# Determining target species for assessment in multispecies and multigear fisheries: insights from an expanded CMFRI-NMFDC database

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## Abstract

This paper highlights the richness of information available in an expanded ICAR-CMFRI-NMFDC fish catch and effort database for the state of Kerala. Strengthening of the database by digitizing data in the old paper data sheets was done under a multi-national project, ICAR-CMFRI-CSIRO-LENFEST Ocean Programme. The high diversity of fished taxa was classified according to the periodicity of its occurrence over this long period. Guidelines for determining the number of species for which stock assessment is to be carried out in the context of a multigear and multispecies fisheries sector were derived. This national-level database will be of immense use to researchers and policy makers for preparing fisheries management plans for the sustainable harvest of marine fishery resources.

***Keywords**: Target species, NMFDC, Expanded database, Stock assessment*

## Introduction

India is among the few countries where a system based on sampling theory is used to collect marine fish catch and effort data. The ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) initiated the collection of marine fish landings data along the west coast of India by developing a stratified multistage random sampling design (SMRSD) in 1959 (Sukhatme *et al*., 1958). The sampling frame was prepared by collecting data on marine fishing villages, landing centres, fishing crafts and fishing gears etc. and was periodically updated to accomodate changes happening in the sector, through all India Frame Surveys. Species wise catch, fishing effort, details of fishing crafts and gears and other related information is collected following the scientific sampling scheme. The SMRSD, developed by ICAR–CMFRI is used to estimate landings and fishing effort each month for smaller non-overlapping geographical regions referred to as fishing zones, covering the entire coast. At present, there are 1269 landing centres (CMFRI-FSI-DoF, 2020) along the mainland coastline which is distributed in 9 coastal states (65 coastal districts) and two Union Territories (UT) under the SMRSD data collection.

In tropical countries where the diversity of marine fishery resources is very high, the most practical fishery data collection approach is a scientific sampling scheme as a complete enumeration of catches and logsheet method of data collection is impractical (Sathianandan *et al*., 2021). In the data collection system, dedicated technicians (harbour-based observers) with species identification skills visit the landing centres according to work schedules generated under SMRSD and record different aspects of the fishery from sampled boats. The data thus collected is stored in a database of the National Marine Fishery Resources Data Centre (NMFDC) maintained in ICAR-CMFRI headquarters at Kochi (Table 1).

Table 1. Summary of data stored in NMFDC

| | |
|---|---|
| National | The entire coast of the mainland India but excluding Lakshadweep, Andaman & Nicobar Islands |
| Region | The mainland along the coast is categorized into four regions namely North-East (West Bengal, Odisha), South-East (Andhra Pradesh, Tamil Nadu and Puducherry), South-West (Kerala, Karnataka and Goa) and North-West (Maharashtra, Gujarat and Daman & Diu) |
| State | The entire coast is divided into nine coastal states and these are West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat |
| UT | The union territories under the central government along the coastline are Puducherry and Daman & Diu. |
| District | These are distinct subdivisions covering the coastal region belonging to the coastal state and UT (65 coastal districts) |
| Fishing Zone | These are non-overlapping exclusive subdivisions of coastal districts (75 fishing zones). |
| Sector | Categorization based on the fishing craft: The fishery is divided into three sectors namely, Mechanized, Motorized and Non-motorized |
| Gear/Fleet | Different craft/gear combinations used for harvesting from the sea are placed under this. There are more than 25 craft-gear combinations and some of the major fleets are Mechanized Trawlnets, Mechanized Gillnets, Mechanized Hooks & lines etc. under the mechanized sector. Outboard Gillnets, Outboard Ringseines, Outboard Hooks & lines under the motorized sector. Besides, several gears are being operated in the non-motorized sector/ artisanal sector. |
| Assemblage | The four categories based on species assemblage are Pelagic, Demersal, Crustacean and Molluscs |
| Species group | The species landed are summarised into 83 resource groups for presentation in theabular form based on their dominance in the fishery and commercial importance |
| Taxonomic Resolution | 1950-1968: All species aggregated into 15 groups |
| | 1969-1981: All species aggregated into 43 groups |
| | 1982-1985: All species aggregated into 63 groups |
| | 1985-2006: All species aggregated into 83 groups |
| | 2007 onwards: Species-level |

## Need for expanding the NMFDC database

Species composition data are very important to understand the changes happening in the ecosystem due to fishing, particularly in biodiversity-rich tropical regions. Besides, fished taxa information is vital to decide on the species to be assessed in a multispecies scenario to derive fishery management strategies and plans. In the past, aggregation of the collected species-level information into resource groups (Table 1) was followed for ease of reporting. However, the aggregated information in the earlier data format cannot be disaggregated electronically. Earlier studies have indicated the high number of fished taxa in India's marine fish landings (Sathianandan *et al*., 2013). In highly biodiverse fisheries, it is very difficult to determine the target and bycatch from among the hundreds of fished taxa in each gear. Besides, a large number of craft-gear combinations (fleets) makes the problem more complicated. Target species in the Mediterranean trawl were defined as those caught by fishers primarily due to its high unit cost or those caught in high quantities while Bycatch was unwanted/ unintended species caught during fishing operations (Stergiou *et al*., 2003). An objective method for distinguishing target and bycatch species is necessary for devising management strategies and the expanded NMFDC database for the state of Kerala that contains data on 884 species landed during the period 1985- 2019, provides such an opportunity. The expansion of the digital database initiated for the state of Kerala was under the ICAR-CMFRI-CSIRO-LENFEST project on "Benchmarks for ecosystem assessment: Indicators and guidelines for ecosystem-based fisheries management (EBFM)". One of the major objectives of the project was the development of models for ecosystem-based fishery management suitable for tropical conditions where fish species diversity is very high and multiple gears are operated for harvesting the resources. Even though fish landings data at species level was available in the NMFDC since 2007, a longer time series was required for modelling studies.

