

Mobulids caught by French purse seiners in the western Indian Ocean between 2005 and 2023

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Abstract

Mobulids (manta and devil rays) are large, generally pelagic rays, that are occasionally caught by various fishing gears, including purse seine. Most mobulids are listed as “Endangered” by IUCN. Here we present an overview of bycatch of mobulids accidentally caught by French purse seiners operating in the western Indian Ocean between 2005 and 2023 based on observer data. We observed 4 distinct species: spinetail devil ray (*Mobula mobular*), giant manta (*M. birostris*), Chilean devil ray (*M. tarapacana*), and smoothtail devil ray (*M. thurstoni*). Bycatch rates were low, with an overall probability of occurrence below 0.12% across the study period. Estimated total catches varied by species and year, ranging from 0 to 90 tons. No clear temporal or spatial trends in mobulids distribution were detected, though *M. thurstoni* was found exclusively in the Mozambique Channel. Species exhibited different associations with tuna school types, with *M. birostris* preferring floating object-associated sets and other species showing more balanced preferences. The study highlights the significant improvement in mobulids release with 89% of individuals being released alive by 2023, following the adoption of best practices for handling and release. The analysis of mobulids size and sex ratio revealed no apparent trends over time. The results underscore the rarity of bycatch of mobulids in the French purse seine fishery and the ongoing need for improved data collection and species identification to support conservation efforts.

Keywords *Mobula* spp | Bycatch | Purse seine | Western Indian Ocean

1. Introduction

Rays from the Mobulidae family (manta and devil rays) are sensitive species present in the Indian Ocean that are classified as globally “Endangered” by the IUCN (IUCN, 2024) and listed on the CITES Appendix II prohibiting trade on this species (CITES, 2023). Mobulids are occasionally bycaught in the Indian Ocean by tuna purse seine fleets, among other fishing gears (Martin, 2020; IOTC, 2023). IOTC Resolution 19/03 prohibits vessels from setting any gear on mobulid rays and requires fishermen to promptly release alive and unharmed any bycaught mobulid rays following certain handling procedures. Like most elasmobranchs, mobulids are particularly vulnerable to overfishing due to their characteristics of low reproductive rates, slow growth, and late maturity (Croll et al., 2016; Martin, 2020). Mobulids were therefore identified as a priority species for conservation by IOTC (IOTC, 2024). Despite mobulid rays being data poor species, the IOTC Scientific Committee shall review the status of mobulids and provide management advice to the Commission, as well as identifying possible hot spots for conservation and management.

In this paper, we provide an overview of data on Mobulidae species accidentally caught by French purse seiners operating in the western Indian Ocean. These data were collected through observer programs between 2005 and 2023. As an overview, we provide the species composition of mobulids, estimated total catch, presence probability in sets, spatio-temporal distribution, fate of individuals and status at release, preference vis-à-vis tuna school type, size distribution, and sex-ratio.

2. Material and methods

2.1. Data

Observations of mobula species were recorded in the frame of observer programs covering French purse seiners operating in the western Indian Ocean between 2005 and 2023: DCF (*Data Collection Framework*) funded by EU and IRD since 2005, and OCUP (*Observateur Commun Unique et Permanent*) funded by the French purse seine fishing industry and public funds since 2013 (Goujon et al., 2017). The onboard observer coverage varied between 1 % and 12 % between 2005 and 2012 when DCF was the only program and ranged between 14 % and 47 % after 2012 when OCUP complemented DCF (Figure 1). Onboard observers record various information about vessel activities and fishing operations, including the occurrence and number of individuals of bycatch species, their fate, status at release, size measurements and sex. When observers were not able to identify Mobulidae rays at the species level, individuals were recorded as RMV, the generic FAO code for the genus *Mobula*. Records that were doubtful or that could be confirmed by pictures, were also degraded to RMV.

2.2. Analyses

Summary

A summary of mobulids data is presented in [Table 1](#), including the number of observed, sampled, individuals, the minimum and maximum sizes in Disk Width (DW, in cm) observed in the samples, the number of sexed individuals and sex ratio.

Species composition

The relative proportion of mobula species is shown in [Figure 2](#).

Presence in sets

The percentage of sets with occurrences of the respective mobula species is presented in [Table 2](#) and [Figure 3](#).

Total catch

The total catch of each mobula species is provided as the weight (in tons) raised to the total fishing effort ([Table 2](#); [Figure 4](#)). This calculation is based on the bycatch/tuna ratio raising method described in [Amandè et al. \(2010\)](#), similarly to the tasks 1 and 2 data annually provided by EU.France to IOTC in the 1RC, 1DI and 3CE forms.

Spatial distribution

The spatial distribution of mobulids in observed sets is shown by quarter ([Figure 5](#)) and year between 2005 and 2023 ([Figure 6](#)).

School type preference

The preference of each mobula species vis-à-vis purse seine school type – free-swimming tuna school set (FSC) and floating object-associated school set (FOB) – is shown in [Figure 7](#).

Status at release (all species)

The fate and status at release of mobulids across the period covered by observer programs is presented by species in [Table 2](#) and for all species grouped in [Figure 8](#).

Size distribution

Sizes of mobula rays were collected in Disk Width (DW, in cm). The overall size distribution of each mobula species is presented in [Figure 9](#), as well as the yearly size distributions as boxplots since the onset of data collection (2005) in [Figure 10](#).

Sex ratio

The percentage of females among individuals for which sex could be collected and determined is presented in [Table 1](#).

3. Results

A total of 311 individuals, classified into 4 species and 1 genus, was observed in the bycatch of French purse seiners between 2005 and 2023 (Table 1). We found 4 mobula species (Table 1; Table 2), with the spinetail mobula *Mobula mobular* (RMM, 44.69 %) being the most common, followed by the giant manta *M. birostris* (RMB, 14.79 %), Chilean devil ray *M. tarapacana* (RMT, 7.4 %), and smoothtail mobula *M. thurstoni* (RMO, 0.32 %). A substantial number of mobulids were not identified at the species level, hence noted *Mobula spp.* (RMT, 32.80 %) (Table 1; Figure 2).

All mobula species were not observed each year (Table 2; Figure 3). The probability of occurrence of mobulids in purse seine sets was very low throughout the period: 0-0.12 % for RMM, 0-0.05 % for RMB, 0-0.03 % for RMT, and 0-0.01 % for RMO.

Total estimated catch, composed of discards only in the case of the French purse seine, ranged from 0 to 90 tons depending on the mobula species (Figure 4). Over the period, RMB yearly varied between 0 and 30 tons, RMM between 0 and 90 tons, RMO was 0 tons except 0.025 tons the year it appeared at one occasion (2015), RMT ranged between 0 and 38 tons, and RMV between 0 and 13 tons.

Mobula species – except RMO – do not exhibit patterns in their distribution related to the seasonality (Figure 5) nor throughout the period (Figure 6). The only RMO bycatch occurred in the southernmost French purse seine fishing grounds in the Mozambique Channel (Figure 5; Figure 6).

School type preference of mobula species varies among species (Figure 7). RMB was mostly present in FOB sets (74 %), while RMM and RMT presence in both set types was relatively balanced (respectively 52 % and 44 % in FOB sets), and RMO was exclusively found in FSC sets.

Throughout the 2005-2023, all mobulids accidentally caught by French purse seiners were discarded (Table 2; Figure 3). The proportion of individuals released alive have varied but mostly have increased over the period, from 0 % in 2005 to 89 % in 2023 (Figure 8).

A total of 153 individuals were measured on the 311 observed (Table 1). RMB ranged between 140 and 550 cm DW (N = 24), RMM between 95 and 360 cm DW (N = 74), the only RMO was 111 cm DW, RMT between 175 and 310 cm DW (N = 11), and the remaining 43 RMV were between 130 and 329 cm DW (Table 1; Figure 9). For none of the mobula species there seems to be a trend over time in the mean size or size distribution of the sampled individuals (Figure 10).

A total number of 70 individuals could be sexed (Table 1). The percentage of females in RMB was 38 % (N = 8), 52 % in RMM (N = 40), 100 % in RMO (N = 1), 67 % in RMT (N = 3), and 72 % in the remaining undetermined mobulas (N = 18).

