IOTC-2023-WPTT25-18_rev1

Preliminary analysis of observer data on the presence of mesh in floating objects used by the French purse seine fleets in the Atlantic and Indian Oceans

David M. Kaplan[1,*], Pascal Cauquil[1], Antoine Duparc[1], Taha Imzilen[1] and Philippe Sabarros[1]

1. MARBEC (Univ. Montpellier, CNRS, Ifremer, IRD), av. Jean Monnet, CS30171, 34203 Sète, France

* *Correspondence:* David M. Kaplan david.kaplan@ird.fr

ABSTRACT

We conducted an initial analysis using data from observers aboard French PS vessels in the Atlantic and Indian Oceans of the composition of FOBs deployed, fished and encountered by the French fleet focusing on the use of netting. Data before 2019 are insufficient for assessing the presence of netting as fields for noting this type of information were only added to observer data protocols and data entry platforms in 2019. There are also a number of important caveats to using this data for assessing the prevalence of netting in FOBs, including the data collection protocol used by observers on French vessels not instruction them to collect detailed data on FOB compositions, the non-zero data entry error rate in observer data, and observed differences in rates of FOBs with netting as a function of observer program and observer country of origin. Nevertheless, our observations are globally consistent with both independent analyses of dFAD composition in the Indian Ocean and more anecdotal observations of dFADs found in coastal environments in the Indian Ocean. Non-negligible numbers of FOBs with netting were recorded in 2019-2020, but rates decline significantly in 2021-2022, with average observed rates of FOBs with netting across observer programs being on the order of 3-5% for both oceans and both years. Non-zero levels of netting are observed in both dFADs and other objects of natural or human origin. Consistent differences in observation rates across observer programs and observer countries of origin suggest that enhanced training and changes in the observation protocol for the French fleet are needed to more accurately estimate the composition of FOBs used by PS vessels. Furthermore, given the very low rate of FOB deployments with netting in 2021-2022, we cannot eliminate the possibility that data entry errors or misinterpretations by observers of data collection instructions explain some or all of the observations. This possibility could potentially be examined by comparison with other data sources (e.g., logbooks) and/or other fleets, as well as interviews with observers. Finally, given the misinterpretation that could be created by PS vessels fishing upon or deploying tracking buoys upon non-dFAD objects that may contain netting (e.g., FALOGs randomly encountered at sea), it would potentially be valuable to implement a policy of not attaching tracking buoys to these objects and permanently removing them from the water when encountered.

1 Introduction

The materials that make up the drifting fish aggregating devices (dFADs) and more generally floating objects (FOBs) deployed and used by purse seine (PS) fisheries have become a major issue of concern in terms of the pollution they can cause (e.g., Imzilen et al. 2021, 2022, MacMillan et al. 2022), potential for entanglement (Filmalter et al. 2013) and compliance with RFMO regulations (e.g., IOTC Secretariat 2019, IPNLF 2023). In particular, a recent report (IPNLF 2023) claimed to have found large numbers of dFADs containing mesh materials posing a potential entanglement risk washing up on the shores of countries in the Western Indian Ocean, raising the question of the extent to which PS vessels continue to use netting in the dFADs they deploy.

Though information is recorded in captain's logbooks regarding the type and construction of dFADs they deploy and interact with, the lack of independence of these data raise questions regarding their reliability. One source of fishery independent data on dFAD use is observer data. Observer programs are run by fishery-independent, certified observer companies and observers are randomly assigned to PS vessels, providing a fishery independent source of information on PS vessel activities. Though primarily focused on recording PS vessel activities and bycatch, in recent years observers have begun to collect increasingly sophisticated data on the FOBs that PS vessels use and deploy. Nevertheless, these data have not yet been extensively used to examine the materials contained in FOBs. Here we provide an initial examination of observer data from the French PS fleets in the Atlantic and Indian Oceans focusing on the presence in FOBs of mesh or netting that potentially pose a risk of entanglement. We also highlight potential inconsistencies in the data and future improvements in data collection that could be implemented.

2 Methods

2.1 Observer programs

Observer data covering the French purse seine (PS) fleet in the Atlantic and Indian Oceans over the period 2005 to 2023 were analyzed in this study to identify information pertinent to describing the materials used in floating objects (FOBs). Observer data from two different observer programs were included in the analysis: the European Union-funded, IRD-coordinated "Data Collection Framework" (DCF; Reg 2017/1004 and 2016/1251) and the "Observateur Commun Unique Permanent" (OCUP) program coordinated by ORTHONGEL, the NGO representing the French PS fleet (Goujon et al. 2017). The data contain information regarding a wide variety of individual PS vessel activities, though here we are solely concerned with activities related to FOBs and associated information on FOB composition.