## Methodology

Processing species-level information available in old paper records maintained in ICAR–CMFRI was a time consuming and manpower demanding task. The old data paper records (~4000 basic data sheets) were digitized with approximately 100 man-months to accomplish it. The digitized records were processed for estimation and further converted to a database. An objective criterion was developed to select the species for stock assessment from the large number of species that are caught in multiple gears. The criteria used for deciding the number of species to be assessed was based on the cumulative frequency distribution of the

quantity of catch as well as the unit price of the resources. The species were arranged in the descending order from 1 to *n* (n being the total number of species) based on the quantities landed. $Q_i$ denote the cumulative percentage of the ordered species in the *i*th position based on quandity landed and Pi represent the cumulative percentage of the ordered species in the *i*th position based on the unit price of the resource. The target species for the assessment was made considering both the cumulative percentages $Q_i$ and $P_i$. The species falling within 95% of the cumulative percentage, within each gear, either based on the quantity landed or based on the price were selected for assessment (i.e., either $Q_i$ or $P_i \leq 95$ %).

# Results

## Species number trends

The average annual number of species landed during the period was 300 and the minimum (192) and maximum (471) species were observed in 1987 and 2016 respectively. The steady increase in species number could be due to the expansion of fishing grounds. The number of species recorded in the landings from 1985 to 2019 and the percentage contribution of major species in the total landings from 1985 to 2019 is given (Fig. 1 & Fig. 2)

## Species categorization

In virtually all ecological communities around the world, most species are represented by few individuals which mostly belong to a few of the most common species. This trend is very clear from the frequency of occurrence of species over time (Fig. 3).

It showed that a maximum number of species (138), which is 15.61% of the total 884 species, occurred only in one of the 35 years. The number of species that occurred in all the 35 years is 78 (8.8%). The frequency of species occurrence decreased with an increase in years. Based on this information, the species were classified into 5 categories, very rare (occurring <10 years); rare (occurring between 10 and 19 years); often (occurring 20-29 years); common (occurring 30-34 years) and most common (occurring in all years) (Table 2). The rarity cutpoint however is often a subjective decision in conservation literature and depends on the data distribution. The

Table 2: Categorization of species based on the frequency of occurrence of species in the landings during 1985-2019 (35 years)

| Category | Criteria | Number of species | Importance |
|---|---|---|---|
| Very Rare | <10 years | 522 | Biodiversity monitoring |
| Rare | 10-19 years | 137 | |
| Often | 20-29 years | 97 | |
| Common | 30-34 years | 50 | Fisheries monitoring |
| Most common | All 35 years | 78 | |
| Total | | 884 | |

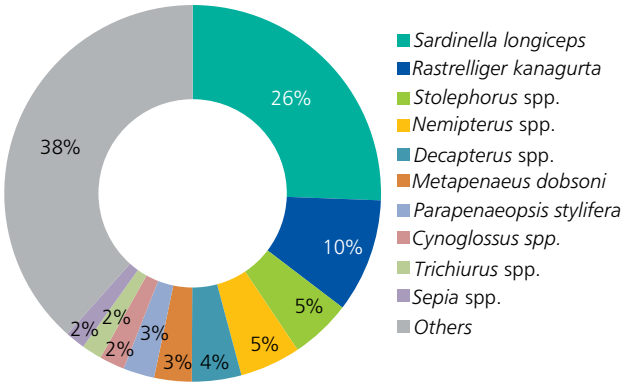


Fig.2. Percentage contribution of ten major species in the total landings during 1985 to 2019

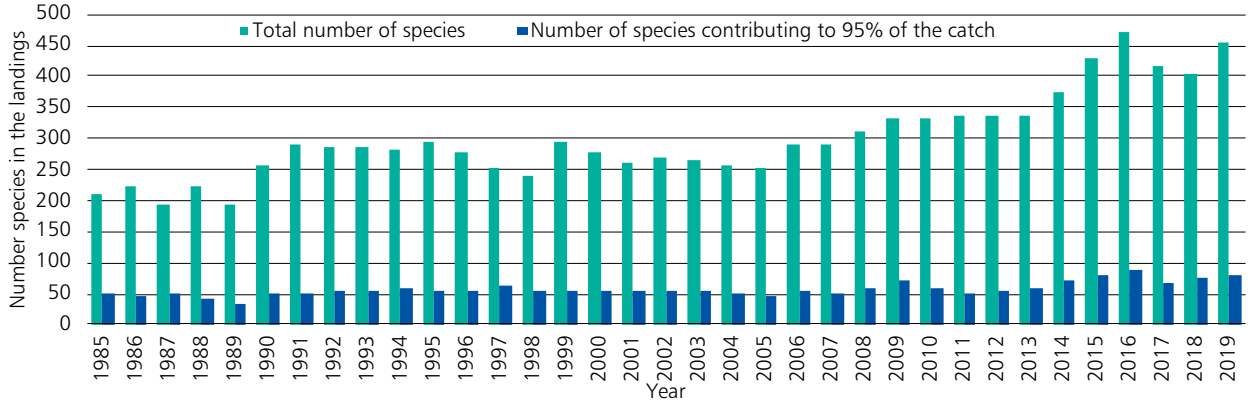


Fig.1. The number of species recorded in the landings from 1985 to 2019 (35 years).

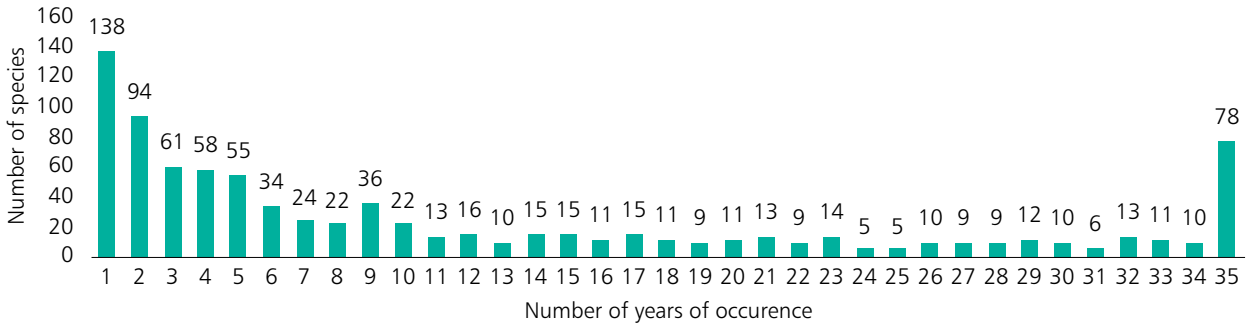


Fig.3. Frequency of occurrence of species during 1985-2019. Numbers over the bars indicate actual values.

number of species in each category and their significance to biodiversity and fisheries monitoring is shown in Table 2. It can be seen that 756 species (86%) are rare or very rare and not common which are also important and needs monitoring from a biodiversity perspective.