4. Discussion

Four species of mobula were found in interaction with French purse seiners throughout the period: RMB, RMM, RMO and RMT. There are other mobula species in the Indian Ocean that were however not observed such as the reef manta ray *Mobula alfredi* (RMA) and the pigmy devilray *Mobula eregoodootenkee* (RME). A substantial number of individuals (33 %) could not be identified at the species level, hence noted RMV. This is because (1) observers were generally not well trained in the earlier period (prior to 2020) to discriminating the different mobula species, and (2) because there might not have been pictures for some observed trips in historical data allowing to identify the species a posteriori. The development of an identification guide by IRD also greatly improved species identification by observers ([Sabarros et al., 2022](#)).

Mobulas are rare bycatch of the French purse seine in the western Indian Ocean with a probability of presence in fishing operations generally under 0.12 %. The yearly total catch of mobula rays greatly varied, from 0 up to 80 tons for certain species, for instance RMM. The total absence of a certain species within a given year can likely be explained by the fact that such rare events as the accidental catch of mobulids have great chances of being missed the lower the observer coverage is. Observer data collected between 2005 and 2013 where coverage was below 20 % are considered less reliable than the period 2014-2023 where coverage ranged between 20 and 47 %. This might be especially relevant is the case of rare bycatch species such as mobulids. Based on our data, no trends seem to stand out in the time series (estimated total catch and presence in sets) of the respective mobula species.

There does not seem to be an effect of the season (quarter) on the distribution patterns of the respective mobula species. Mobulas are randomly distributed in the observed sets within the French purse seine fishing grounds. Only RMO exhibit a particular pattern even though it is only one individual: it was found in the southernmost fishing grounds located within the Mozambique Channel.

Mobula species such as RMO appears to associate with tuna free-swimming schools while RMB seems to associate more to the surroundings of floating objects. The other two species, RMM and RMT, appear to equally associate with both types of tuna schools.

All mobulas that were accidentally caught by French purse seiners were discarded. The proportion of individuals released alive was null or relatively low in the earlier years but the situation drastically improved since 2013 with the majority of individuals being released alive thanks to the implementation best practices for safe handling and release of elasmobranchs ([Poisson et al., 2014](#)), to end up with 89 % of the mobulas released alive in 2023.

The sizes of encountered individuals fall well within the minimum and maximum sizes known for the respective species ([Martin, 2020](#)). The size distributions of the different mobula rays, despite the number of sampled individuals being relatively low for some of the species (RMO and RMT), do not show any trend over period.

The number of sexed individuals was too low to do any spatio-temporal analyses and investigate potential reproductive seasonality and reproductive grounds, in addition to the fact that sexual maturity cannot be assessed non-invasively by observers.

5. Acknowledgements

Data collection through DCF was co-financed by IRD and EU via FEAMPA funds, and OCUP was funded by the French purse seine industry and public funds.

6. References

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7. Tables

Table 1. Summary of data on mobulids observed and sampled in the bycatch of French purse seiners in the western Indian Ocean between 2005 and 2023

| FAO code | Common name | Scientific name | IUCN Red List status | Observed | Sampled | Measure type | Min obs. size | Max obs. size | Sexed | % females |
|----------|-------------------|--------------------------|----------------------|----------|---------|--------------|---------------|---------------|-------|-----------|
| RMB | Giant manta | <i>Mobula birostris</i> | Endangered | 46 | 24 | DW | 140 | 550 | 8 | 38 |
| RMM | Devil fish | <i>Mobula mobular</i> | Endangered | 139 | 74 | DW | 95 | 360 | 40 | 52 |
| RMO | Smoothtail mobula | <i>Mobula thurstoni</i> | Endangered | 1 | 1 | DW | 111 | 111 | 1 | 100 |
| RMT | Chilean devil ray | <i>Mobula tarapacana</i> | Endangered | 23 | 11 | DW | 175 | 310 | 3 | 67 |
| RMV | Mobula nei | <i>Mobula spp</i> | - | 102 | 43 | DW | 130 | 329 | 18 | 72 |

Table 2. Number of observed mobulas by year, estimated total catch (in tons), probability of presence in sets (%) and percentage of individuals discarded alive

| FAO code | Year | Observed | Total catch (t) | Probability in sets (%) | Discarded alive (%) |
|----------|------|----------|-----------------|-------------------------|---------------------|
| RMB | 2007 | 5 | 30,728 | 0,04 | 40 |
| RMB | 2013 | 2 | 3,113 | 0,02 | 0 |
| RMB | 2014 | 2 | 3,263 | 0,02 | 100 |
| RMB | 2015 | 1 | 1,682 | 0,01 | 100 |
| RMB | 2016 | 9 | 3,052 | 0,07 | 100 |
| RMB | 2018 | 9 | 8,04 | 0,05 | 56 |
| RMB | 2019 | 6 | 4,202 | 0,05 | 83 |
| RMB | 2020 | 2 | 0,81 | 0,02 | 100 |
| RMB | 2022 | 7 | 13,663 | 0,05 | 43 |
| RMB | 2023 | 3 | 2,238 | 0,03 | 100 |
| RMM | 2007 | 3 | 7,81 | 0,02 | 67 |
| RMM | 2008 | 4 | 15,108 | 0,02 | 25 |
| RMM | 2009 | 1 | 2,527 | 0,01 | 0 |
| RMM | 2013 | 1 | 1,128 | 0,01 | 100 |
| RMM | 2014 | 8 | 2,974 | 0,05 | 62 |
| RMM | 2015 | 19 | 5,759 | 0,12 | 89 |
| RMM | 2016 | 18 | 3,202 | 0,12 | 83 |
| RMM | 2017 | 33 | 30,021 | 0,05 | 91 |
| RMM | 2018 | 14 | 2,748 | 0,06 | 50 |
| RMM | 2019 | 8 | 1,32 | 0,04 | 88 |
| RMM | 2020 | 5 | 3,326 | 0,04 | 60 |
| RMM | 2021 | 2 | 1,298 | 0,02 | 100 |
| RMM | 2022 | 8 | 89,875 | 0,07 | 75 |
| RMM | 2023 | 15 | 2,817 | 0,1 | 87 |
| RMO | 2015 | 1 | 0,024 | 0,01 | 0 |
| RMT | 2005 | 1 | 37,751 | 0,01 | 0 |
| RMT | 2008 | 1 | 4,031 | 0,01 | 0 |
| RMT | 2009 | 2 | 5,923 | 0,02 | 50 |
| RMT | 2014 | 4 | 3,04 | 0,03 | 100 |
| RMT | 2017 | 1 | 0,136 | 0,01 | 100 |
| RMT | 2019 | 4 | 2,211 | 0,03 | 75 |
| RMT | 2020 | 5 | 17,257 | 0,03 | 40 |
| RMT | 2021 | 3 | 2,042 | 0,02 | 0 |
| RMT | 2023 | 2 | 1,239 | 0,02 | 50 |
| RMV | 2006 | 12 | 11,268 | 0,02 | 0 |
| RMV | 2008 | 1 | 12,782 | 0,01 | 0 |
| RMV | 2009 | 8 | 8,042 | 0,04 | 62 |
| RMV | 2011 | 1 | 0,573 | 0,01 | 0 |
| RMV | 2012 | 1 | 0,559 | 0,01 | 0 |
| RMV | 2013 | 4 | 3,879 | 0,03 | 75 |
| RMV | 2014 | 11 | 5,005 | 0,07 | 55 |
| RMV | 2015 | 24 | 13,272 | 0,12 | 62 |
| RMV | 2016 | 15 | 2,812 | 0,06 | 93 |
| RMV | 2017 | 7 | 1,293 | 0,04 | 100 |
| RMV | 2018 | 4 | 0,925 | 0,04 | 75 |
| RMV | 2019 | 1 | 0,435 | 0,01 | 100 |
| RMV | 2020 | 5 | 2,606 | 0,04 | 80 |
| RMV | 2022 | 1 | 0,209 | 0,01 | 100 |
| RMV | 2023 | 7 | 1,704 | 0,04 | 100 |

