity (1.737) and lowest equitability (0.584) of the study period, suggesting that one or a few dominant species contributed strongly to the catch composition and reduced overall community balance.

The trophic structure of the fish reported in the study confirms the complexity of the food web structure in the catch area and indicates abundant prey availability. A habitat capable of supporting 54 apex predator species and 34 top-level carnivore species suggests a productive ecosystem with a diverse lower-trophic forage base, including invertebrates, plankton or smaller fish, which may not be fully represented by the finfish categories alone.

The IUCN status of the reported fish indicates that most recorded fish species were classified as Least Concern, accounting for 81.67% of the total, while 4.17% were Data Deficient and require biological surveys to better understand their conservation status. Among the recorded species, 8.33% were threatened with extinction. Species-specific management, fishing regulations or habitat restoration should therefore target these species (Chart 4).

All reported ichthyofaunal diversity at Dholai Fishing Harbour is presented in Table 4.

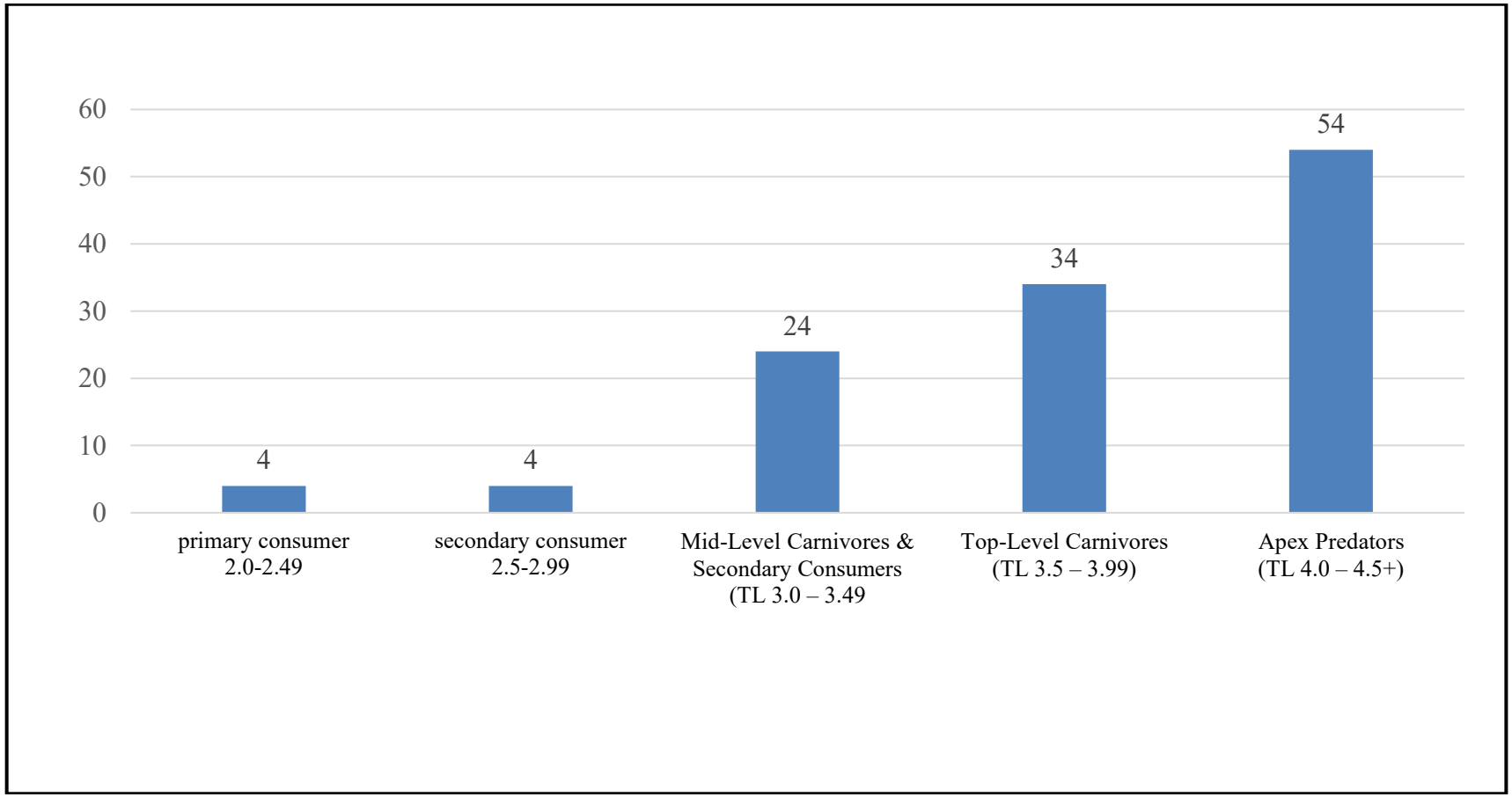

Chart 3. Trophic status of recorded fish

Table 4. Ichthyofaunal Biodiversity of Dholai fishing harbour

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
1	Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Rhizoprionodon acutus* (Rüppell, 1837)	Milk shark	Shingada, khagi	(VU)	4.2
2			Carcharhinidae	*Scoliodon laticaudus* Müller & Henle, 1838	Spadenose shark	musi, magra	(NT)	4.1