The 78 species (8.8%) which occurred in all the 35 years (most common) constitutes 87.33% of the total landings during the period 1985-2019. The contribution to landings of species with frequency of occurrence was 30-34 years is 7.26% and for species with frequency of occurrence 20-29 years was 3.50% (Table 3). The species with frequency of occurrence less than 10 years, the contribution to the total landings is very negligible (0.70%). This indicates that there are 78 most common species which are the mainstay of the marine fisheries of Kerala and have to be tracked consistently on a scientific basis to support fisheries management.

Table 3: Contribution to the total Marine Fish landings of different categories of species (1985-2019)

| Frequency of occurrences (in years) | Proportion to total landings |
|---|---|
| All 35 years | 87.33% |
| 30 to 34 years | 7.26% |
| 20 to 29 years | 3.50% |
| 10 to 19 years | 1.21% |
| <10 years | 0.70% |

## Taxonomic distribution of the most common species

The taxonomical distribution at genus, family, order, class and phyla levels to the most common of 78 species are shown in Figures 4 to 8. This hierarchical classification shows that these species belong to 63 genera comprising 41 families from 13 orders and 4 classes from three phyla (Fig. 4 – Fig. 8). The genus which dominated the distribution is *Sardinella* (5%), the family Scombridae (12%), Order Perciformes (53%), Class Actinopterygii (80%) and Phylum Chordata (85%). The distribution of the most common 78 species in different assemblages (pelagic, demersal, crustacea and mollusca) indicated pelagic finfish formed 50% of the most common species (Fig. 9).

## Dynamic change in ranks of species

The top four species with the highest landings over 35 years is depicted through colour gradients (Fig.10). The species which comes in the first position (red colour) is followed by orange, yellow and green for the second, third and fourth positions respectively. *Sardinella longiceps* was the major species landed, which occupied the first position in most of the years (26 out of 35). But, species such as *Cynoglossus bilineatus*, *Priacanthus hamrur*, *Sardinella fimbriata* and *Trichiurus lepturus* were also observed as the highest landed species once in the last 35 years. The sudden jump in landings of red toothed triggerfish (*Odonus niger*) in recent years with record landings in 2019 leading to occupying the first position was never observed earlier in the first four positions during the 35 years monitored.

## Gearwise species distribution

The 35-year extended database indicated 15 craft-gear combinations (fleets) that contribute substantially to the marine fish landings in Kerala. The outboard ringseine (OBRS) is the major gear followed by the mechanized trawlnet (MTN) and mechanized multiday trawlnet (MDTN) (Fig. 11). The gearwise average catch and the

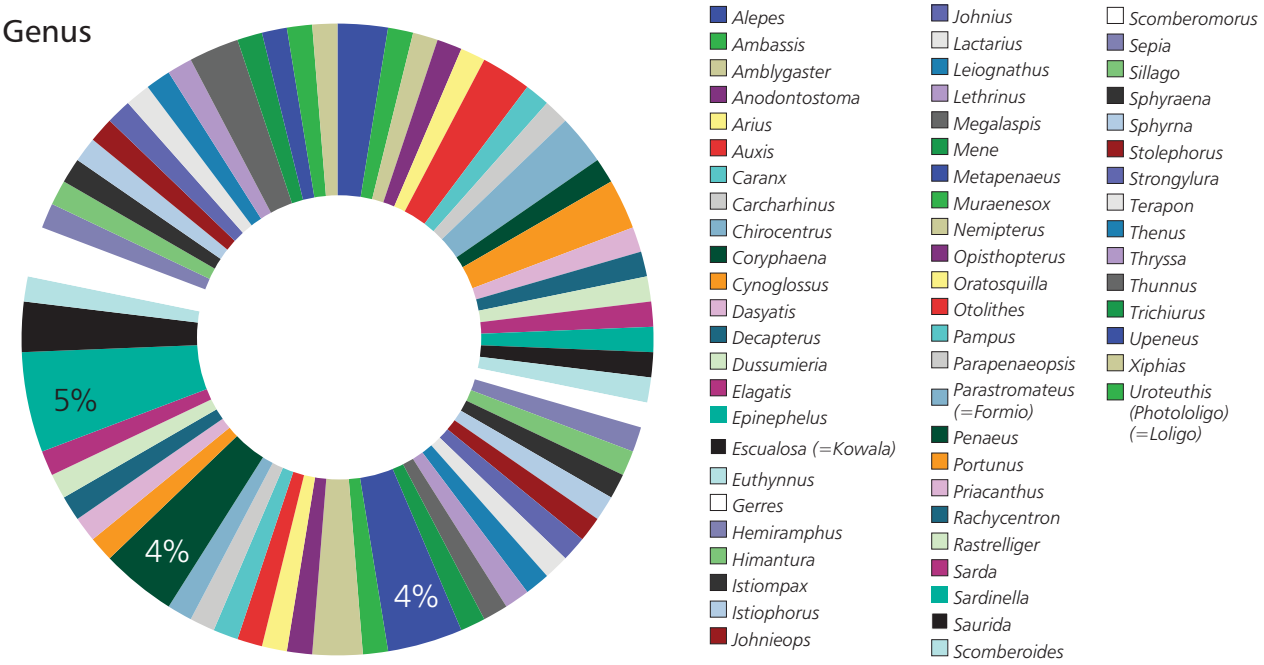


Fig.4. Distribution of 78 species over different genera (total 63 genera)