8. Figures

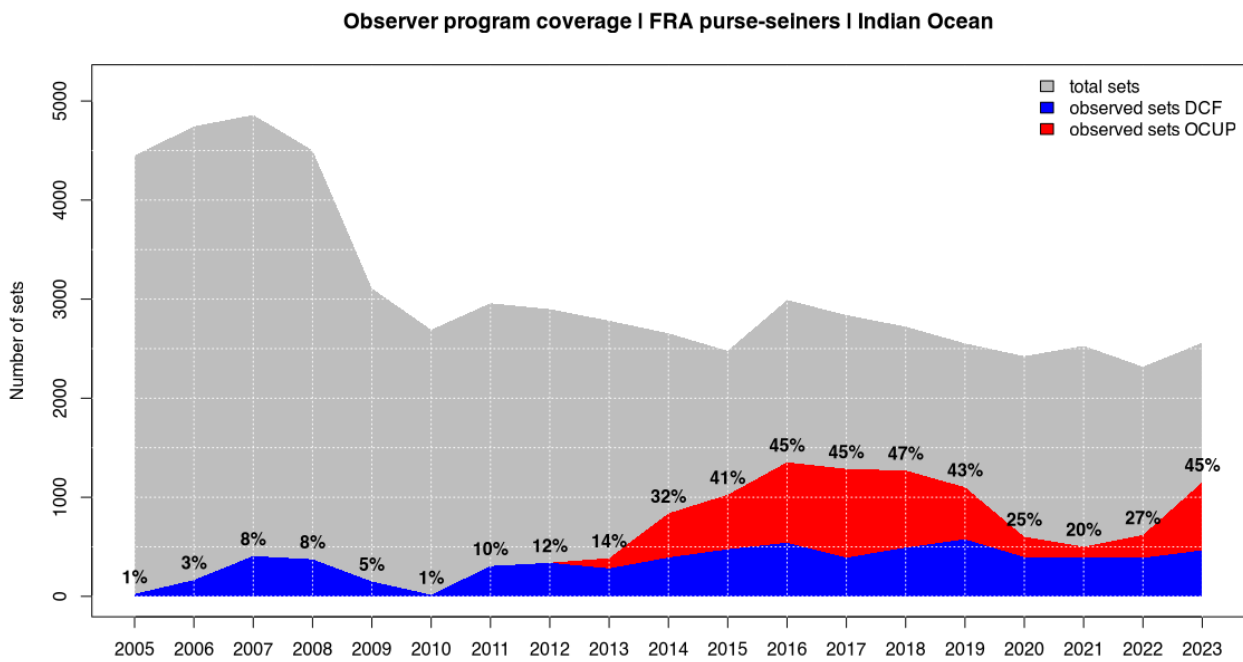


Figure 1. Observer coverage (in sets) on French purse seiners operating in the Indian Ocean between 2005 and 2023

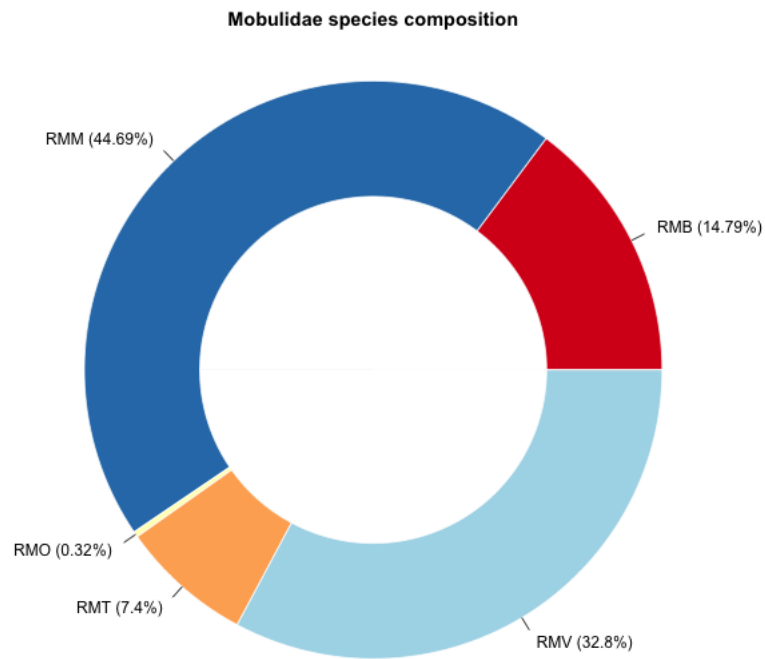


Figure 2. Mobulidae species composition in French purse seiners bycatch in the western Indian Ocean between 2005 and 2023

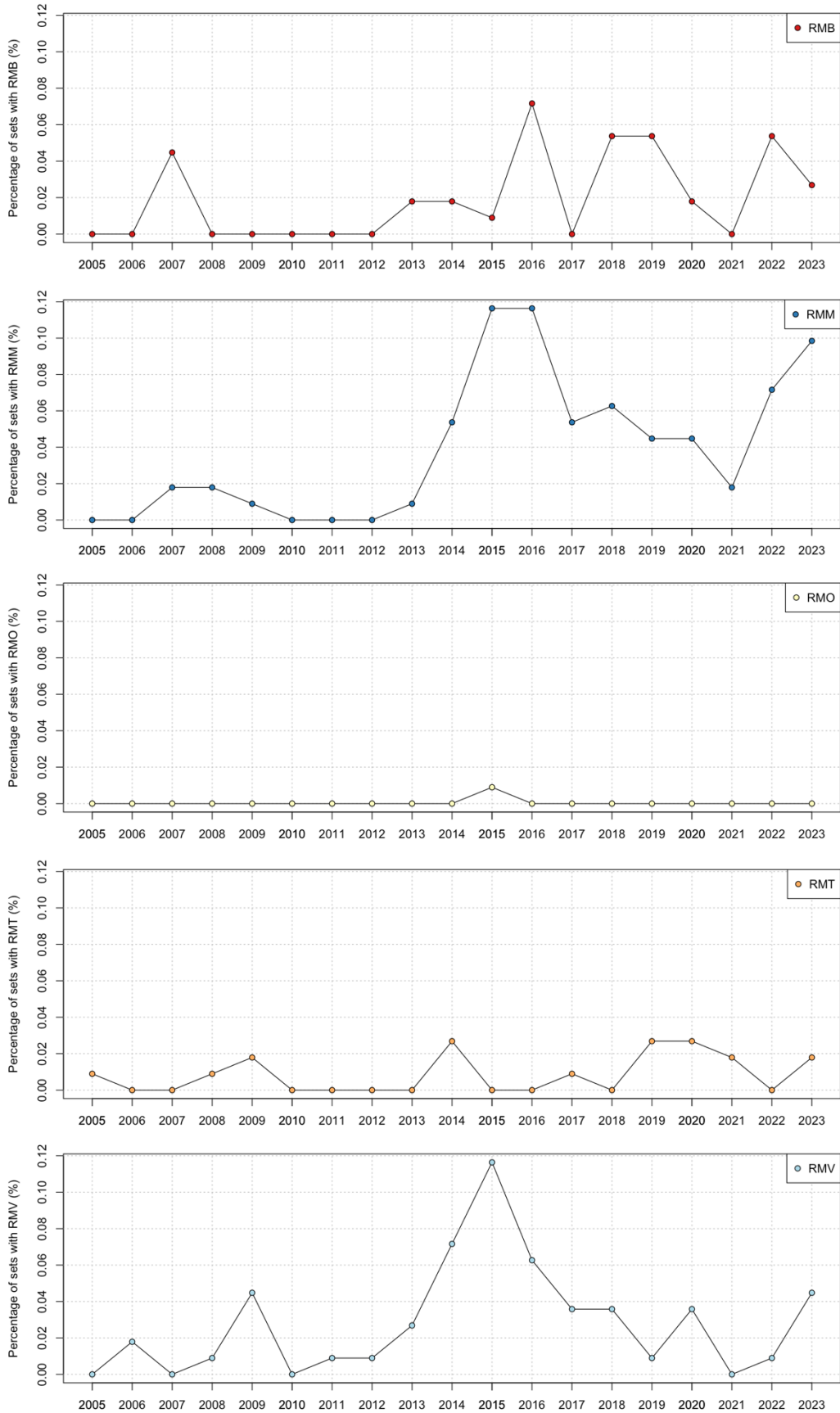


Figure 3. Occurrence probability of mobulids in purse seine sets between 2005 and 2023