3			Sphyrnidae	*Sphyrna mokarran* (Rüppell, 1837)	Hammerhead Shark		(CR)	4.5
4		Myliobatiformes	Aetobatidae	*Aetobatus narinari* (Euphrasen, 1790)	Spotted eagle ray	Tabla	(EN)	3.8
5			Dasyatidae	*Brevitrygon imbricata* (Bloch & Schneider, 1801)	Scaly whipray	Tabla,	(DD)	3.5
6			Dasyatidae	*Brevitrygon walga* (Müller & Henle, 1841)	Dwarf whipray	Tabla,	(NT)	3.5
7			Dasyatidae	*Himantura undulata* (Bleeker, 1852)	Leopard whip ray	Tabla	(EN)	3.7
8			Dasyatidae	*Maculabatis gerrardi (Gray, 1851)*	Sharpnose whipray	Tabla	(VU)	3.6
9			Dasyatidae	*Pateobatis uarnacoides* (Bleeker, 1852)	Bleeker's whipray	Tabla	(VU)	3.36
10		Orectolobiformes	Hemiscylliidae	*Chiloscyllium arabicum Gubanov, 1980*	Arabian carpet shark	Magru	(NT)	3.9
11		Rhinopristiformes	Rhinidae	*Rhina ancylostomus* Bloch & Schneider, 1801	Bowmouth guitarfish		(CR)	3.8
12			Rhinidae	*Rhynchobatus laevis* (Bloch & Schneider, 1801)	Smoothnose wedgefish	Magru	(CR)	3.9
13		Torpediniformes	Narkidae	*Narke dipterygia* (Bloch & Schneider, 1801)	Numbray (Electric ray)	Tabla	(DD)	3.4
14			Torpedinidae	*Torpedo marmorata* Risso, 1810	marbled electric ray	Tabla,	(DD)	4.0
15		Acanthuriformes	Drepaneidae	*Drepane punctata* (Linnaeus, 1758)	Spotted sicklefish		(LC)	3.3
16			Ephippidae	*Platax teira* (Forsskål, 1775)	Longfin spadefish		(LC)	2.8
17		Acanthuriformes	Lobotidae	*Lobotes surinamensis* (Bloch, 1790)	Atlantic tripletail		(LC)	4.0
18			Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat	Chaapka	(LC)	2.3
19			Siganidae	*Siganus luridus* (Rüppell, 1829)	Dusky spinefoot		(LC)	2.0