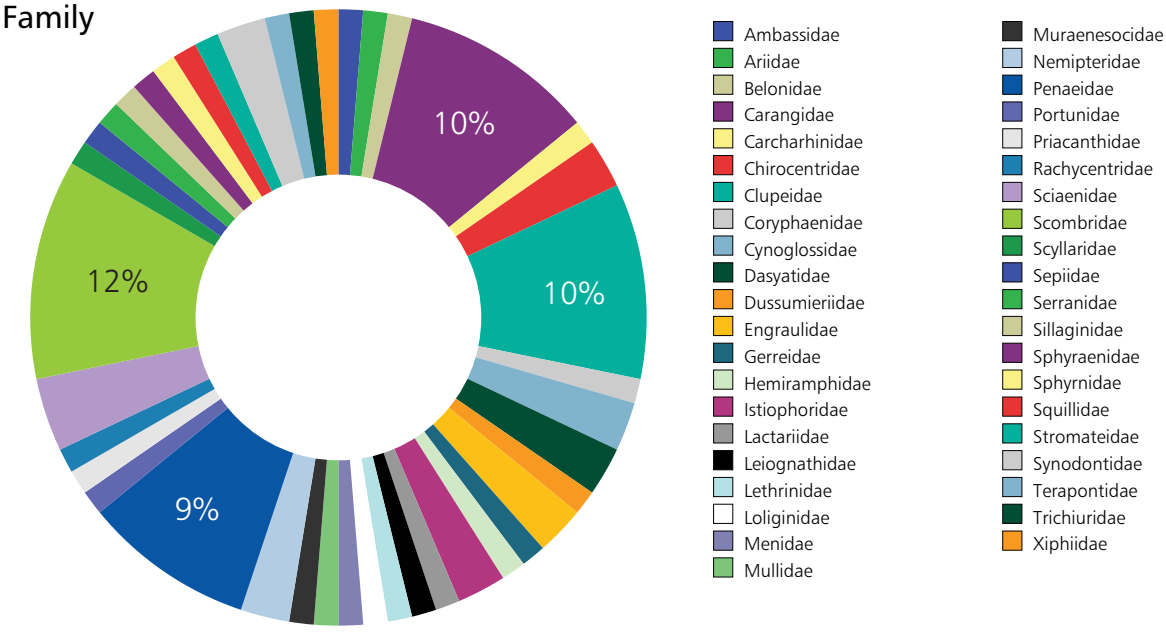


Fig.5. Distribution of 78 species over 41 different Families

number of species exploited by each gear indicated maximum number of species being caught in trawlnet followed by gillnet with the least number of species in shoreseine (Table 4).

Twenty species were reportedly caught in all the 15 gears while 278 species were exclusively caught in a single gear. The number of species exclusively caught in each gear is given in Table 5. Maximum exclusive species