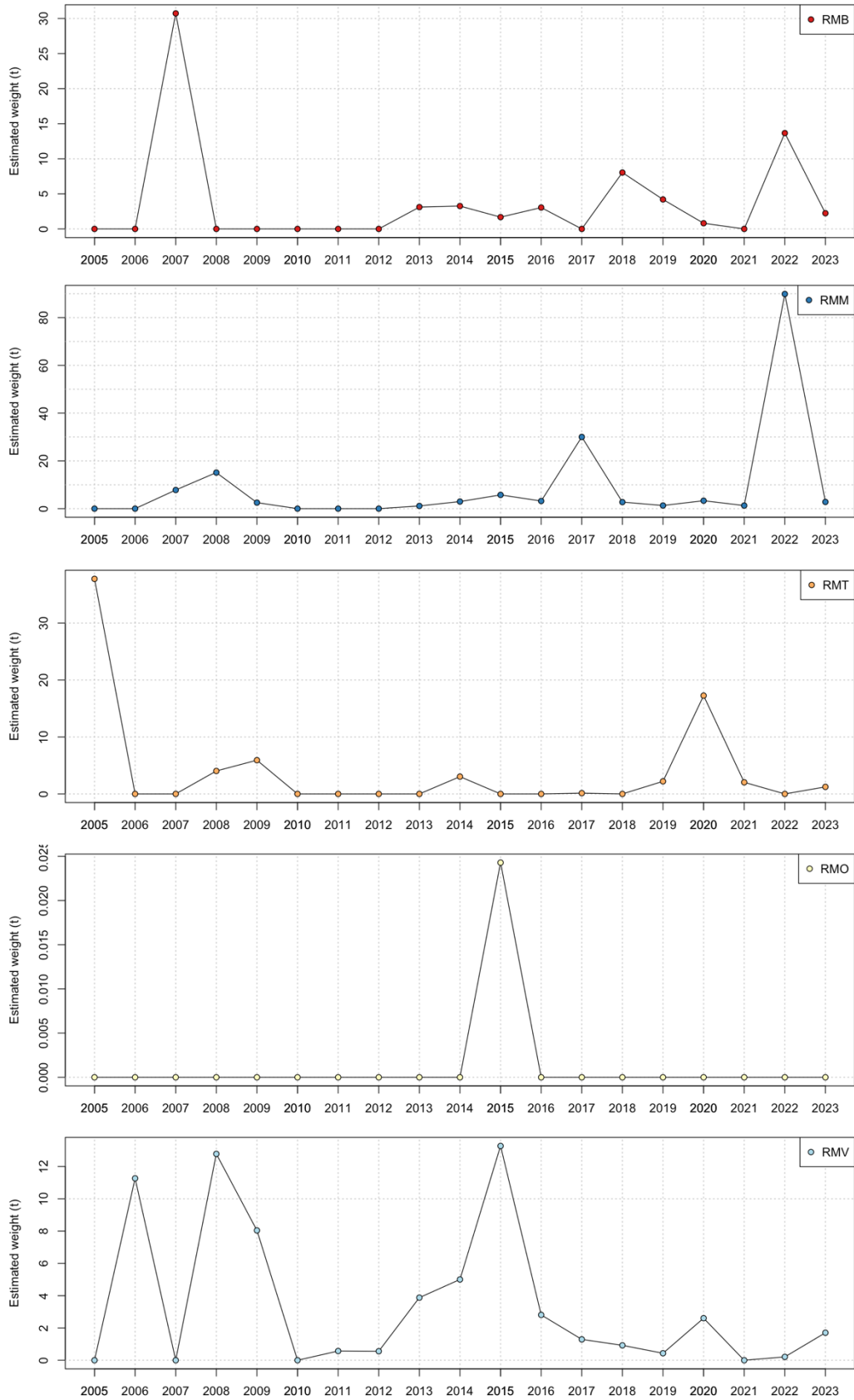


Figure 4. Estimated total catch (in tons) of mobula species between 2005 and 2023

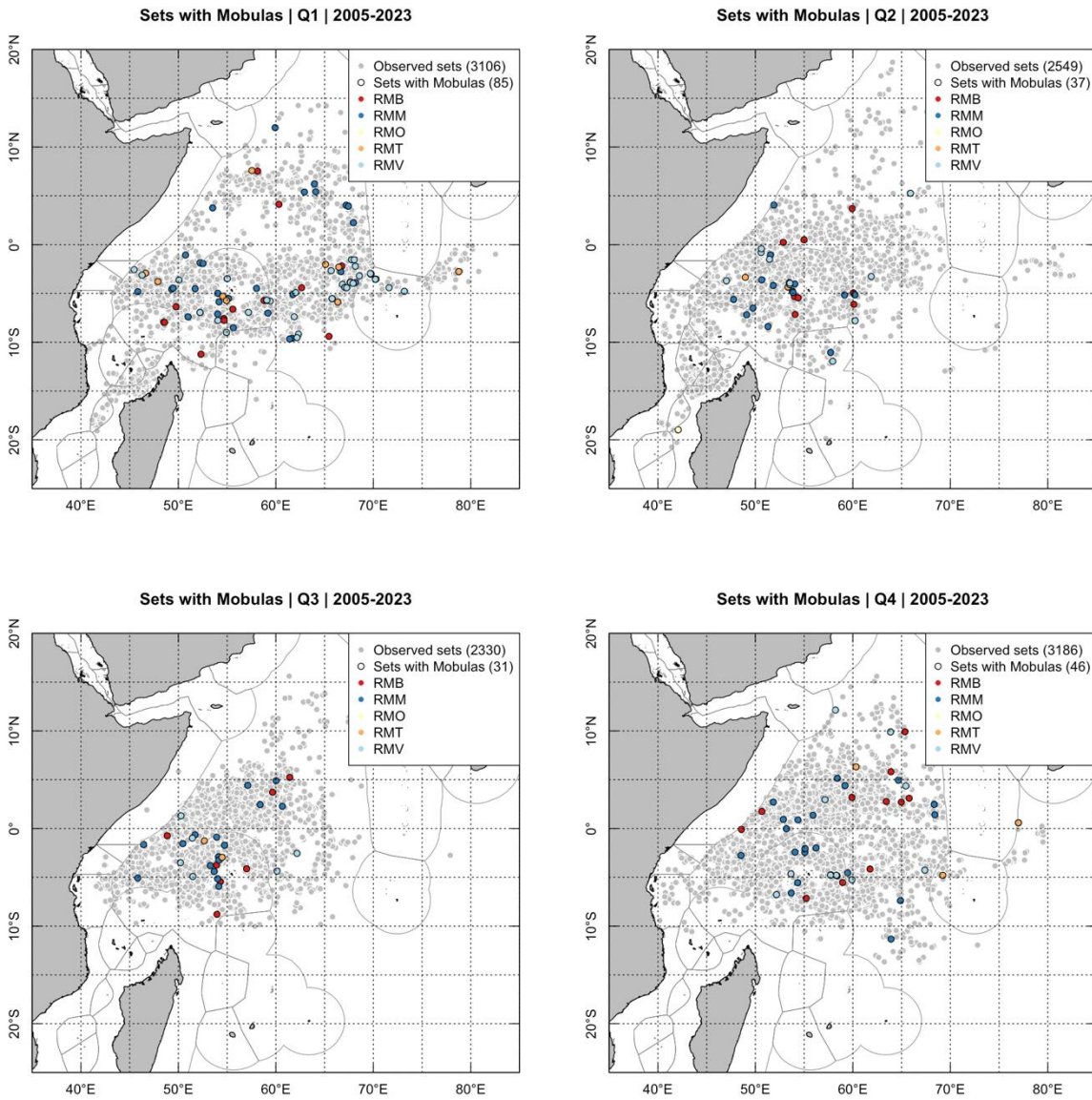


Figure 5. Quarterly distribution maps of observed sets and sets with mobulas (2005-2023)