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
					(Rabbitfish)			
20	Teleostei	Anguilliformes	Muraenesocidae	*Congresox talabonoides* (Bleeker, 1853)	Indian pike conger	Piri Vaam	(LC)	4.3
21			Muraenesocidae	*Muraenesox cinereus (Forsskål, 1775)*	Eel	Kari Vaam	(LC)	3.4
22		Apogoniformes	Apogonidae	*Ostorhinchus fasciatus* (White, 1790)	Broad-banded cardinalfish	pali	(LC)	4.4
23		Aulopiformes	Harpadontidae	*Harpadon nehereus (Hamilton, 1822)*	Bombay duck	Bumla	(LC)	4.4
24			Harpadontidae	*Saurida tumbil (Bloch, 1795)*	Greater lizardfish	Chor bumla / bhungar	(LC)	4.4
25		Beloniformes	Belonidae	*Ablennes hians (Valenciennes, 1846)*	Flat needlefish	Kagla, Kagda	(LC)	4.2
26			Exocoetidae	*Cheilopogon furcatus* (Mitchill, 1815)	Spotfin flyingfish		(LC)	3.1
27			Hemiramphidae	*Hemiramphus lutkei* Valenciennes, 1847	Lutke's halfbeak	Kaagda	(LC)	2.7
28		Carangiformes	Carangidae	*Alectis ciliaris* (Bloch, 1787)	African pompano		(LC)	3.8
29				*Alectis indica* (Rüppell, 1830)	Indian threadfish	Chandaliyo	(LC)	3.9
30	Teleostei			*Alepes kleinii* (Bloch, 1793)	Banded scad (Banded crevalle	Bangdi	(LC)	3.6
31				*Atropus atropos* (Bloch & Schneider, 1801)	Cleftbelly trevally	Bangada	(LC)	3.7
32				*Caranx heberi* (Bennett, 1830)	Blacktip trevally	Bangada	(LC)	4.1
33				*Caranx ignobilis* (Forsskål, 1775)	Giant trevally	Bangada	(LC)	4.4
34				*Caranx sexfasciatus* Quoy & Gaimard, 1825	Bigeye trevally	Bangada	(LC)	4.2
35		Carangiformes	Carangidae	*Decapterus russelli* (Rüppell, 1830)	Indian Scad	Bangda	(LC)	3.5
36				*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo Scad (Hardtail scad)	Bangada	(LC)	3.9
37				*Parastromateus niger* (Bloch, 1795)	Black pomfret	Halvo	(LC)	3.2
38				*Platycaranx chrysophrys* (Cuvier, 1833)	Longnose trevally	Bangada	(LC)	3.8
39				*Scomberoides commersonnianus* Lacepède, 1801	Talang Queenfish		(LC)	4.4

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
40	Teleostei	carangiformes	Carangidae	*Scomberoides tol* (Cuvier, 1832)	Queen fish		(LC)	4.1
41				*Scomberomorus commerson (Lacepède, 1800)*	Spanish mackrel	Surmai	(NT)	4.5
42				*Seriolina nigrofasciata* (Rüppell, 1829)	Black-banded trevally	Kariyo	(LC)	3.9
43			Coryphaenidae	*Coryphaena hippurus* Linnaeus, 1758	Mahi-Mahi		(LC)	4.4
44			Echeneidae	*Echeneis naucrates* Linnaeus, 1758	Live sharksucker (Remora)	Chusiyu	(LC)	3.8
45			Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	Cobia		(LC)	4.1
46		Centrarchiformes	Terapontidae	*Terapon jarbua* (Forsskål, 1775)	Target perch (Jarbua/Largescale)		(LC)	3.7
47				*Terapon theraps Cuvier, 1829*	Target perch (Jarbua/Largescale)		(LC)	3.5
48		Clupeiformes	Chirocentridae	*Chirocentrus dorab (Forsskål, 1775)*	Wolf herring	Daai	(LC)	4.5
49				*Chirocentrus nudus* Swainson, 1839	Wolf herring	Daai	(LC)	4.4
50			Dorosomatidae	*Anodontostoma chacunda* (Hamilton, 1822)	Chacunda gizzard shad		(LC)	2.1
51				*Tenualosa ilisha* (Hamilton, 1822)	Hilsa shad	Jaksi, pavla, modar,	(LC)	2.6
52			Dussumieriidae	*Dussumieria acuta* Valenciennes, 1847	Rainbow sardine	Nurza	(LC)	3.2
53		Clupeiformes	Engraulidae	*Coilia dussumieri* Valenciennes, 1848	Goldspotted grenadier anchovy	Mendli	(LC)	3.4
54				*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa	Taalar	(LC)	3.4
55			Pristigasteridae	*Pellona ditchela* Valenciennes, 1847	Indian pellona	Taalar	(LC)	3.5
56		Elopiformes	Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)	Indo-Pacific tarpon	Kaati	(DD)	4.1