Coverage of observer programs has varied significantly over the time period considered, as has the level of detail recorded in data on FOB operations and FOB composition (i.e., the materials used to construct FOBs). Before ~2013, observer coverage is low (~5-15%) in both oceans with the exception of certain moratoria periods in the Atlantic Ocean before 2005, data for which have not been included in our analysis as little or no information was recorded on FOB construction materials. From 2014 to the onset of COVID pandemic, coverage increased to nearly 100% in the Atlantic Ocean and to

~25-50% in the Indian Ocean (below 100% due to constraints imposed by the threat of Somali piracy). During 2020-2021, coverage decreased due to the COVID pandemic, particularly in the Indian Ocean, but has since begun to rebound in 2022.

The relatively strong observer coverage since ~2014 does not mean that recording of FOB construction materials has been constant over time. Before 2019, observers were presented with a relatively limited set of options for describing the general composition of FOBs and were not permitted to select multiple different materials. Available options for FOB materials generally did not explicitly mention netting and/or were open to interpretation (e.g., "Non-entangling object"). As such, for this period we cannot conclude that netting was not used based on observer data (and available knowledge of dFAD construction would suggest that netting of various sizes was regularly used). Data for this period are therefore included in this study for completeness purposes, but should not be considered as evidence for or against the presence of netting in dFADs.

From 2019 onward, a much more detailed set of options for describing FOB materials was presented to observers, including information on netting and mesh size, and multiple categorizations of FOBs were permitted. However, different strategies regarding the level of information demanded of observers were chosen by the French and Spanish PS fleets. Whereas Spanish observers were requested to enter detailed information regarding the use of netting and mesh size (in particular whether or not mesh size was less than or greater than 7 cm), French observers were only requested to describe FOB composition up to the categorization level developed in the CECOFAD program (Table 1), which does not include detailed information on netting. This choice for the French fleet was made based on considerations of how much information it was assumed that observers could reliably obtain and enter into data collection platforms in the time that is typically available to make observations and taking into account the other data that observers must reliably collect (e.g., bycatch data). Nevertheless, either because of due diligence or because observer training is not always adapted to the specific requirements of the French fleet or for some other as of yet unidentified reason, more detailed information on FOB composition is recorded for some FOBs in the French observer data. See Section 2.3 for more details on how this information was used to place FOBs into different categories regarding their composition.

2.2 FOB operations classification

We separated the different vessel activities on FOBs into three different categories as follows:

1) Vessel activities with numerical code `6` were classified as `Fishing`
2) Object operations indicated as deployments were classified as `Deployment`
3) All other activities, including FOB visits for inspection or modification of FOBs, were classified as `Other`

The composition of FOBs is indicated in observer data both when the vessel arrived at the FOB and when the vessel left the FOB, the two potentially being different due to modifications to the FOB during the vessel activity. For the purposes of our analyses, FOB categories described below (Section 2.3) were assessed when arriving at the FOB for `Fishing` activities, when leaving for `Deployment` activities, and as a combination of both for `Other` activities.

2.3 FOB materials classification

Observers record information on the composition of FOBs during vessel encounters with FOBs, either to fish on them, deploy new FOBs or visit existing FOBs. Nevertheless, it is complicated to use this data to directly assess whether a FOB includes netting for a number of technical and conceptual reasons. One reason is that FOB composition entries are presented to observers as a hierarchy of nested categories. For example, the material `Open net with mesh >7cm` is actually associated with the following hierarchy: `Open net with mesh >7cm` ⊂ `Mesh` ⊂ `Subsurface structure` ⊂ `DFAD (drifting FAD)` ⊂ `FAD` ⊂ `FOB`. Observers can generally select any point along the hierarchy instead of the final leaf as a material used in the FOB, meaning that the association of a given material with an object should positively indicate that the material is present (excluding data entry errors), but the presence of a material higher up in the hierarchy (e.g., `Subsurface structure` in the given case) does not necessarily indicate the presence or absence of the specific material (i.e., `Open net with mesh >7cm` in the example given). This is particularly pertinent given the instructions to observers on French vessels to use the more coarse-grained CECOFAD classification system (Table 1) and not necessarily collect more detailed information on FOB materials, as described in Section 2.1.

Another complication is that the system is generally designed to confirm the presence of a material, but not specifically to confirm the absence of other materials, which must be assumed implicitly via the absence of those materials in the description of the FOB. There are some exceptions to these rules, such as material categories `No subsurface structure` or `Not covered` that explicitly exclude certain materials, but in general we assume that the absence of indications of mesh in a FOB combined with the presence of indications of fine-grained non-mesh, non-entangling materials is an indicator (after 2019) that the object does not include netting.

Given these limitations, we developed a system of classification of FOBs that is designed to be relatively conservative when assigning labels to FOBs. Categories were assigned in an order, with the first such valid category being that assigned to the FOB. The order of association was:

1) Any vessel interactions with FOB for which no FOB composition details were recorded were put in the `No info` category. This category almost exlcusively concerns older data well before 2019.