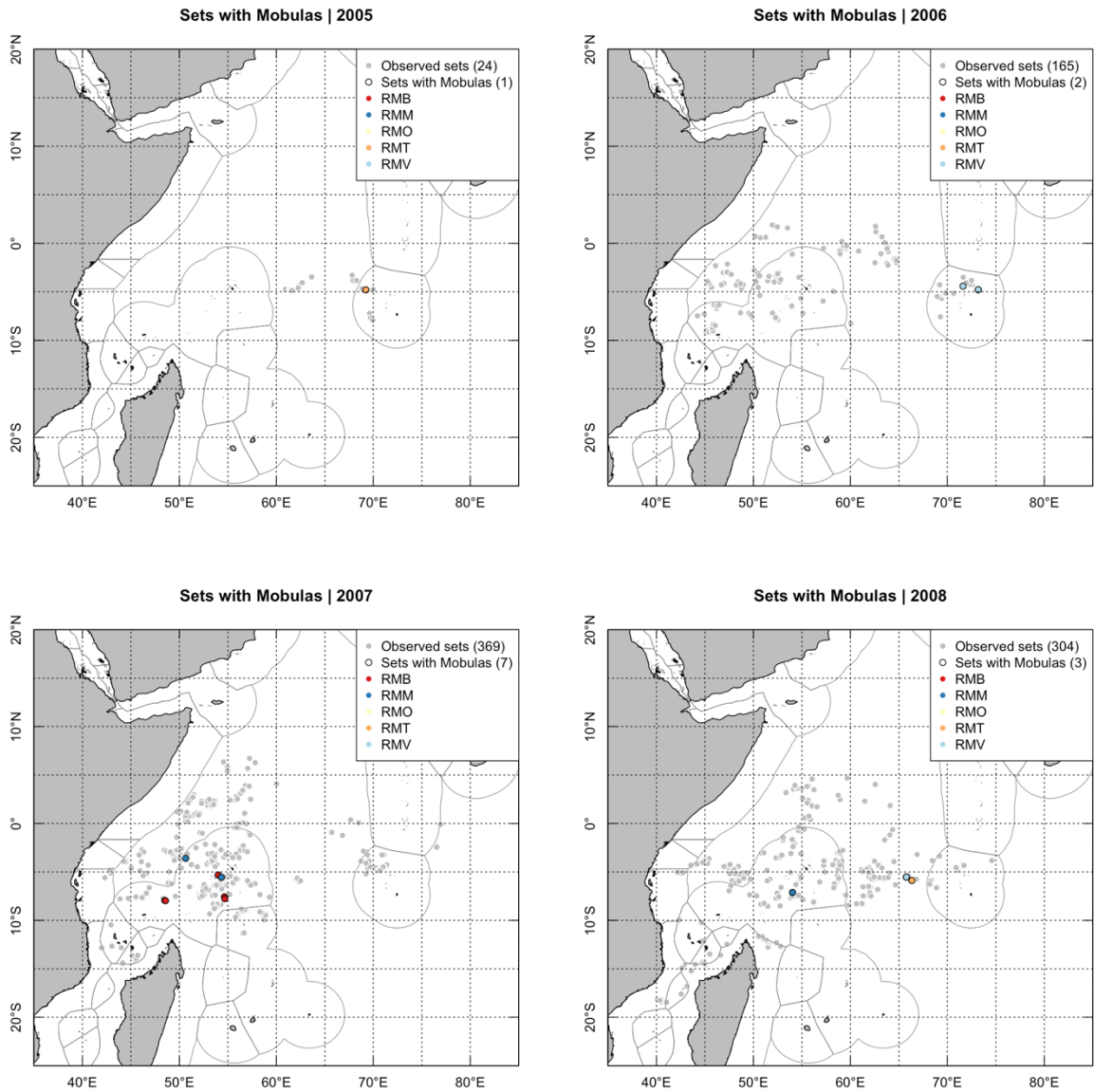


Figure 6. Yearly distribution maps of observed sets and sets with mobulas (2005-2023)

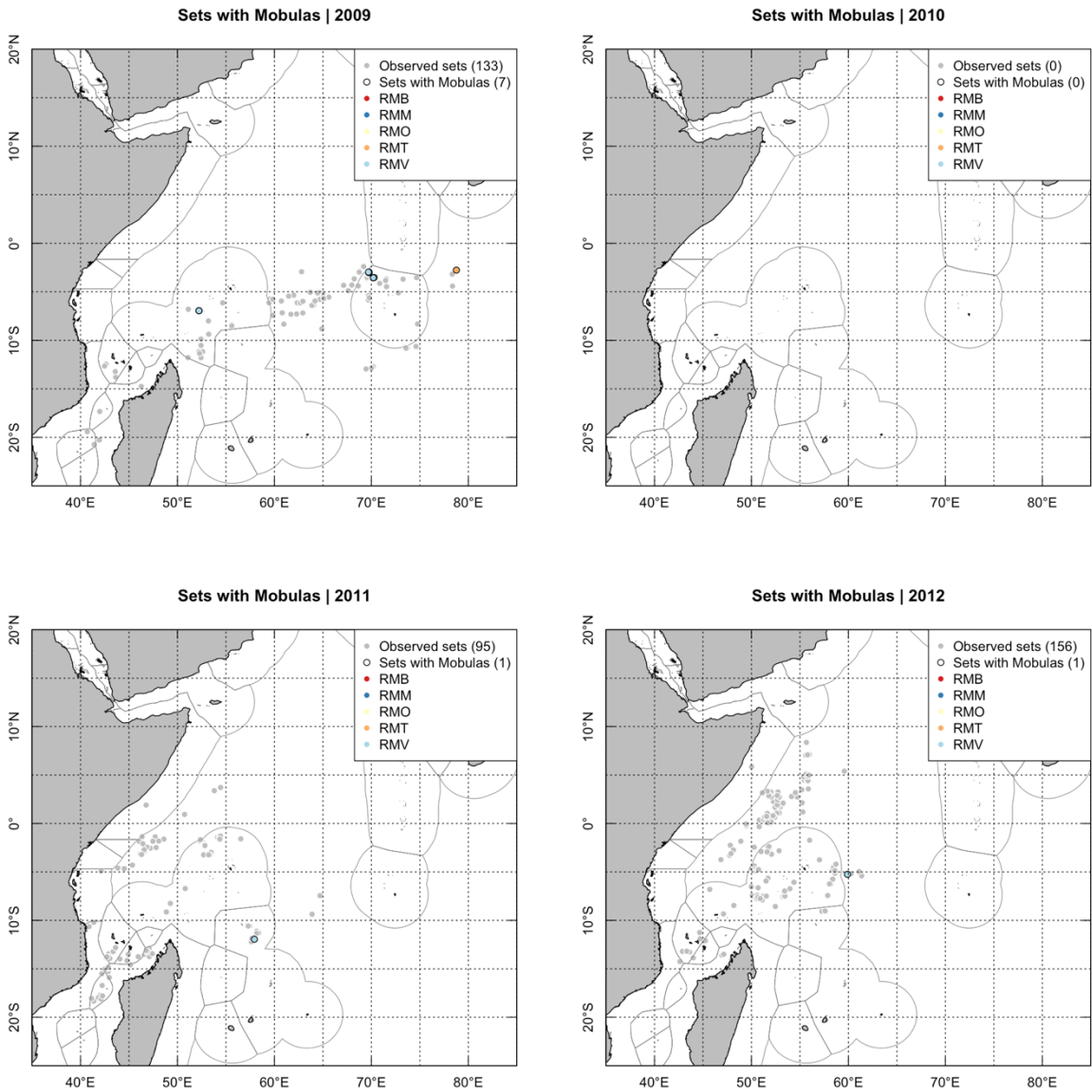


Figure 6 (continued). Yearly distribution maps of observed sets and sets with mobulas (2005-2023)