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
57	Teleostei	Mugiliformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758	Grey mullet	boy	(LC)	2.1
58		Mulliformes	Mullidae	*Upeneus moluccensis (Bleeker, 1855)*	Goldband goatfish	Patta Rani	(LC)	3.6
59		Ophidiiformes	Brotulidae	*Brotula multibarbata* Temminck & Schlegel, 1846	Cusk-eel		(LC)	3.9
60		Perciformes	Epinephelidae	*Cephalopholis formosa* (Shaw, 1812)	Bluelined hind	Vekhali	(LC)	4.0
61				*Cephalopholis sonnerati* (Valenciennes, 1828)	Tomato hind	Vekhali	(LC)	4.1
62				*Epinephelus coioides(Hamilton, 1822)*	Orange-spotted grouper	Vekhali	(NT)	4.2
63				*Epinephelus diacanthus* (Valenciennes, 1828)	Spinycheek grouper	Vekhali	(LC)	4.0
64				*Epinephelus erythrurus* (Valenciennes, 1828)	Cloudy grouper	Vekhali	(LC)	4.0
65				*Epinephelus latifasciatus* (Temminck & Schlegel, 1842)	Striped grouper	Vekhalu	(LC)	4.1
66				*Epinephelus malabaricus* (Bloch & Schneider, 1801)	Malabar grouper	Vekhali	(LC)	4.3
67			Gerreidae	*Gerres filamentosus* Cuvier, 1829	Whipfin silver-biddy	Mosangi	(LC)	3.3
68			Haemulidae	*Diagramma pictum* (Thunberg, 1792)	Painted sweetlips		(LC)	3.5
69				*Plectorhinchus schotaf* (Forsskål, 1775)	Sombre sweetlips	Raja	(LC)	3.6
70				*Pomadasys furcatus* (Bloch & Schneider, 1801)	Banded grunter	Raja	(LC)	3.5
71				*Pomadasys maculatus (Bloch, 1793)*	Saddle grunt	Raja	(LC)	3.4
72			Lactariidae	*Lactarius lactarius* (Bloch & Schneider, 1801)	False trevally (whitefish)		(LC)	3.9
73			Lethrinidae	*Lethrinus nebulosus* (Forsskål, 1775)	Spangled emperor	Marghi machli	(LC)	3.9
74			Lutjanidae	*Lutjanus fulviflamma* (Forsskål, 1775)	Blackspot snapper (Dory snapper)	Raja	(LC)	4.0
75				*Lutjanus johnii* (Bloch, 1792)	Golden snapper	Raja	(LC)	4.1