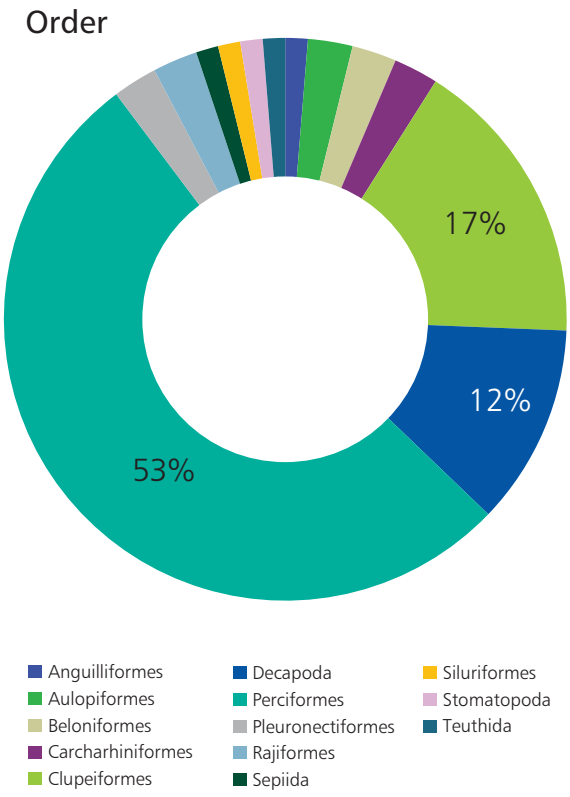


Fig.6. Distribution of 78 species over 13 different orders

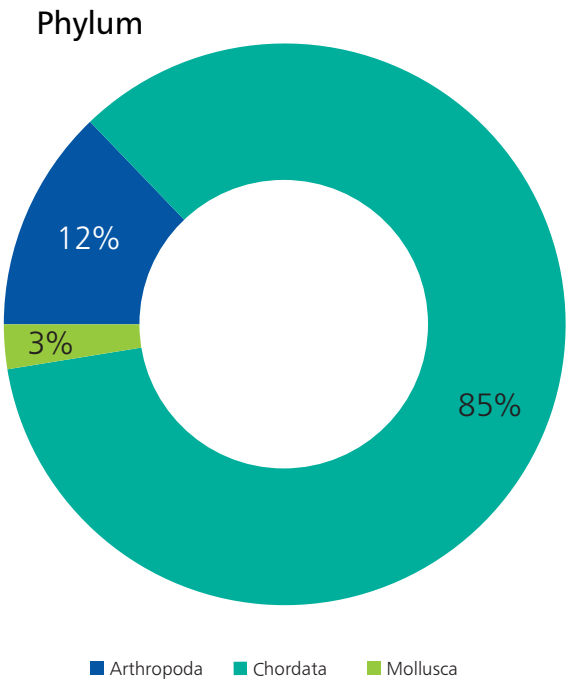


Fig.8. Distribution of 78 species over 3 different Phyla

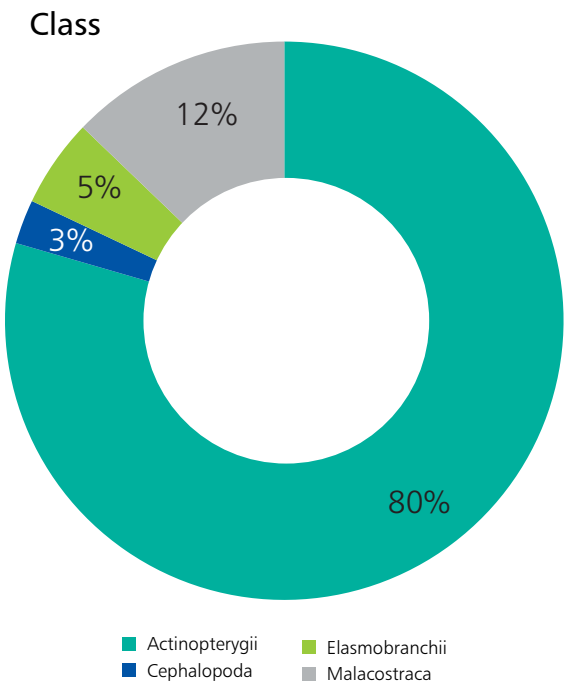


Fig.7. Distribution of 78 species over 4 different Classes

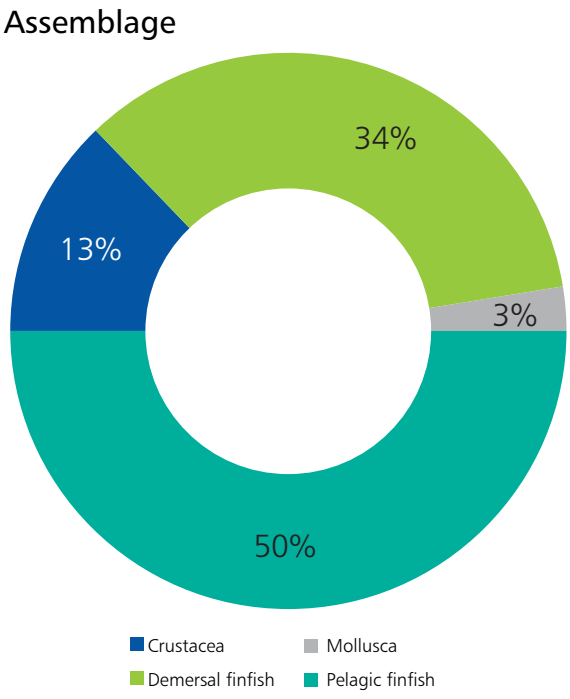


Fig.9. Distribution of 78 species by species assemblages

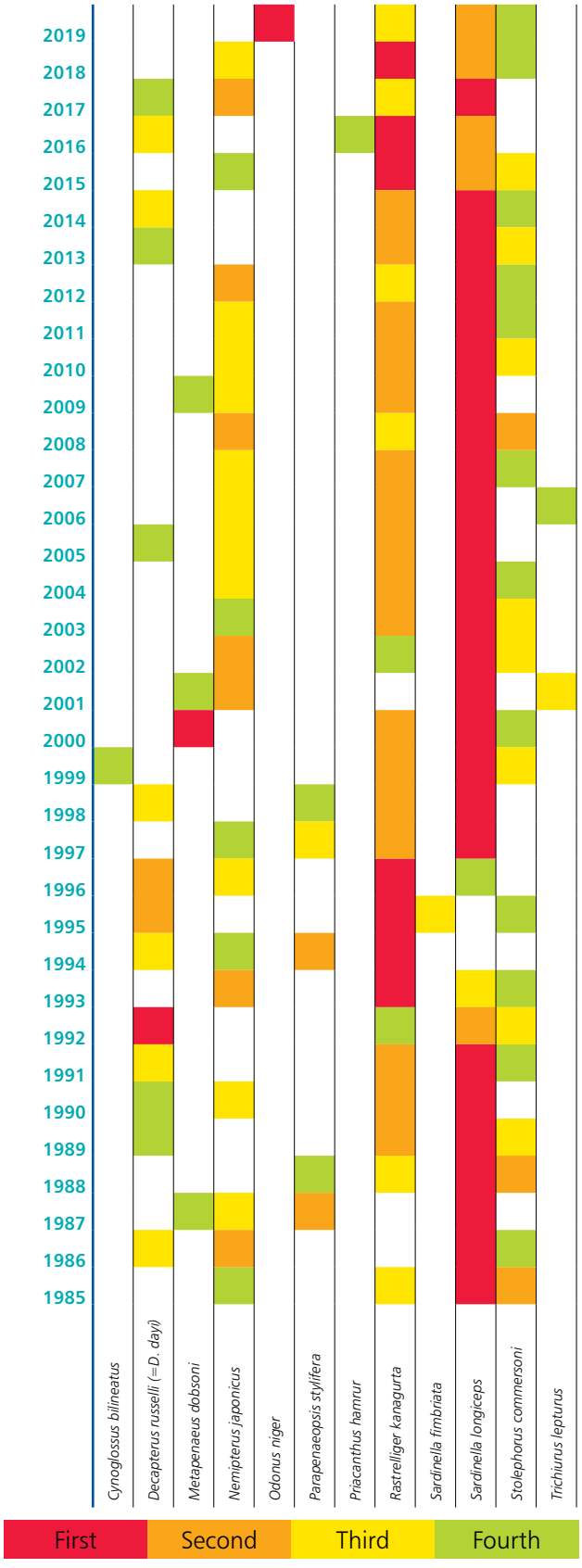


Fig.10. Top four ranked species with the highest landings during 1985-2019

Table 4. Gear-wise ranking based on number of species caught.

| Gear Name | Gear Code | Number of species |
|---|---|---|
| Mechanised Trawlnet (Single day) | MTN | 764 |
| Mechanised Trawlnet (Multi day) | MDTN | 750 |
| Outboard Gillnet | OBGN | 585 |
| Non-Mechanised (Artisanal) | NM | 549 |
| Mechanised Combination Gears | MCGR | 424 |
| Outboard Hook & Line | OBHL | 400 |
| Mechanised Gillnet | MGN | 345 |
| Outboard Ringseine | OBRS | 329 |
| Mechanised Hook & Line | MHL | 291 |
| Outboard Boatseine | OBBS | 282 |
| Outboard Combination Gears | OBCGR | 279 |
| Outboard Trawlnet | OBTN | 211 |
| Mechanised Ringseine | MRS | 210 |
| Mechanised Purseseine | MPS | 120 |
| Outboard Shoreseine | OBSS | 89 |

were observed in MTN and MDTN followed by NM and OBGN. The MTN which is operated very close to the shore have the highest number of species caught and also the maximum species which are exclusively caught by the gear. The seine nets (MPS, MRS, OBSS, OBBS and OBRS) have minimum exclusive species. This information indicates that biodiversity is concentrated in the nearshore benthic region of the ecosystem.