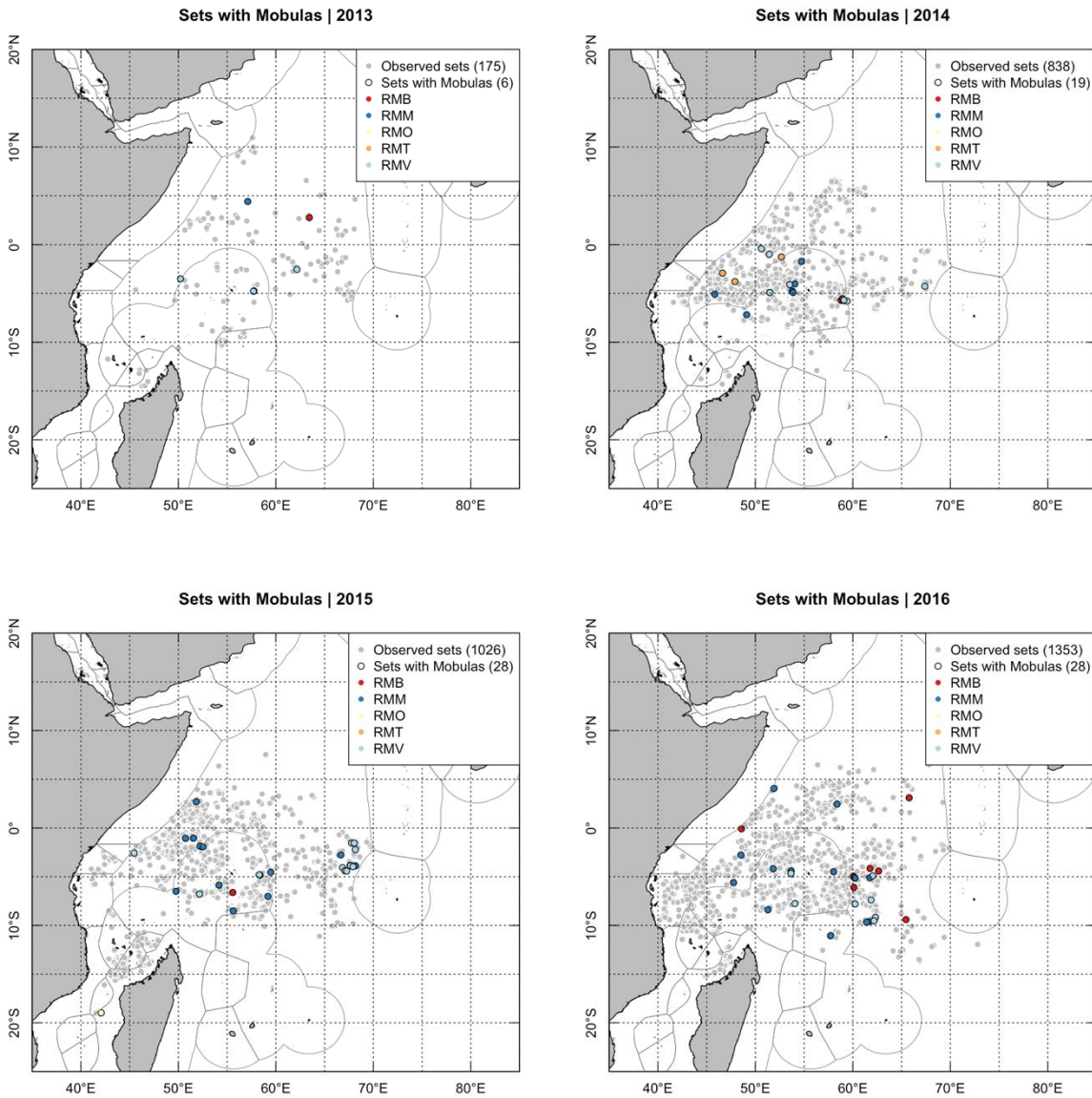


Figure 6 (continued). Yearly distribution maps of observed sets and sets with mobulas (2005-2023)

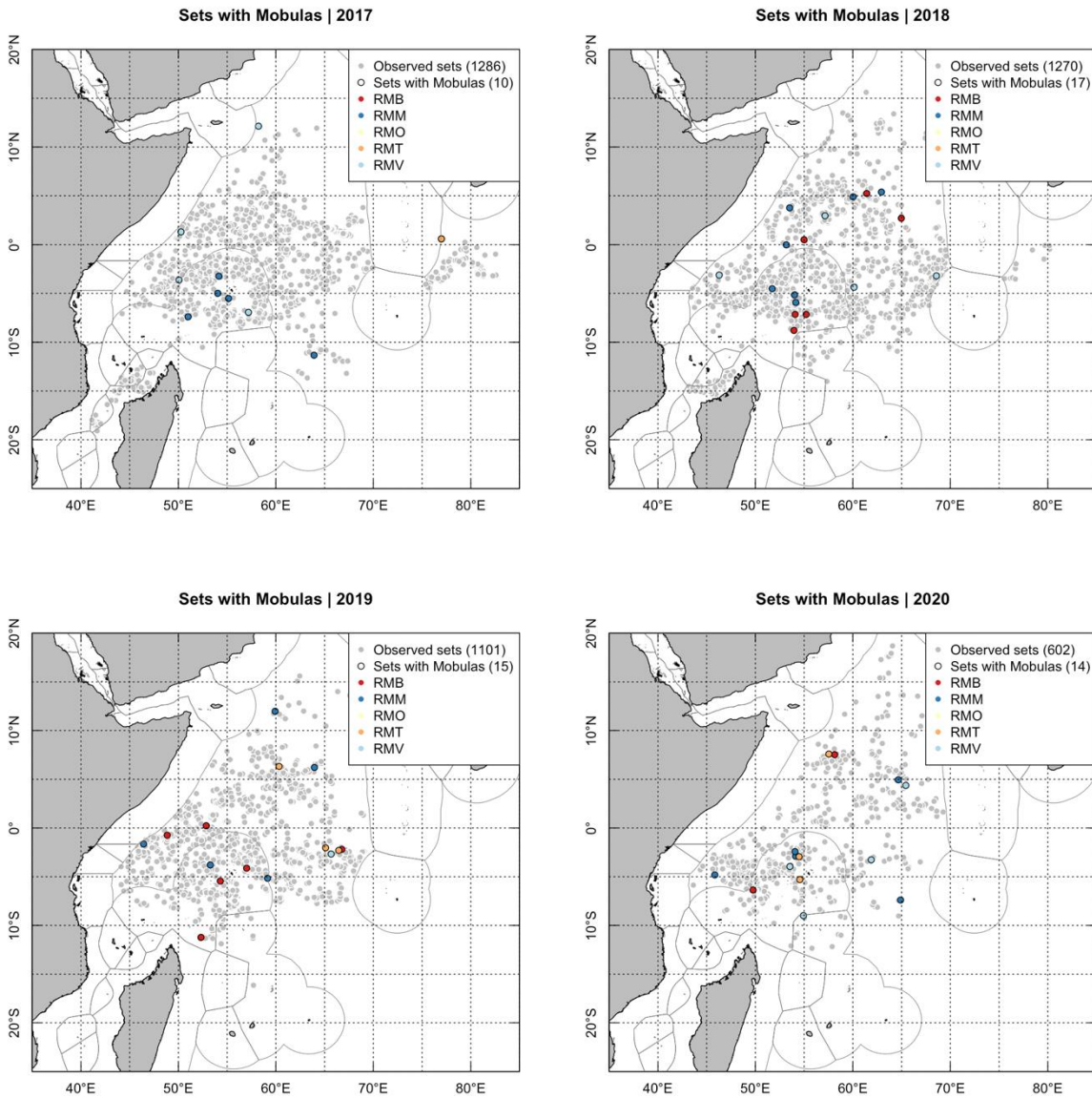


Figure 6 (continued). Yearly distribution maps of observed sets and sets with mobulas (2005-2023)