2) Any remaining FOBs (i.e., not classified in the previous step) for which there was an indication that it included large mesh netting (>7cm) or mesh netting of unknown dimensions was placed in the `Large mesh` category. The specific materials that were considered to indicate large mesh were:

   - `Net with mesh >7cm`, `Net in sausage`, `Open net with mesh >7cm`, `Single net pieces with mesh >7cm`, `Net, piece of net`, `Net with mesh of unknown mesh size`, `Open net with mesh of unknown size`, `Single net pieces joined with mesh of unknown size`, `Several FAD entangled`, `Entangling`

3) Any remaining FOBs for which there was an indication of small mesh netting was placed in the `Small mesh` category. The specific small mesh terms were:

   - `Net with mesh =<7cm`, `Open net with mesh =<7cm`, `Single net pieces with mesh =<7cm`

4) Any remaining FOBs for which there was some indication that part of the FOB was not visible was placed in the `Not visible` category. Not visible terms were:

   - `Not visible`, `Submerged or half-submerged`, `Other, unknown`

5) Any remaining FOBs for which there were materials that could be considered non-entangling were placed in the `No netting` category. This implicitly assumes that FOB descriptions are complete (unless there were explicit indications of incomplete visibility) so that any netting would have been noted and classified in the previous steps. No netting terms were:

   - `No subsurface structure`, `Not covered`, `Rope/no mesh`, `Tree, branche`, `Vegetal, canes,bamboo`, `Corks`, `Coverage without mesh`, `Palms, canes`, `VNLOG (vegetal NLOG)`, `Palm tree, palm`, `Carrion`

6) Any remaining FOBs were placed in the `Uncertain` category, meaning that there was no indication that they used netting, but there also wasn't a clear indication that they did not use netting.

Though this system is conservative in that it will have a tendency to consider an object as either containing mesh or uncertain unless there is a specific, positive indication of non-mesh materials, the `No netting` classification should still be interpreted as "no observed netting".

In addition to placing individual objects into the classes described above, we also obtained the CECOFAD classification (Table 1) for each FOB. As a small number (<5%) of FOBs were associated with multiple CECOFAD classes (e.g., due to being the result of combining multiple objects), a "dominant" CECOFAD class was assigned to the object so as to emphasize elements that might explain the presence or absence of netting in the following order (first that applied was kept): `FALOG`, `HALOG`, `VNLOG`, `ANLOG`, `AFAD`, `DFAD`, `FAD`, `FOB`.

2.4 Time periods for analyses

We focus on 4 distinct time periods for analyses. We initially provide an overview of the full observer dataset from the mid-2000's, but as noted above data on the use of netting in FOBs are not available before 2019. Next, we focus on the period 2019-2022, during which observers had the possibility of recording detailed FOB composition information, including information on netting. For certain analyses, we limit ourselves to the period 2020-2022 during which the deployment of FOBs with netting was formally prohibited in the Indian Ocean by Resolution 19/02 (IOTC Secretariat 2019). Finally, to focus on the most recent period characterized by low levels of observations of FOBs with netting, we limit some analyses to the period 2021-2022.

3 Results

Figure 1 shows the temporal pattern of FOB observations in observer data since the mid-2000's. The temporal changes in observer coverage and data collection are clearly visible, with low coverage before ~2014, much higher coverage between 2014 and 2019, and a more recent reduction due to COVID that has begun to rebound in 2022. There is a clear change in the nature of the data in 2019, with few observations of netting before 2019 and a high prevalence of low-precision `Uncertain` observation. From 2019 onward, the categorization of dFADs becomes more diverse, including the appearance of categories with mesh materials.

Based on these elements, we only focus on the period 2019-2022 for further analyses. The Atlantic and Indian Oceans show overall similar temporal patterns (Figure 2), though there is the curious lack of indicators of difficulty with FOB visibility in the Atlantic Ocean compared to the Indian Ocean, and greater prevalence of the `Uncertain` category (generally indicating FOB descriptions were limited to the CECOFAD FOB categories) in the Atlantic relative to the Indian. The prevalence of netting in FOB observations is highest in both oceans in 2019 and the first half of 2020, representing roughly 15-40% of the deployed FOBs during this time period. Observations of netting diminish significantly in 2021 and 2022, dropping below 5%, though non-zero observations are regularly recorded throughout the time period for both oceans and all classes of vessel/object activities.