Twenty species were caught in all the 15 gears, and these include *Alepes* spp., *Ambassis* spp., *Arius* spp., *Caranx* spp., *Cynoglossus* spp., *Decapterus* spp., *Euthynnus affinis, Megalaspis cordyla, Mene maculata, Parastromateus niger, Penaeus indicus, Rastrelliger kanagurta, Scomberoides tol, Scomberomorus commerson, Scomberomorus guttatus, Sphyraena* spp., *Uroteuthis* spp. There are also 278 species which are exclusively caught only in one of the fishing gears in operation (Table 5 & 6) which indicates the multigear and multispecies nature of the marine fisheries in Kerala.

## Determining gear interactions with ETP species

A major conservation concern is the interaction of different gears with ETP (Endangered, Threatened and Protected) species and the expanded database allows us to examine this in the long term. The maximum interaction was observed with MGN followed by MDTN, MTN and OBHL. In terms of the percentage of the catch of all the ETP species by the gears it is less than 0.05% of the total. Many gears such as MPS and MRS did not record any interaction with ETP species (Fig.12).

Table 5. Number of species caught exclusively by a gear

| Gear | MDTN | MGN | MHL | MCGR | MPS | MRS | MTN | NM | OBBS | OBGN | OBHL | OBCGR | OBRS | OBSS | OBTN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of species | 68 | 11 | 15 | 9 | 0 | 1 | 93 | 32 | 0 | 25 | 15 | 2 | 5 | 0 | 2 |

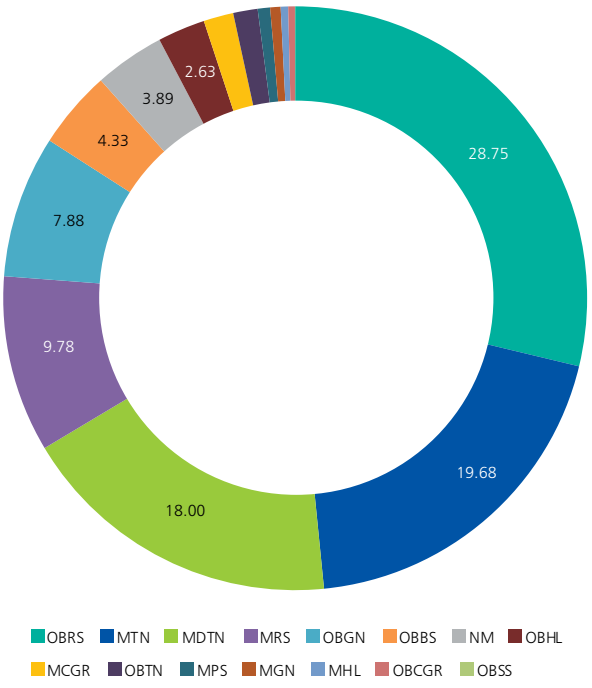


Fig.11. Percentage contribution of gear-wise landings to the total landings from 1985 to 2019. [MDTN- Multiday Trawlnet, MGN-Mechanised Gillnet, MHL- mechanised Hook& Line, MCGR-Mechanised Combination Gears, MPS-Mechanised Purseseine, MRS- Mechanised Ringseine, MTN-Mechanised Trawlnet, NM- Non-Mechanised (Artisanal), OBBS-Outboard Boatseine, OBGN- Outboard Gillnet, OBHL-Outboard Hook & Line, OBCGR- Outboard Combination Gears, OBRS- Outboard Ringseine, OBSS- Outboard Shoreseine, OBTN- Outboard Trawlnet]

Table 6. Number of species that occurred in multiple gears

| No. of gears | No. of species caught |
|---|---|
| 15 | 20 |
| 14 | 39 |
| 13 | 32 |
| 12 | 33 |
| 11 | 35 |
| 10 | 36 |
| 9 | 38 |
| 8 | 58 |
| 7 | 50 |
| 6 | 53 |
| 5 | 72 |
| 4 | 85 |
| 3 | 131 |
| 2 | 190 |
| 1 | 278 |

## Determining species that are to be assessed

In the multispecies and multigear fisheries as in Kerala, it is important to develop an objective methodology to determine which are the species to be assessed, for determining their stock status. In an ecosystem perspective, it is not feasible to assess many of them due to several reasons and stock assessments cannot be practically done for all the 78 most common species every year. Species

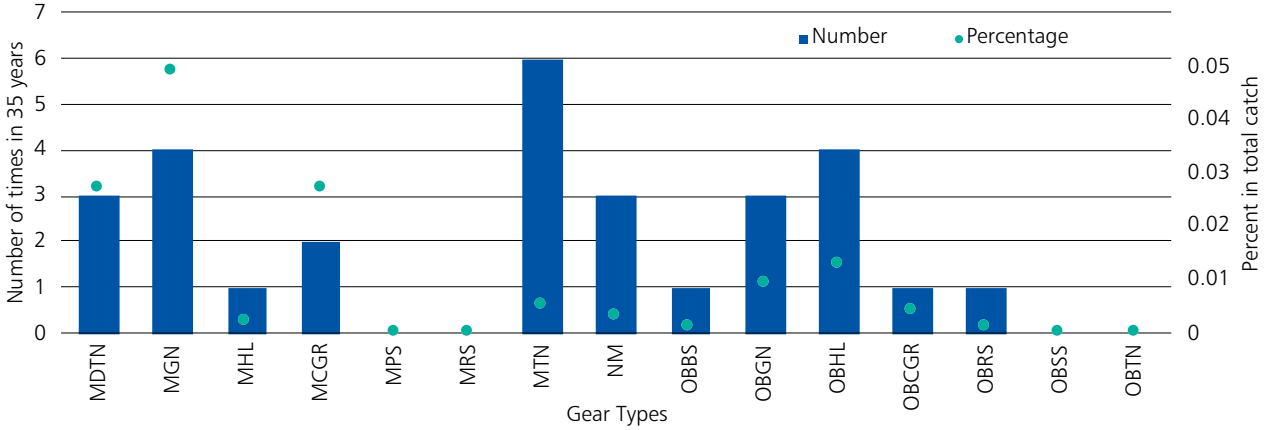


Fig.12. Record of incidental capture of ETP species in Kerala during the 35 years.

that form a substantial portion of the catch (and thence a major component of the ecosystem) and those having high economic value are usually the targets of fishers. The remaining catch is usually considered a bycatch or incidental catch. Many authors have classified bycatch as low-value bycatch (LVB), trash etc (Dineshbabu *et al*., 2014; Mahesh *et al*., 2019).

