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Inventory of fishery resources using participatory research approach in Mandovi Estuary in Central western coast of India

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Abstract

Aim: The fisheries resources of Mandovi Estuary, along the central west coast of India were analysed for taxonomic, functional, feeding and population aspects and also to record and prepare an inventory on fish and shellfish species.

Methodology: Finfish and shellfish taxa were monitored for four years (2016 to 2020) through surveys in small and regional markets, fishermen surveys, fishing gear samplings, telephonic interviews and photographs.

Results: A total of 318 taxa are counted comprising of 169 (53.1%) demersal, 71 (22.3%) pelagic fish, 37 (11.6%), molluscan and 41 (12.9%) crustacean species. The community was dominated by marine immigrants and the freshwater types contributed least to the composition. In the inventory, majority of the resources were of commercial value and this category contributed 70% of total documented species. Even though detailed analyses were required, nearly 2% of the fauna appeared to be endemic to the region. Further, more than 30% species listed were data deficient. Out of 318 species, 10% were unknown in the Mandovi estuary.

Interpretation: This data set comprehensively documents the finfish and shellfish diversity of Mandovi estuary from 2016 to 2020. The type of fish assemblage is briefly discussed focusing on the management of these resources in the estuary.

Key words: Inventory, Diversity, Mandovi Estuary, Shellfish

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Introduction

Estuaries are interface ecosystems providing nursery habitats for several aquatic species due to the availability of prey resources, refuge habitats and high primary and secondary productivity (Beck *et al.*, 2001). The estuaries provide nursery habitats with the presence of structurally complex habitats such as seagrass, mangroves, salt pans and salt marsh, which is crucial in the life history of aquatic species (Nicolas *et al.*, 2010). Mangrove habitats along the estuarine gradient determines the ecosystem function and the composition of fish species (Ávila-Flores *et al.*, 2020). Tropical estuaries also function as rich feeding grounds for predatory, benthic and herbivorous fishes, and thereby harbour a number of fish species (Blaber *et al.*, 2000; Baker and Sheaves, 2006; Blaber, 2007; Elliott *et al.*, 2007), and add economic value to subsistence and artisanal fishermen. Conservation strategies are often based on geographic patterns of biodiversity (Roberts *et al.*, 2002; Brooks *et al.*, 2006). The data gaps in the knowledge on resources have been the bottle-neck in developing conservation strategies for various aquatic ecosystems. Recently, the studies from estuaries along west coast of India documented the list of inhabiting fish species from Vembanad, Nethravathi-Gurupura, Narmada, and Ulhas (Asha *et al.*, 2015; Deepashree *et al.*, 2017; Bhakta *et al.*, 2019; Lal *et al.*, 2020). The fish taxa of Zuari estuary has been documented earlier (Sreekanth *et al.*, 2016). The fish community of Zuari estuary consisted of 286 finfish and shellfish species comprising of 156 demersal fish, 68 pelagic fish, 38 molluscs and 24 crustacean species. There were 148 carnivores, 88 omnivores, 44 planktivores and 6 herbivores identified from Zuari based on the trophic level and feeding mode.

The habitat degradation, pollution, and coastal development impacted the fish nursery habitats of estuaries and in this context, the researchers should carry out scientific studies to catalogue, manage and protect these ecosystems (França and Cabral, 2016). Hence, precise and dependable estimates on fish taxa in estuaries, are required.

The Mandovi estuary (ME) is approximately 4 km wide at the mouth, and the stretch, on average, is marginally deeper (5 m) than the rest of the estuarine channel. The flow in the estuarine channel is primarily tidal, and tidal influence is experienced up to 50 km upstream. The estuary remains saline and dry (no freshwater flow) for eight months (postmonsoon and premonsoon) annually after the monsoon season (June-September). During the dry period, the average salinity of the ME is 25.3 psu and marine conditions persist. The fishing is active during the dry period because of the operational constraints (high out flow and turbulence) during the wet season. Fish assemblage and diversity data for Mandovi Estuary is limited. The occurrence of a highly diverse and mobile suite of fish species, together with the isolated nature of fishing operations, make it difficult to apply the conventional field survey methods. Additionally, surveys were

also conducted in the conventional way to get maximum data and a proper inventory of fish taxa. Innovative solutions are needed to gather data on fish biodiversity and small-scale fisheries in diverse tropical systems (Silvano and Begossi, 2012). The settings in estuaries, although challenging for conventional approaches, may provide unique opportunities for accessing biodiversity data through alternative methods such as Participatory Research Approach (PRA), which engages communities in data collection, build capacity, enhances ecological understanding and draws local knowledge. Therefore, the data are collected based on fishermen interviews and participation of the students from the locality. A participatory approach also provides a cost-effective means for increasing the area of sampling and reporting of fish data. In view of the above, this study aimed to identify and catalogue the fisheries resources like fish, crustacean and mollusc species from Mandovi Estuary through a participatory research approach and to classify the species based on taxonomy, vertical distribution and resource type, estuarine use, habitat type, IUCN status and feeding mode.