3.1 Origins of FOB observations with netting

To better understand sources of observations of FOBs with netting, we examined just those observations classified as `Small mesh` or `Large mesh` for the period 2020-2022 with respect to various factors that could help explain these observations. Though FALOGs (i.e., fishing materials used as a FOB) are not surprisingly both numerically (Table 2) and in terms of percent prevalence (Table 3) an important source of FOBs with netting, there are non-zero numbers of dFADs (i.e., objects manufactured and deployed by PS vessels) with netting throughout the time series (Table 4). Considering just deployments, we find observations of both dFADs and other objects with netting, though the numbers and percentages are relatively small for the period 2021-2022 (Table 5).

There are notable differences in reporting rates of FOBs with netting as a function of ocean, observer program and country of origin of the observer. In the Indian Ocean, observers in the industry-financed OCUP program have a consistently higher rate of observations of FOBs with netting than observers in the EU-funded DCF program, whereas in the Atlantic the reverse is true (Table 6). In the Indian Ocean, this is potentially explained by Seychelles observers using a single data collection protocol for both Spanish and French vessels, thereby always collecting fine-grained information, though errors and/or misinterpretation of the FOB materials categories cannot be eliminated as possible explanations. In the Atlantic Ocean, the trend is more curious, but one potential explanations would be training differences for the distinct companies that provide observers to the DCF and OCUP programs. For the countries providing large number of observers to the two programs (France, Ivory Coast, Seychelles), temporal patterns of observations of FOBs with netting are similar, though observers from the Ivory Coast and the Seychelles tends to have a somewhat higher rate of observation of netting than observers from France (Table 7).

Analysis of the observation rate of FOBs with netting for the period 2021-2022 (i.e., the period for which only a small percentage of FOBs have netting) indicate significant heterogeneity between vessels in terms of the observed rate of deployment of FOBs with netting (Figure 3). Though many vessels rarely deploy FOBs observed to have netting (<10% or even 0% in some cases), a few vessels have >20% of observations with netting. It is important to caution, however, that differences in observer coverage by the two different observer programs at the vessel level and the limited number of observations or observers for some vessels could potentially explain part or all of this heterogeneity. The majority of vessels are associated with observations of FOBs with netting on either zero or one fishing trips, but 7 out of 20 vessels are associated with such observations on two or three trips and, of these, 4 had such observations by two or three distinct observers. 5 vessels have observations of FOBs with netting in both 2021 and 2022.

Examinations of the relative proportion of observations of FOB deployments with netting over the period 2021-2022 that correspond to individual observers, we find that only about 10-20% of observers note FOBs with netting. In the Atlantic, observations of FOBs with netting are highly skewed to three observers, with one observer accounting for ~75% of observations (Figure 4a). In the Indian Ocean, observations come from a somewhat more diverse group of observers, with five observers contributing at least 5% of the total number of observations (Figure 4b).

In terms of the precise materials that lead FOB observations to be classified as containing netting, in both oceans the material `Net with mesh =<7 cm` associated with the surface raft of a dFAD, followed by the vague FALOG material `Net, piece of net` are numerically the most important (Table 8). In the Indian Ocean (Table 8b), the dFAD subsurface material `Net in sausage` is numerically important, whereas, in the Atlantic Ocean (Table 8a), the subsurface materials `Single net pieces with mesh =<7cm` and `Open net with mesh =<7cm` are relatively common. All other materials are relatively uncommon and largely constrained to 2020.

4 Discussion

Our analysis of observations indicating the potential existence of dFADs containing netting used by the French fleet in recent years and the large decrease in their prevalence in 2021-2022 are globally consistent with both independent analyses of other dFAD composition data in the Indian Ocean (IOTC Secretariat 2023) and more anecdotal observations of dFADs found in coastal environments in the Indian Ocean (IPNLF 2023). In particular, the significant reduction in 2021-2022 with respect to 2019-2020 in the number of FOBs with netting is consistent with the trend in the characteristics of FOBs found in coastal environments reported by IPNLF (2023). In general, they observe FOBs in 2020-2021 with significant amounts of netting (e.g., Figure 5a), followed in 2022-2023 by objects with ropes and/or weights, but little observable netting (e.g., Figure 5b & Figure 5c) and objects with far less total material and no netting (e.g., Figure 5d). Nevertheless, additional work combining observer data with observer photos of FOBs, logbook data and data from other projects that have examined deployed FOBs (e.g., INNOV-FAD) is needed confirm this trend in dFAD construction. Furthermore, our analysis grouped together observations of netting in the subsurface structure of a FOB with observations of netting in the surface raft of a FOB, whereas future analyses might consider separating these two due to their distinct potentials for environmental impacts.