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
76	Teleostei	Perciformes	Lutjanidae	*Lutjanus lemniscatus* (Valenciennes, 1828)	Yellowstreaked snapper	Raja	(LC)	4.0
77				*Lutjanus russellii* (Bleeker, 1849)	Russell's snapper	Raja	(LC)	3.9
78			Nemipteridae	*Nemipterus bipunctatus (Valenciennes, 1830)*	Delagoa threadfin bream	Raani	(LC)	3.5
79				*Nemipterus japonicus (Bloch, 1791)*	Japanese threadfin bream	Raani	(LC)	3.6
80				*Scolopsis vosmeri* (Bloch, 1792)	Whitecheek monocle bream	Raani	(LC)	3.4
81			Platycephalidae	*Grammoplites suppositus* (Troschel, 1840)	flathead	gokhar	(LC)	3.9
82				*Insidiator macracanthus* (Bleeker, 1869)	flathead	Gokhar	(LC)	3.8
83			Polynemidae	*Eleutheronema Tetradactylum* (Shaw, 1804)	Fourfinger threadfin	Raavas	(LC)	4.1
84				*Filimanus heptadactyla* (Cuvier, 1829)	Sevenfinger threadfin	Sandy	(VU)	3.7
85			Polynemidae	*Leptomelanosoma indicum* (Shaw, 1804)	Indian threadfin	Cheriyu	(LC)	4.1
86			Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)	Lunar tail bigeye	Lal	(VU)	3.8
87			Sciaenidae	*Daysciaena albida* (Cuvier, 1830)	Two bearded croaker	Dhoma	(LC)	3.7
88		Perciformes	Sciaenidae	*Otolithes cuvieri* Trewavas, 1974	Lesser tiger-tooth croaker	Dhoma	(LC)	3.9
89			Sciaenidae	*Otolithes ruber* (Bloch & Schneider, 1801)	Tiger-tooth croaker	Dhoma	(NT)	4.1
90			Sciaenidae	*Otolithoides biauritus* (Cantor, 1849)	Bronze croaker	Dhoma	(LC)	4.2
91			Sciaenidae	*Otolithoides pama* (Hamilton, 1822)	Pama Croaker	Dhoma	(LC)	3.9
92			Sciaenidae	*Paranibea semiluctuosa* (Cuvier, 1830)	Half-mourning croaker	Dhoma	(NT)	3.6

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
93			Sciaenidae	*Protonibea diacanthus* (Lacepède, 1802)	Blackspotted croaker (Ghol)	Ghol, dhoma	(LC)	4.1
94			Sillaginidae	*Sillago sihama* (Forsskål, 1775)	Silver sillago (Ladyfish)	Kanchli, jira, kunga	(LC)	3.4
95			Sparidae	*Acanthopagrus berda* (Forsskål, 1775)	Goldsilk seabream	Bhavla	(LC)	3.6
96			Sphyraenidae	*Sphyraena jello* Cuvier, 1829	Pickhandle barracuda	Kaancheli	(LC)	4.5
97	Teleostei		Sphyraenidae	*Sphyraena obtusata* Cuvier, 1829	Obtuse barracuda	Kaancheli	(LC)	4.2
98		Pleuronectiformes	Cynoglossidae	*Cynoglossus arel (Bloch & Schneider, 1801)*	Large-scale tonguesole	Jeepta	(LC)	3.3
99			Paralichthyidae	*Pseudorhombus arsius* (Hamilton, 1822)	Large-tooth flounder	Daatra	(LC)	3.9
100			Psettodidiae	*Psettodes erumei* (Bloch & Schneider, 1801)	Indian spiny turbot (Indian halibut)	Favdo	(LC)	4.4
101			Soleidae	*Solea elongata* Day, 1877	Elongate sole	Jeepta	(LC)	3.2
102			Soleidae	*Zebrias quagga* (Kaup, 1858)	Fringefin zebra sole	Jeepta	(LC)	3.3
103			Soleidae	*Zebrias synapturoides* (Jenkins, 1910)	Zebra sole	Jeepta	(LC)	3.3
104			Ariommatidea	*Ariomma indica* (Day, 1871)	Indian ariomma		(LC)	3.2
105			Scombridae	*Auxis thazard* (Lacepède, 1800)	Frigate tuna		(LC)	4.3
106		Scombriformes	Scombridae	*Rastrelliger kanagurta* (Cuvier, 1816)	Indian mackerel	Bangada	(LC)	3.2
107			Scombridae	*Rastrelliger brachysoma* (Bleeker, 1851)	Short mackerel	Malbaar bangada	(LC)	3.1
108			Scombridae	*Scomberomorus koreanus* (Kishinouye, 1915)	Korean seerfish	Surmai	(DD)	4.5
109			Scombridae	*Thunnus tonggol* (Bleeker, 1851)	Longtail tuna		(LC)	4.5
110			Stromateidae	*Pampus argenteus* (Euphrasen, 1788)	Silver pomfret	Paaplet	(LC)	3.3
111	Teleostei		Trichiuridae	*Lepturacanthus pantului* (Gupta, 1966)	Coromandel hairtail	Taapi, Baga	(LC)	4.1
112			Trichiuridae	*Lepturacanthus savala* (Cuvier, 1829)		Taapi, Baga	(LC)	4.2