The number of species to be assessed was determined based on the cumulative distribution of both catch percentage & value and the gear-wise distribution of the 78 species is provided (Fig. 13 & 14). The lines on the top show the gears in which a few species are dominant, while those at the bottom show a more diverse species distribution. This indicates that outboard gears such as OBTN, OBRS and OBSS and the mechanised gears such as MRS and MPS are exploiting only a few species and attained the maximum for cumulative percentage with the species ranked within ten species. For other gears, the species diversity is more.

Of the 78 species, the list of species selected as per the criteria are shown in Table 7. Among these, the genera indicated with spp. are those in which the species have to be identified based on their dominance among the genera. Evidently, several species require multigear assessments (Fig.15)

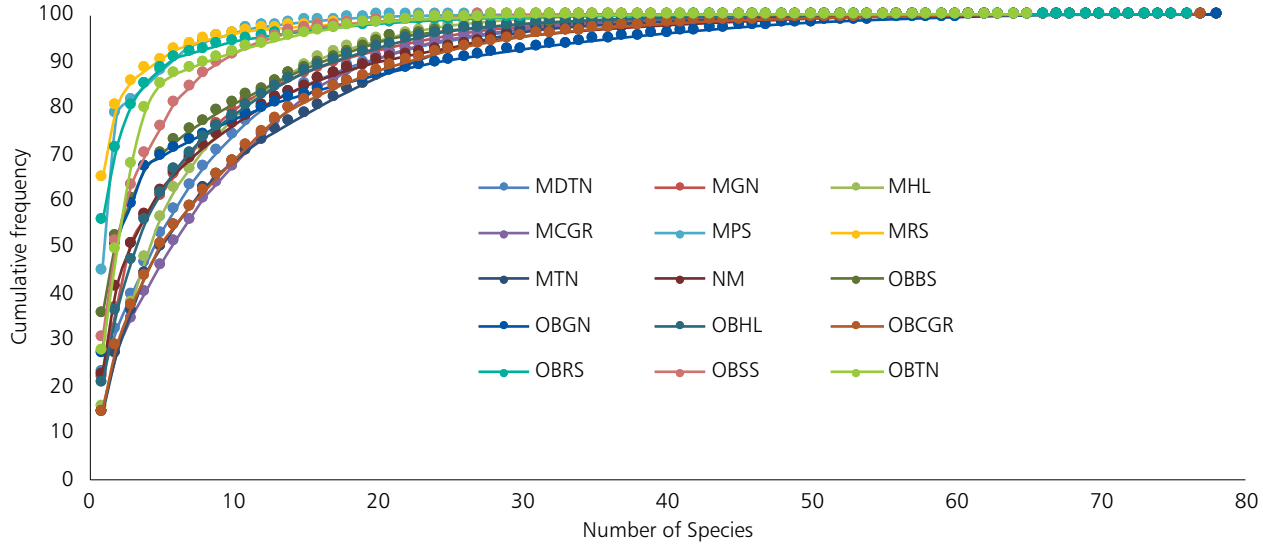


Fig.13. Cumulative frequency distribution (Based on landings) of the selected 78 species in each gear.

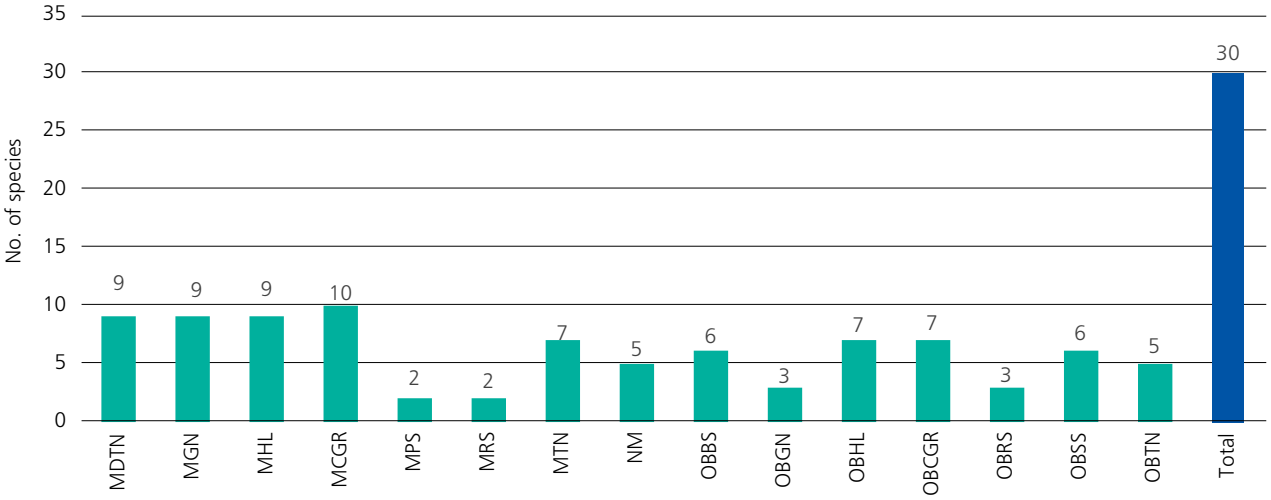


Fig.14. Gear-wise distribution of the number of species to be assessed

Table 7. Gear-wise list of species to be assessed.