Though the rates of FOB observations with netting are consistently low across oceans in 2021-2022 (generally of order 3-5% average across observer programs), non-zero levels of dFADs with netting are observed throughout the time series for both oceans and for fishing and deployment activities. Though we would like to draw conclusions from this, we unfortunately cannot entirely eliminate the possibility that data entry errors or misinterpretations of the data collection protocol explain part or all of these observations. PS observer data for bycatch are known to have a non-zero error rate (e.g., Briand et al. 2018), and it is reasonable to assume that similar errors occur in the FOB composition data. The observation, for example, of FALOGs, typically objects randomly encountered at sea, recorded as deployed by French PS vessels (Table 2) is one possible indication of such errors. Data entry errors are unlikely to explain the rather high rate of observation of FOBs with netting in 2019-2020, but it is not impossible that the low observed rates of FOBs with netting in 2021-2022 are close to the error floor in this type of data. The existence of such observations in both oceans with different rules regarding dFAD construction (e.g., the Atlantic allows some netting to be used in dFADs, whereas the Indian does not), all years and various types of vessel operations suggests that this possibility is remote, but differences in rates between observer programs could be indicative of error playing some role. To eliminate this possibility, future work should compare results with other data sources, such as logbooks or data from other fleets, and interviews with observers that noted netting in FOBs should be carried out.

Consistent differences in observation rates between observer programs and observer countries of origin suggest that improved training and changes in the observation protocol for the French fleet are needed to more accurately estimate the composition of FOBs used by PS vessels based on observer data. In particular, requesting French observers to follow a protocol inspired from Spanish observer data collection regarding FOB composition would be helpful to gather accurate data on the use of netting in FOBs (though the impact of this change on other observer data collection activities should be given ample consideration). Comparison of results with Spanish observer data would be very useful for understanding differences between fleets and between observer programs and data collection protocols, thereby contributing to more accurately estimating the use of nets in FOBs by all PS fleets.

Though a non-negligible portion of the observed FOBs with netting are dFADs, FALOGs (i.e., fishing materials randomly encountered or recycled as FOBs) are also a major source of FOBs with netting (Figure 6). Given the confusion that could be caused by PS vessels fishing upon or deploying tracking buoys upon these objects, even if these objects have been randomly encountered as lost gear in the marine environment, it would potentially be valuable to implement a policy of not attaching tracking buoys to these objects and permanently removing them from the water when encountered.

5 Acknowledgements

We thank the IRD-Ob7 pelagic observatory of the MARBEC laboratory for French IO tropical tuna logbook and observer data management and preparation. We thank Orthongel, the professional organization representing the French tropical tuna purse-seine fishery, for facilitating access to observer data of the OCUP observer program. We thank Théotime Fily for discussions that benefited the paper and for sharing FOB photos.

References

Briand K, Sabarros PS, Maufroy A, Relot-Stirnemann A, Couls SL, Goujon M, Bach P (2018) Improving the sampling protocol of electronic and human observations of the tropical tuna purse seine fishery discards. IOTC–2018–WPEB14–18 Rev_1. IOTC 14th Working Party on Ecosystem and Bycatch

Filmalter JD, Capello M, Deneubourg J-L, Cowley PD, Dagorn L (2013) Looking behind the curtain: Quantifying massive shark mortality in fish aggregating devices. *Frontiers in Ecology and the Environment* **11**:291–296. doi:10.1890/130045

Goujon M, Maufroy A, Relot-Stirnemann A, Moëc E, Bach P, Cauquil P, Sebarros P (2017) Collecting data on board French and Italian tropical tuna purse seiners with common observers: Results of Orthongel's voluntary observer program OCUP (2013-2017) in the Indian Ocean. IOTC-2017-WPDCS13-22_Rev1. 13th IOTC Working Party on Data Collection and Statistics (WPDCS), Mahé, Seychelles

Imzilen T, Lett C, Chassot E, Kaplan DM (2021) Spatial management can significantly reduce dFAD beachings in Indian and Atlantic Ocean tropical tuna purse seine fisheries. *Biological Conservation* **254**:108939. doi:10.1016/j.biocon.2020.108939

Imzilen T, Lett C, Chassot E, Maufroy A, Goujon M, Kaplan DM (2022) Recovery at sea of abandoned, lost or discarded drifting fish aggregating devices. *Nature Sustainability* **5**:593–602. doi:10.1038/s41893-022-00883-y

IOTC Secretariat (2019) Resolution 19/02: Procedures on a Fish Aggregating Devices (FADs) Management Plan. RESOLUTION 19/02. Indian Ocean Tuna Commission

IOTC Secretariat (2023) A recent overview of the large-scale purse seine fishery operating in the Indian Ocean with drifting Fish Aggregating Devices. IOTC-2023-WGFAD05-03. IOTC Working Group on FADs

IPNLF (2023) Sustained systematic non-compliance of drifting fish aggregating devices (dFADs) with Resolution 19/02 "Procedures on a Fish Aggregating Devices (FADs) Management Plan." IOTC-2023-CoC20-INF01_Rev1. 19th Session of the IOTC Compliance Committee