Sr. No.	Class	Order	Family	Species Name	Common Name	Local Name	IUCN Status	Trophic Level
113	Teleostei	Siluriformes	Arridae	*Nemapteryx caelata* (Valenciennes, 1840)	Engraved catfish	Shingada, khagi	(LC)	3.8
114			Arridae	*Osteogeneiosus militaris* (Linnaeus, 1758)	Blacktip sea catfish	Shingada, khagi	(LC)	3.7
115			Arridae	*Plicofollis dussumieri* (Valenciennes, 1840)	Soldier catfish	Shingada, khagi	(LC)	3.9
116		Tetraodontiformes	Balistidae	*Odonus niger* (Rüppell, 1836)	Redtoothed triggerfish		(LC)	3.4
117			Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	Unicorn leatherjacket	Don	(LC)	2.9
118			Tetraodontidae	*Lagocephalus lunaris* (Bloch & Schneider, 1801)	Pufferfish	Popcha	(LC)	3.7
119			Tetraodontidae	*Lagocephalus spadiceus (Richardson, 1845)*	Pufferfish	Popcha	(LC)	3.6
120			Triacanthidae	*Triacanthus biaculeatus* (Bloch, 1786)	Short-nosed tripodfish	Dalamiyo/chirkundo	(LC)	3.2