Materials and Methods

Study area: Mandovi estuary is situated in the Western coast of India and the estuarine mouth is approximately 4 km wide and 4-5 m deep. The estuary is under the influence of semi-diurnal tide with an amplitude of 2.5 m. The area covered in the current study is from the estuarine mouth to the range of tidal influence measuring 35.5 km².

Data collection: The fish species data was collected from 2016 to 2020 from small and regional markets (21), 'Manas' areas (sluice gate fishing) (21), fishermen surveys (10), telephonic interviews (120), and photographs (1393) shared by fishermen, students, and biodiversity management committee members, observations from fish landings in gillnets (18-120 mm mesh size), stake nets (12-16 mm) and cast nets (20-40 mm). Firstly, the species caught in gillnets, stake nets and cast nets were counted from Dona Paula, Chorao, Panjim, Caranzalem, Miramar, Marcela, Diwar and Old Goa. Visits were undertaken to these sites once in every month to note down the species caught in these nets. The market and Manas surveys (Amona, Banastarim, Marcel, Gandaulim, Cumbharjua, Sarmanas, Pilgao, Divar, Narve, Chorao, Mapusa, Pomburpa, Britona, Ribander, Panaji, Betim, Dona Paula, Verem, Caranzalem, Nerul and Corjuem) were carried out once in a month following a random sampling methodology, which was stratified. The first seven markets (1-7) and seven Manas (1-7) were surveyed in between the first 10 days of a month. The next seven (8-14) were surveyed in between days 10 and 20 during that month. The remaining (15-21) were surveyed in between days 20 and 30 of the month. However, if fish was not available in the market /manas during a visit, the same visit was excluded from the sampling frame. A total of 500 fish and shell fish photographs were compiled and ten active fishermen operating gillnets and cast

nets were surveyed. The interactions were arranged in such a way that we could interview all these fishermen on a monthly basis to ensure the availability of species information for the month. Telephonic interviews were also conducted once in every twenty days with Biodiversity Management Committee Members (who often visits the fishing sites and interact with fishermen) regularly by sharing them the photographs and links to check that any rare/unique species were encountered. Finally, fishermen, students and BMC members were encouraged to share the photographs of fishes when they were unable to tag it to the photo library. Thus, they shared 1393 photographs, which also formed a proper dataset in the survey.

Fish and shellfish fauna were identified based on the colour, morphology, meristic counts and body patterns (Fischer and Bianchi, 1983; Froese and Pauly, 2019). They were also classified in resource groups as pelagic, demersal, crustacean and molluscan resources (CMFRI, 2014). The species were categorised on the basis of habitats (pelagic; sandy; sandy and rocky; sandy and muddy; rocky and coral; rocky and estuarine; sandy and estuarine; muddy and estuarine) and feeding type (planktivores (PK), herbivores (HV), detritivores (DV), zooplanktivores (ZP), piscivores (PS), zoobenthivore (ZB), carnivores (CR) and omnivores (OV)). The fish were also classified into guilds based on estuarine use (marine stragglers (MS), marine migrant opportunist (MMO), marine and estuarine dependent (MMD), estuarine species (ES), anadromous (AN), catadromous (CA) and freshwater migrants (FM)). The IUCN criteria were assigned to the documented species (Vulnerable (VU), Near threatened (NT), Least concern (LC), Data deficient (DD), and Not evaluated (NE)). To analyse the commercial importance, the species were also segregated into categories such as highly commercial, medium, minor and non-commercial species.

Results and Discussion

Three-hundred and eighteen species classified into 108 families were recorded from the Mandovi estuary. The highest count of species were reported from the following families Carangidae (21), Sciaenidae (17), Leiognathidae (10), Penaeidae (15), Portunidae (8), Ariidae (11), Lutjanidae (11) and Engraulidae (10) (Fig. 1). There were 53.2% demersal fish, 22.3% pelagic fish, 11.6% mollusc and 12.9% crustaceans in the total list. The estuarine use guilds were distributed as follows; 1.9% anadromous, 0.3% catadromous, 8.8% estuarine residents, 2.2% freshwater migrants, 10.7% marine estuarine dependents, 51.2% marine migrant opportunists and 24.8% marine stragglers. Based on the trophic level and feeding type, there were 40.6% carnivores, 24.2% omnivores, 10.7% planktivores, 14.5% zoobenthivores, 2.2% herbivores, 2.8% detritivores, 1.3% piscivores and 3.7% zooplanktivores. There were 28.9% high, 41.5% medium, 20.8% minor and 8.8% non-commercial species in Mandovi estuary. While considering the preferred habitats, the