MacMillan I, Attrill MJ, Imzilen T, Lett C, Walmsley S, Chu C, Kaplan DM (2022) Spatio-temporal variability in drifting Fish Aggregating Device (dFAD) beaching events in the Seychelles Archipelago. *ICES Journal of Marine Science* **79**:1687–1700. doi:10.1093/icesjms/fsac091

List of Tables

Table 1: Table of CECOFAD FOB classifications, largely reproduced from https://www.iccat.int/Documents/Recs/compendiopdf-e/2021-01-e.pdf

Abbreviation	Description	Example
DFAD (drifting FAD)	Drifting FAD	Bamboo or metal raft
AFAD (anchored FAD)	Anchored FAD	Very large buoy
FALOG (fishing ALOG)	Artificial log resulting from human activity (and related to fishing activities)	Nets, wreck, ropes
HALOG (not fishing ALOG)	Artificial log resulting from human activity (not related to fishing activities)	Washing machine, oil tank
ANLOG (animal NLOG)	Natural log of animal origin	Carcasses
VNLOG (vegetal NLOG)	Natural log of plant origin	Branches, trunk, palm leaf

Table 2: Number of `Large mesh` and `Small mesh` FOBs by CECOFAD category and type of fishing/object operation in observer data from 2020-2022 for the Atlantic and Indian Oceans.

(a) Atlantic, Small mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	0	0	1
HALOG	0	0	3
VNLOG	0	1	9
DFAD	256	156	209

(b) Atlantic, Large mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	31	104	279
HALOG	0	0	1
DFAD	50	37	30

(c) Indian, Small mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	0	1	3
HALOG	0	3	4
VNLOG	1	1	14
DFAD	101	68	103

(d) Indian, Large mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	8	53	143
HALOG	0	0	2
VNLOG	0	2	31
ANLOG	0	0	1
DFAD	120	42	50

Table 3: Percentage of FOBs from 2020-2022 in the Atlantic and Indian Oceans that were classified as `Large mesh` and `Small mesh` for each CECOFAD category and type of fishing/object operation. Empty entries indicate that no FOBs of the given CECOFAD category and type of fishing/object operation were encountered over the time period.

(a) Atlantic, Small mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	0.0	0.0	0.2
HALOG	0.0	0.0	3.1
VNLOG		0.8	1.7
ANLOG		0.0	0.0
AFAD			0.0
DFAD	7.3	6.1	4.0

(b) Atlantic, Large mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	96.9	80.0	69.2
HALOG	0.0	0.0	1.0
VNLOG		0.0	0.0
ANLOG		0.0	0.0
AFAD			0.0
DFAD	1.4	1.4	0.6

(c) Indian, Small mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	0.0	0.5	0.7
HALOG		5.6	4.0
VNLOG	100.0	1.1	5.6
ANLOG		0.0	0.0
AFAD			0.0
DFAD	5.3	3.4	3.2

(d) Indian, Large mesh

CECOFAD cat.	Deployment	Fishing	Other
FALOG	80.0	28.3	31.4
HALOG		0.0	2.0
VNLOG	0.0	2.3	12.3
ANLOG		0.0	33.3
AFAD			0.0
DFAD	6.2	2.1	1.5

Table 4: Percent of observed FOBs with mesh for each year and CECOFAD category from 2020-2022 based on observer data. All `Fishing`, `Deployment` and `Other` vessel/object activities grouped together for this analysis. Empty entries indicate that no FOBs of the given CECOFAD category were encountered in that year.

(a) Atlantic

CECOFAD cat.	2020	2021	2022
FALOG	70.8	60.6	80.2
HALOG	7.1	1.4	4.9
VNLOG	3.7	0.5	1.8
ANLOG	0.0	0.0	0.0
AFAD	0.0		
DFAD	12.3	4.1	4.2

(b) Indian

CECOFAD cat.	2020	2021	2022
FALOG	34.9	32.3	25.7
HALOG	11.7	8.7	0.0
VNLOG	25.4	4.0	2.5
ANLOG	33.3	0.0	0.0
AFAD	0.0		
DFAD	13.1	3.5	3.0

Table 5: Number (a,c) and percent (b,d) of observed FOB deployments with mesh by ocean for each year and CECOFAD category from 2020-2022 based on observer data. Empty entries indicate that no FOBs of the given CECOFAD category were encountered in that year.

(a) Atlantic, Number

CECOFAD cat.	2020	2021	2022
FALOG	3	2	26
HALOG		0	
DFAD	154	63	89

(b) Atlantic, Percent

CECOFAD cat.	2020	2021	2022
FALOG	100.0	100.0	96.3
HALOG		0.0	
DFAD	17.9	5.8	5.7

(c) Indian, Number

CECOFAD cat.	2020	2021	2022
FALOG	5	2	1
VNLOG		1	
DFAD	142	48	31

(d) Indian, Percent

CECOFAD cat.	2020	2021	2022
FALOG	71.4	100.0	100.0
VNLOG		100.0	
DFAD	26.5	9.2	3.6

Table 6: Percent of FOBs with mesh for each year and observer program from 2020-2022 based on observer data. All vessel/object activity categories (i.e., `Fishing`, `Deployment` and `Other`) were grouped together for this analysis.