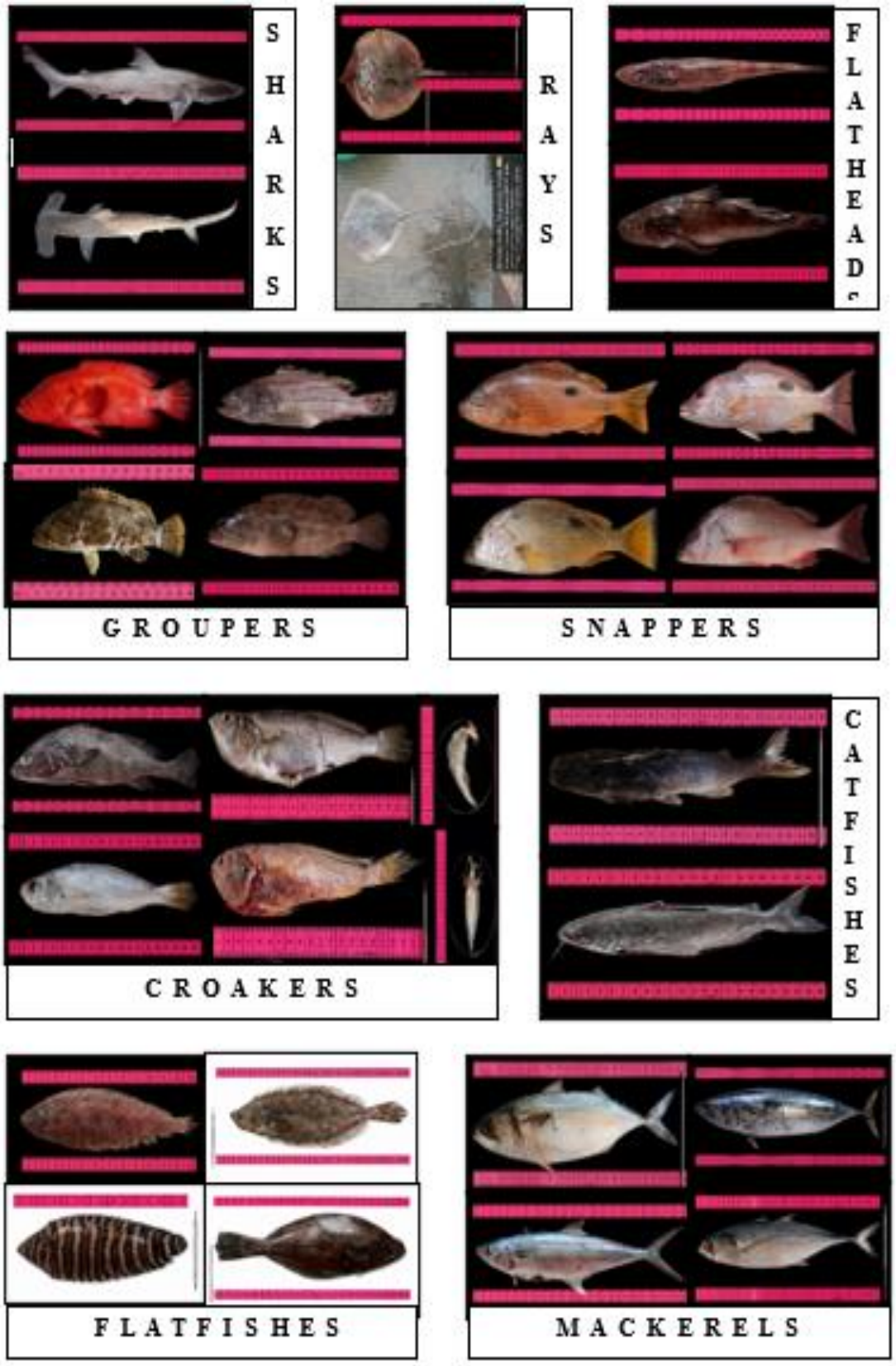

Fig. 2. Different fish groups with their included species

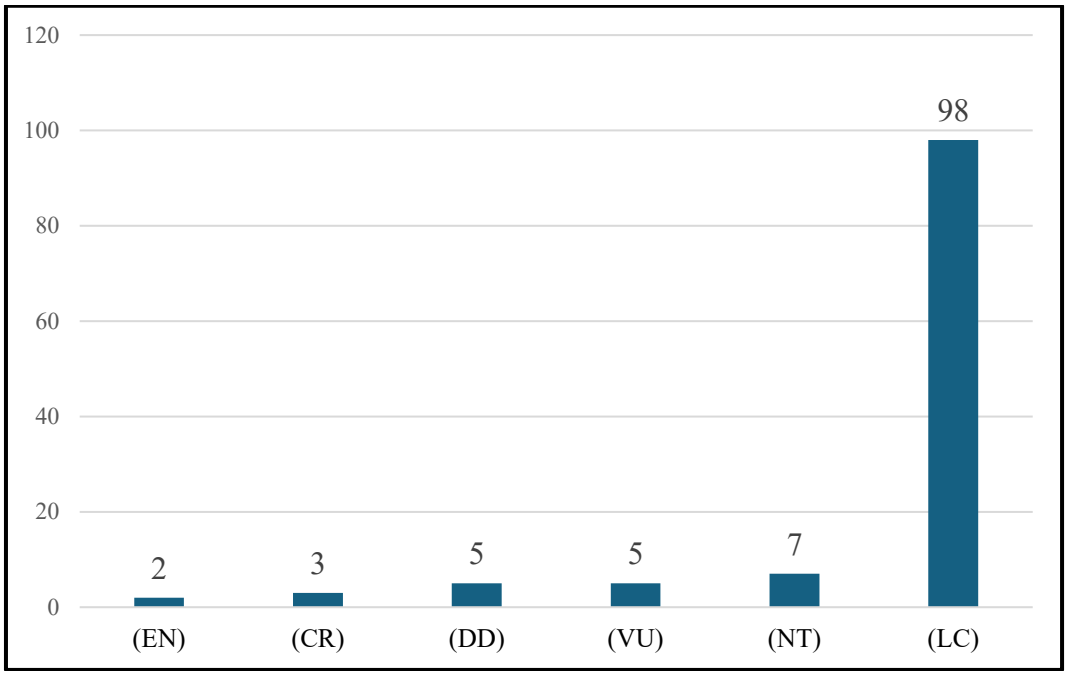

Chart 4. IUCN status of recorded fish

4. Conclusions

The present study documented 120 finfish species from Dholai Fishing Harbour, Gujarat, during September 2025 to April 2026. These species belonged to 96 genera, 60 families and 22 orders, indicating considerable ichthyofaunal diversity in the landings of this fishing centre. Teleost fishes formed the major component of the recorded diversity, with 106 species, while elasmobranchs were represented by 14 species. Catch composition varied across months and fishing methods, with trawlers contributing a wide range of finfish groups and gillnetters landing selected commercially important species.

The present study supports the previous study by Borichangar et al. (2022), who documented 136 finfish and shellfish species from Dholai during their extended five-year survey. During the present study, the presence of 120 fish species at the landing harbour highlights a diverse marine fish assemblage associated with nearby habitats. This species richness indicates a complex food web and provides baseline information for regional conservation and fisheries-related assessments. Diversity indices showed monthly variation, with the highest Shannon diversity and Margalef richness recorded in December 2025, whereas lower diversity values were observed during April 2026. Evenness values also varied across the study period, suggesting seasonal changes in the relative contribution of different fish groups. The trophic and conservation-status information compiled for the recorded species adds supporting baseline data for understanding the ecological composition of the landed catch. Overall, the study provides a useful inventory of finfish species landed at Dholai Fishing Harbour and may support future monitoring, comparison and fisheries-management studies in the region.