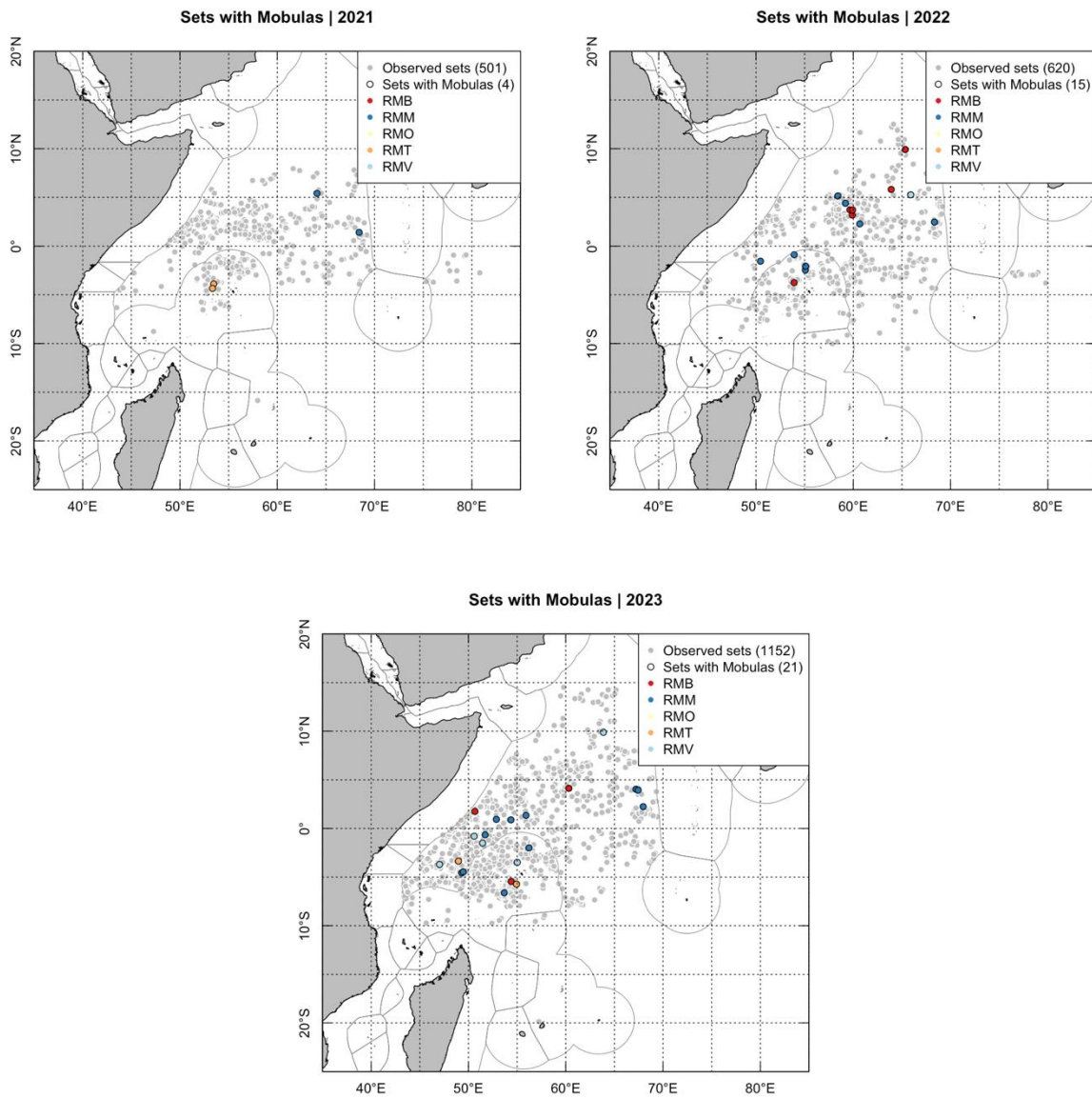


Figure 6 (continued). Yearly distribution maps of observed sets and sets with mobulas (2005-2023)