21.1% species were from muddy and estuarine, 9.4% pelagic, 12.6% rocky and coral associated, 1.3% rocky and estuarine, 0.9% sandy, 3.5% sandy and estuarine, 48.4% sandy and muddy and 2.8% sandy and rocky habitats (Fig. 1). The IUCN classification recorded 1.9% Vulnerable, 1.3% Near threatened, 42.5% Least concern, 2.8% Data deficient and 51.5% Not evaluated species.

Among the total species recorded from the estuary, 61.9% were marine migrants distributed in MMD and MMO, which spawn in sea and often enter estuaries in high counts, particularly as juveniles. The underlying principle in estuarine fish research is that nursery-habitat concept: some near-shore, juvenile habitats contribute invariably to the recruitment of individuals to fish populations (Beck *et al.*, 2001). Mandovi Estuary is characterised by presence of considerable mangrove vegetation along its banks (Misra *et al.*, 2015). Therefore, the higher frequency of marine immigrants clearly indicates nursery role of the system. The second major estuarine use guild was marine stragglers that contributed 24.8% of the total count. Estuarine species shared only 8.8 % of the species composition in the estuary. The estuarine use guild proportions indicate a decline in the estuarine resident guild was evident and there were very few freshwater species collected from the estuarine zone (just about 2%). There is a gradual decrease in the average rainfall since the last few years in Goa. This rainfall pattern and construction of a dam in upstream of Mandovi river are responsible for increased salinity (Fernandes and Nayak, 2009) and sedimentation in the river basin. These factors could be a possible reason for the decrease in the freshwater fish species. Hence, the observed feeding guild patterns in Mandovi Estuary caution on the further reduction of freshwater discharge, increasing salinity and tidal influence might turn this important estuary into an arm of the ocean in the future.

Carnivorous (40.6%), and omnivorous (24.2%) guilds contributed major proportion of feeding types in the Mandovi Estuary. Zoo-benthivores (14.5%) and planktivores (10.69%) also contributed notable proportion of feeding mode functional guilds. The percentage of piscivores was very low (1.5%) among the feeding types. Generally, the estuarine fish community index (EFCI), assembles fish data, the contributions and counts of zoobenthivore and piscivorous fish species, and it highlights the integrity of estuarine ecosystem (Harrison and Whitfield, 2006). However, the proportions of these groups found to be very low in Mandovi Estuary, and that necessitates the reinstatement of benthic ecology.

Due to lack of corresponding information on the biological attributes, about half of the species (51.5%) were categorized as “not evaluated” and 2.8% were “data deficient” in the total count. Instead, 42.4% were listed as “least concern”. *Tenulosa toli*, *Hemirampus xanthopterus*, *Hippocampus kuda*, *Glaucostegus granulatus*, *Glaucostegus obtusus* and *Himantura uarnak* were the six species reported under the “Vulnerable” category (IUCN,

Fig. 1 : Distribution of fish species based on (a) Family; (b) Shellfish order wise; (c) Finfish order wise; (d) Estuarine use; (e) Feeding mode; (f) Habitat and (g) commercial value. Feeding guilds are planktivores (PK), herbivores (HV), detritivores (DV), zooplanktivores (ZP), piscivores (PS), zoobenthivore (ZB), carnivores (CR) and omnivores (OV). Estuarine use guilds are marine stragglers (MS), marine migrant opportunist (MMO), marine estuarine dependent (MMD), estuarine species (ES), anadromous (AN), catadromous (CA) and freshwater migrants (FM).

2020). *Scoliodon laticaudus*, *Pastinachus sephen*, *Chilloscyllium griseum* and *C. indicum* were the “Near-threatened” type (IUCN, 2020). The incidence of threatened and near-threatened species indicated that the estuary provides a sheltered habitat for these types and fishing operations that could harm these species should be regulated (Sreekanth *et al.*, 2020). The mean length of all these species from estuaries indicate that these ecosystems provide nursery habitats for the vulnerable and threatened species (Sreekanth *et al.*, 2020). The categories such as “data deficient” and “not evaluated” would be a matter of concern as the species in these categories are remaining as such for last so many years and these categories are not assessed for its population status in recent years (IUCN, 2020). Moreover, availability of endangered/vulnerable species poses a serious concern that some species from these categories may fall under the threatened species category, unless a proper population assessment is carried out. Hence, research projects should be undertaken on these groups to document the biology, stock assessment and population features in the years to come. Two exotic and invasive species recorded from the estuary were *Oreochromis mossambicus* (Mozambique tilapia) and *Clarias gariepinus* (African catfish) with significant biomass. These species possess a serious threat to the indigenous fish stocks as they have already established themselves in the upper stretches of the estuaries (Grace, 2014; Rabelo *et al.*, 2014). A study is also recommended on the species invasion for aquatic ecosystems of Goa to measure the ecological impacts of their invasions.