The present study also highlights the absence of fish processing units in nearby areas; therefore, fishermen need to sell fish in domestic fish markets in fresh or iced condition, while the majority of fish landings are transported to fish processing units in Bombay or Veraval. This may reduce revenue for boat owners because the rate offered at the landing centre may be lower than that offered at Bombay and Veraval due to transportation charges. The requirement for infrastructural facilities was also emphasised by Bengani et al. (2025). Fisheries management agencies should consider establishing a fish processing unit at Dholai to improve revenue potential and fish quality. Exporting these valuable marine fish may also generate foreign currency.

5. Limitations

The study was limited to finfish species landed at Dholai Fishing Harbour during September 2025 to April 2026 and therefore represents diversity observed in landings rather than the complete fish diversity of the surrounding

marine ecosystem. The assessment was based on samples and observations from trawlers and gillnetters, and species that were not captured or not landed during the study period may have remained undocumented. Seasonal coverage was restricted to eight months, which may not fully represent annual or interannual variation in species composition. The study also depended on external morphological characters for species identification, and molecular confirmation was not included. Catch composition, relative abundance and diversity indices were derived from landing data, which can be influenced by fishing effort, gear type, fishing ground, market preference and operational practices. Therefore, the findings should be interpreted as baseline information on landed finfish diversity rather than as a complete assessment of population size or stock status. Maximum care was taken during sampling to avoid bias by implementing a higher number of sampling sessions.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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