Ocean	Observer program	2020	2021	2022
Atlantic	DCF	32.2	14.0	21.5
Atlantic	OCUP	10.2	3.6	6.1
Indian	DCF	14.2	2.3	3.6
Indian	OCUP	17.4	11.4	4.6

Table 7: Number and percent of FOBs with mesh in data by year and observer country of origin from 2020-2022 based on observer data. In (b), empty entries indicate no FOBs were encountered for the given year by observers from the given country.

(a) Number

Observer country	2020	2021	2022
Comoros	56	0	4
France	184	32	43
Ivory Coast	510	230	358
Madagascar	2	0	16
Seychelles	251	77	61
Gabon	0	8	36
Guinea	0	2	18
Senegal	0	0	7
São Tomé and Príncipe	0	0	23

(b) Percent

Observer country	2020	2021	2022
Comoros	17.3		2.4
France	14.2	2.3	4.1
Ivory Coast	13.6	6.4	8.6
Madagascar	16.7		2.5
Seychelles	19.9	11.4	8.0
Gabon		3.2	10.7
Guinea		0.6	3.5
São Tomé and Príncipe			12.4
Senegal			2.9

Table 8: The number of times individual materials with netting were observed by year in FOBs for the period 2020-2021. The column "Position" indicates whether the material is associated with the surface structure (e.g., raft) or the subsurface structure of the FOB. The column "CECOFAD cat." indicates the CECOFAD category in the hierarchy of materials associated with each given material.

(a) Atlantic

Material	Category	Position	CECOFAD cat.	Total	2020	2021	2022
Net with mesh =<7cm	Small mesh	Surface	DFAD	515	321	108	86
Net, piece of net	Large mesh		FALOG	414	84	83	247
Single net pieces with mesh =<7cm	Small mesh	Subsurface	DFAD	255	94	80	81
Open net with mesh =<7cm	Small mesh	Subsurface	DFAD	127	127	0	0
Single net pieces joined with mesh of unknown size	Large mesh	Subsurface	DFAD	76	0	0	76
Several FAD entangled	Large mesh		DFAD	30	12	18	0
Net with mesh >7cm	Large mesh	Surface	DFAD	17	14	0	3
Net in sausage	Large mesh	Subsurface	DFAD	11	10	1	0
Single net pieces with mesh >7cm	Large mesh	Subsurface	DFAD	7	7	0	0
Entangling	Large mesh			6	6	0	0
Open net with mesh >7cm	Large mesh	Subsurface	DFAD	6	6	0	0
Net with mesh of unknown mesh size	Large mesh	Surface	DFAD	4	0	0	4

(b) Indian

Material	Category	Position	CECOFAD cat.	Total	2020	2021	2022
Net with mesh =<7cm	Small mesh	Surface	DFAD	291	236	45	10
Net, piece of net	Large mesh		FALOG	197	115	38	44
Net in sausage	Large mesh	Subsurface	DFAD	193	125	12	56
Net with mesh >7cm	Large mesh	Surface	DFAD	84	63	7	14
Single net pieces with mesh =<7cm	Small mesh	Subsurface	DFAD	75	70	0	5
Open net with mesh =<7cm	Small mesh	Subsurface	DFAD	69	65	1	3
Single net pieces with mesh >7cm	Large mesh	Subsurface	DFAD	30	25	5	0
Several FAD entangled	Large mesh		DFAD	26	18	5	3
Open net with mesh >7cm	Large mesh	Subsurface	DFAD	18	17	0	1
Entangling	Large mesh			15	15	0	0
Net with mesh of unknown mesh size	Large mesh	Surface	DFAD	4	0	0	4