The studies to document the fisheries resources in Mandovi are limited. This study has provided a more strengthened fish species dataset for Mandovi. The estuary has structural habitats like sandy, muddy, estuarine, rocky and mangrove (Ansari *et al.*, 2003). The record of the species was very high (318 species) in the current study and this illustrates the common fish diversity pattern in estuaries that follow a larger number of species with low individual proportions (Whitfield, 1999; Rojo-Vazquez *et al.*, 2008; Sreekanth *et al.*, 2018). The study showed that majority of the species recorded are of commercial importance and thus, the estuary contributes significantly to local fisheries of Goa (Ansari *et al.*, 1995; Sreekanth *et al.*, 2018). The complex functional habitats along with sandy, muddy, rocky substrates in the Mandovi must have supported the huge diversity of fish species (Sreekanth *et al.*, 2018). A participatory approach involving local fishers and population was not conducted in earlier studies. The finfish, crustacean and mollusc species recorded from earlier studies as follows- Mandovi-Zuari (finfish: 59) (Ansari *et al.*, 1995), Mandovi-Zuari (finfish: 52) (Ansari *et al.*, 2003), Coastal area off Goa (121, 40, 18) (Velip and Rivonkar, 2015), and Zuari (224, 24, 38) (Sreekanth *et al.*, 2018). These studies however used specific sampling gears like bottom trawl, gillnet and hook and line, beach seine and traps to harvest the species. However, in this work, the data were collected from multiple sources such as various landing

centres, small and regional markets, fishermen surveys, telephonic interviews, photographs shared by fishermen, observations from fish landings in gillnets, stake nets and cast nets. Therefore, the total species count was remarkably high compared to earlier records. This was perhaps possible due to long-term sampling (2016 to 2020) and multiple fishing gears used for the study. The methodology followed in this study was appropriate and relevant to document the fish counts holistically in morphometrically complex and remotely located ecosystems.

The area demarcated for the surveys were 10 km inward from the estuarine mouth. However, the habitat associations of the documented species indicate representations from different habitats like rocky patches, sandy bed, muddy shore and coral outcrops. The observation of the coral reef-inhabited species might be a reflection of the existence of submerged rocks, aggregating artificial structures and coral outcrops. The mangrove cover along an estuarine gradient is critical in determining the fish counts (Misra *et al.*, 2015). To preserve the mangrove vegetation in Mandovi estuary, Goa government has declared Chora Island, a dense mangrove occupied Island as a reserved forest (Indian Forest Act, 1927)). Subsequently, the mangrove area of the Island has also declared as Dr. Salim Ali Bird Sanctuary in 1988 (Wildlife (Protection) Act, 1972). The government has also initiated afforestation programmes to restore the degraded mangrove patches in the State. Therefore, following these management measures, the mangrove vegetation in Mandovi had increased from 149.4 ha in 1973 to 1059.7 ha in 2011 (Misra *et al.*, 2015). These efforts have positively influenced in preserving the fish and shellfish diversity of the ecosystem.

This study has thus, established a detailed dataset of fish and shellfish taxa of the estuary. The fish guild composition highlighted the dominance of marine immigrant species over the estuarine resident species. Our analysis also resulted in almost 3% of species being the “data deficient”, suggesting the immediate need for focused study on this group. This database is a ready reference for the researchers and government authorities to plan research and developmental activities in this ecologically complex, yet commercially important ecosystem.

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Add-on Information

Author's contribution : **G.B. Sreekanth:** Sampling, Data collection, Writing- Original draft preparation; **P. Rivonkar:** Sampling, Data collection, Writing- Original draft preparation; **T.S. Mayekar:** Data analysis, Writing- Reviewing and Editing; **A. Giriyan:** Sampling, Data collection, Writing- Original draft preparation; **F. D'souza:** Conceptualization, Methodology, Data analysis, Writing- Reviewing and Editing; **S. Dourado:** Sampling, Data collection, Writing- Original draft preparation; **B. Ingle:** Conceptualization, Methodology, Data analysis, Writing- Reviewing and Editing; **E.B. Chakurkar:** Conceptualization, Methodology, Data analysis, Writing- Reviewing and Editing.

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