| MDTN | MGN | MHL |
|---|---|---|
| 1. *Decapterus russelli* | 1. *Auxis thazard** | 1. *Carcharhinus* spp. |
| 2. *Metapenaeus dobsoni* | 2. *Carcharhinus* spp.* | 2. *Epinephelus* spp.* |
| 3. *Nemipterus* spp. | 3. *Euthynnus affinis* | 3. *Euthynnus affinis* |
| 4. *Priacanthus* spp.* | 4. *Rastrelliger kanagurta* | 4. *Istiophorus platypterus* |
| 5. *Rastrelliger kanagurta* | 5. *Scomberomorus commerson* | 5. *Sepia* spp. |
| 6. *Saurida tumbil** | 6. *Scomberomorus guttatus** | 6. *Thunnus albacares* |
| 7. *Sepia* spp. | 7. *Thunnus albacares* | 7. *Trichiurus* spp. |
| 8. *Trichiurus* spp. | 8. *Parastromateus (=Formio) niger(=F. niger)* | 8. *Himantura* spp. |
| 9. *Uroteuthis duvaucelii* | 9. *Himantura* spp. | 9. *Uroteuthis duvaucelii* |

| MCGR | MPS | MRS |
|---|---|---|
| 1. *Carcharhinus* spp. | 1. *Rastrelliger kanagurta* | 1. *Rastrelliger kanagurta* |
| 2. *Decapterus russelli* | 2. *Parastromateus (=Formio) niger(=F. niger)* | 2. *Sardinella longiceps* |
| 3. *Euthynnus affinis* | | |
| 4. *Istiophorus platypterus* | | |
| 5. *Nemipterus* spp. | | |
| 6. *Rastrelliger kanagurta* | | |
| 7. *Scomberomorus commerson* | | |
| 8. *Thunnus albacares* | | |
| 9. *Trichiurus* spp. | | |
| 10. *Uroteuthis duvaucelii* | | |

| MTN | NM | OBBS |
|---|---|---|
| 1. *Cynoglossus* spp. | 1. *Decapterus russelli* | 1. *Amblygaster sirm** |
| 2. *Decapterus russelli* | 2. *Rastrelliger kanagurta* | 2. *Rastrelliger kanagurta* |
| 3. *Metapenaeus dobsoni* | 3. *Sardinella gibbosa* | 3. *Sardinella longiceps* |
| 4. *Nemipterus* spp. | 4. *Sardinella longiceps* | 4. *Sardinella fimbriata* |
| 5. *Parapenaeopsis stylifera* | 5. *Stolephorus* spp. | 5. *Stolephorus* spp. |
| 6. *Stolephorus* spp. | | 6. *Uroteuthis duvaucelii* |
| 7. *Uroteuthis duvaucelii* | | |

| OBGN | OBHL | OBCGR |
|---|---|---|
| 1. *Euthynnus affinis* | 1. *Auxis rochei** | 1. *Cynoglossus* spp. |
| 2. *Rastrelliger kanagurta* | 2. *Caranx* spp.* | 2. *Euthynnus affinis* |
| 3. *Sardinella longiceps* | 3. *Euthynnus affinis* | 3. *Parapenaeopsis stylifera* |
| | 4. *Rastrelliger kanagurta* | 4. *Penaeus indicus* |
| | 5. *Scomberomorus commerson* | 5. *Rastrelliger kanagurta* |
| | 6. *Sepia* spp. | 6. *Sardinella longiceps* |
| | 7. *Uroteuthis duvaucelii* | 7. *Stolephorus* spp. |

| OBRS | OBSS | OBTN |
|---|---|---|
| 1. *Rastrelliger kanagurta* | 1. *Amblygaster sirm* | 1. *Cynoglossus* spp. |
| 2. *Sardinella longiceps* | 2. *Leiognathus* spp. | 2. *Metapenaeus dobsoni* |
| 3. *Stolephorus* spp. | 3. *Rastrelliger kanagurta* | 3. *Oratosquilla nepa* |
| | 4. *Sardinella fimbriata* | 4. *Parapenaeopsis stylifera* |
| | 5. *Sardinella gibbosa* | 5. *Sardinella longiceps* |
| | 6. *Stolephorus* spp. | |

Appropriate species may be chosen for assessment as per expert opinion for Genus name with spp. ; *species exclusively caught in one gear

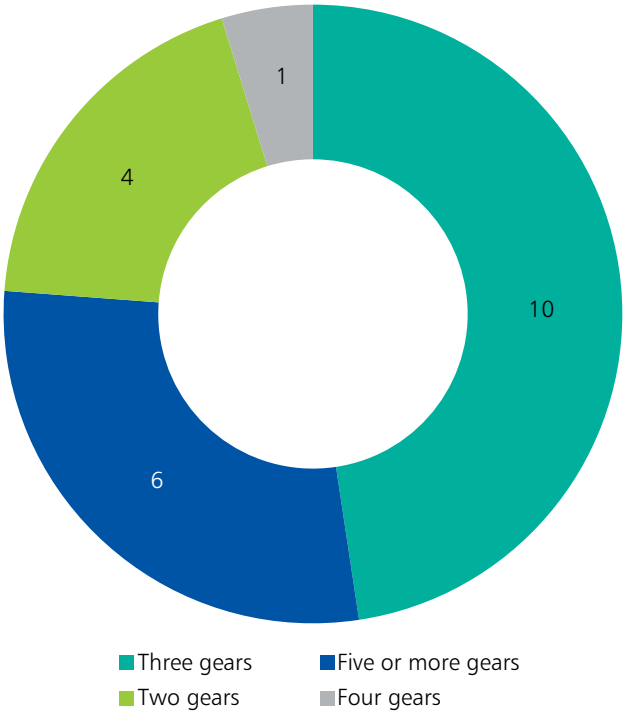


Fig.15. Number of species that require multigear assessments

## Conclusion

Expanding the NMFDC database has helped to explore the full range of species information in the catch and effort database. Assessing the status of fish stock is of utmost importance to develop management strategies for the sustainable harvest of marine fishery resources. To make it possible regularly in the case of tropical regions where species diversity is high, two components are very essential viz., the data about the status of marine fish stocks over periods and the number of stocks to be assessed. The periodicity of assessment of important species has been already reported by Kuriakose *et al*. (2020) based on longevity and life-history parameters. We believe that this analysis would be helpful to the researchers to objectively identify species that are to be assessed and for policymakers to set up guidelines for the management of the marine fishery resources in tropical regions.

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