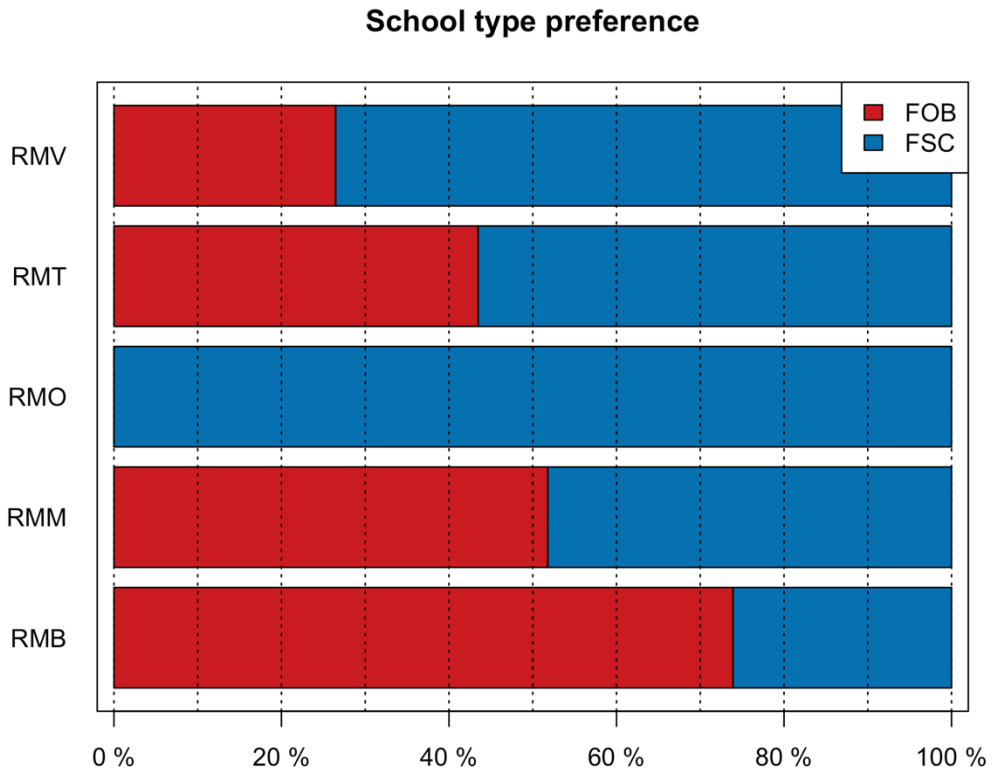


Figure 7. Purse seine school type preference of mobula species

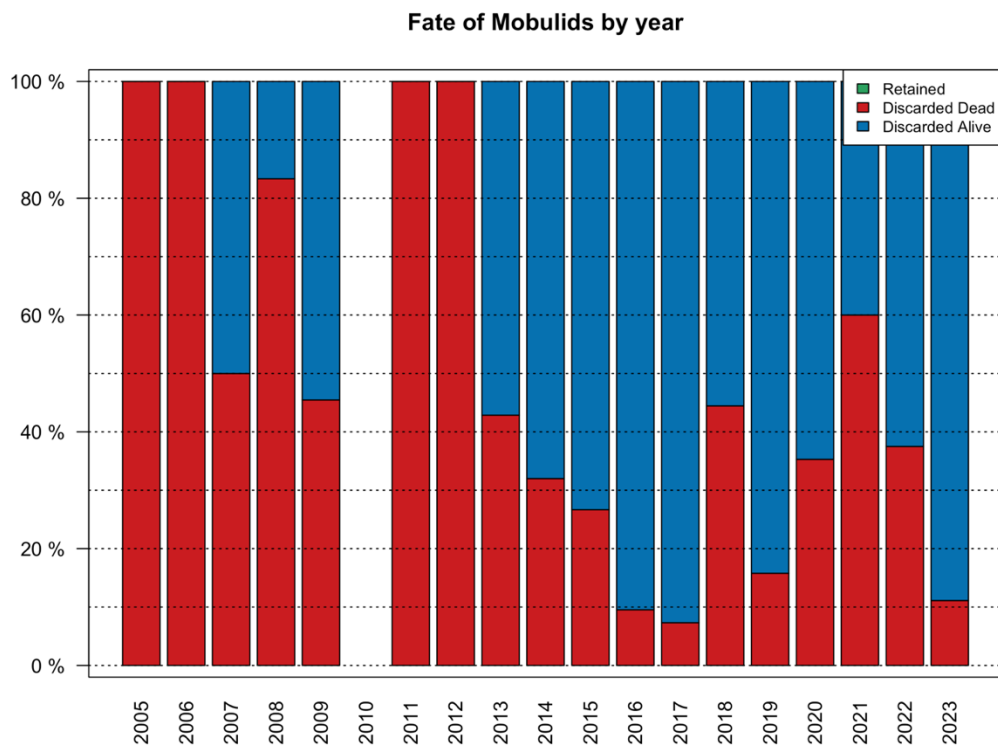


Figure 8. Fate and status at release of mobulids caught by French purse seiners

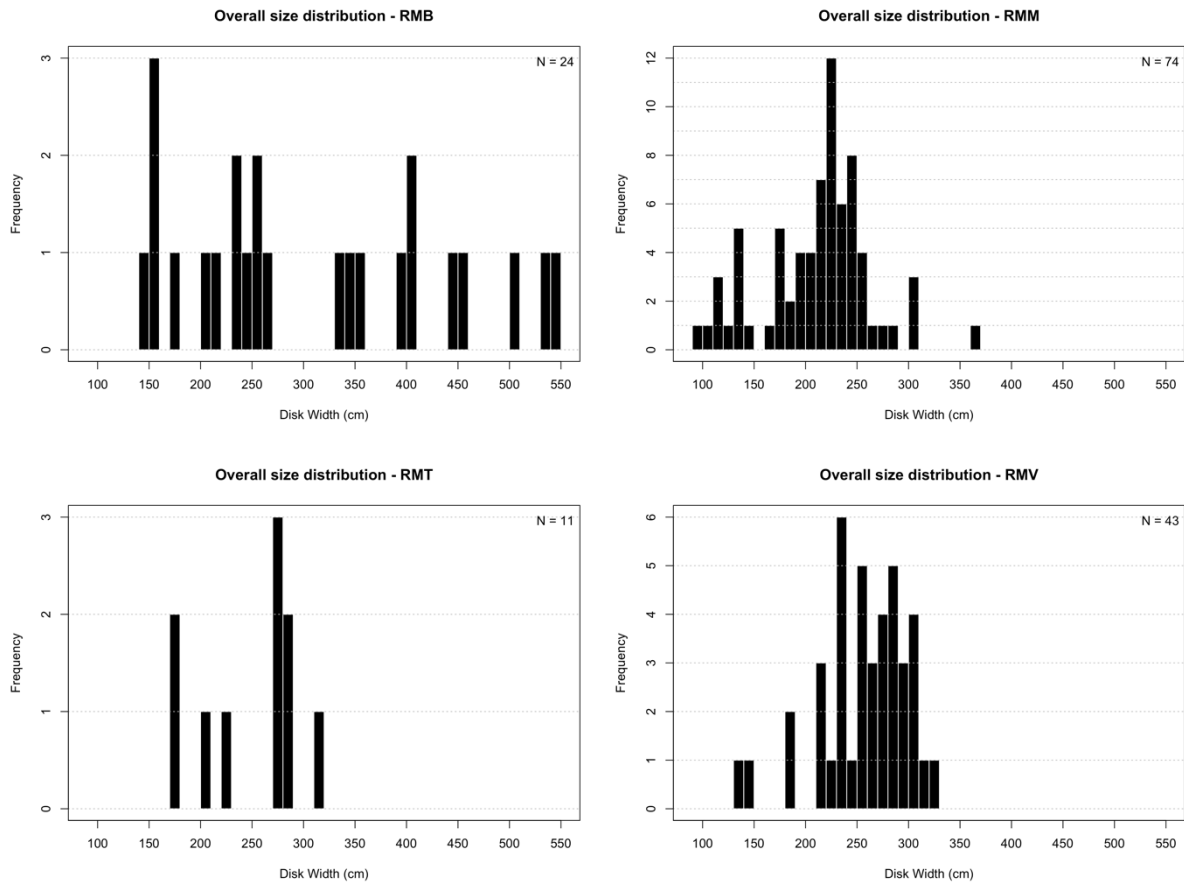


Figure 9. Overall size distributions of mobulids caught by French purse seiners in the Indian Ocean between 2005 and 2023

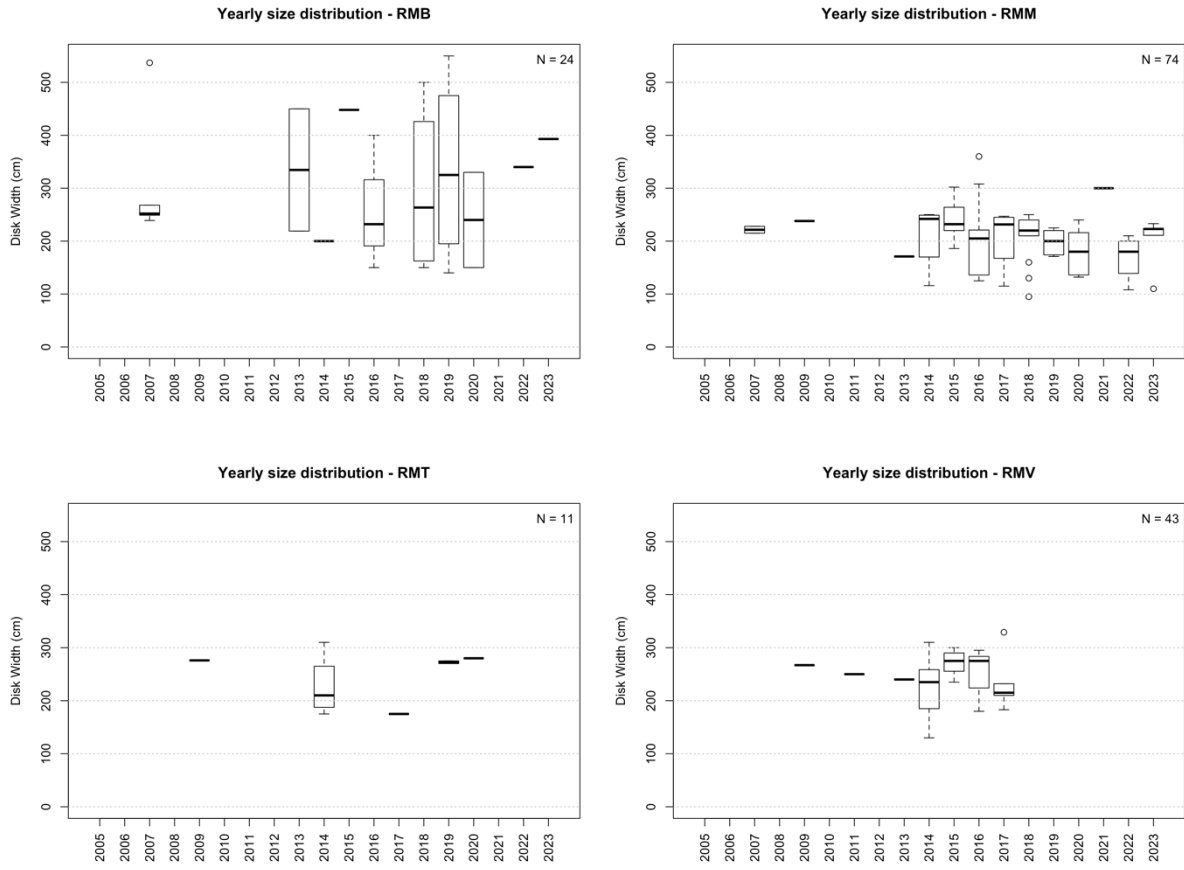


Figure 10. Yearly size distributions of mobilulids caught by French purse seiners in the Indian Ocean