List of Figures

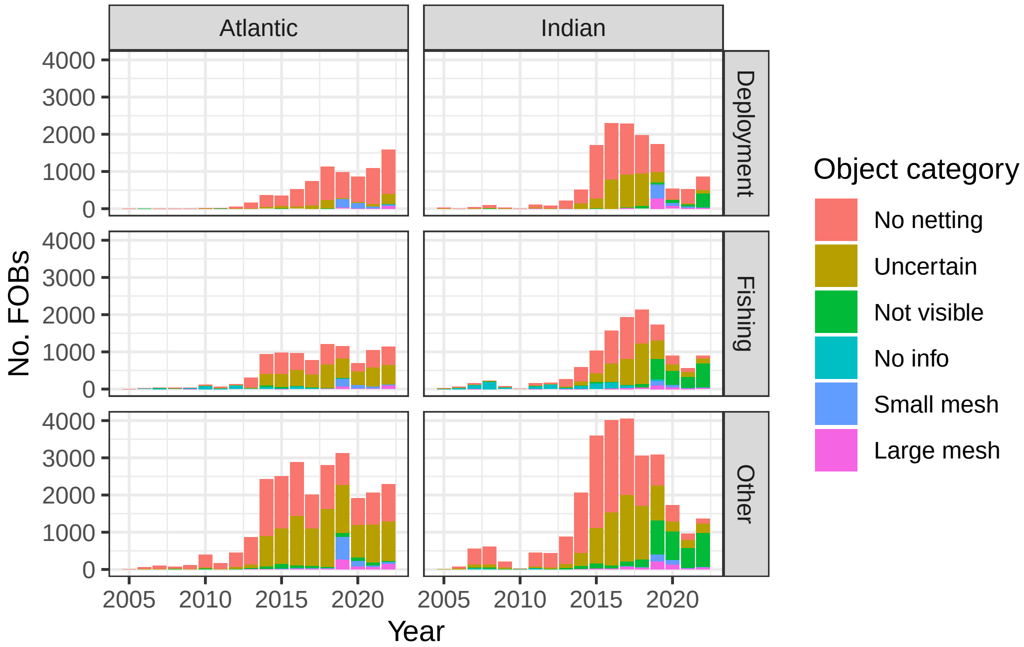


Figure 1: Stacked bar plot of number of FOBs in each category as a function of year by ocean and fishing activity type. Please see the Methods for caveats regarding the FOB classifications.

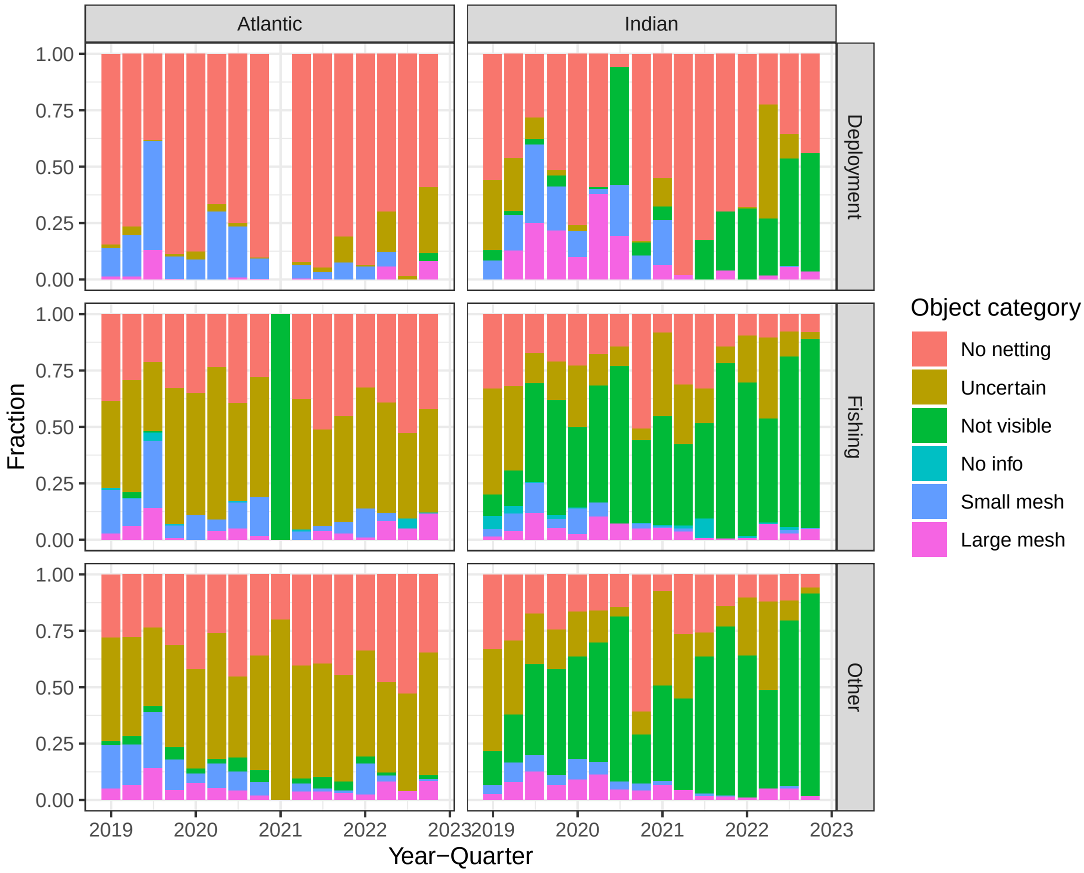


Figure 2: Fraction of FOBs in each category as a function of quarter since 2019 by ocean and fishing activity type. Please see the Methods for caveats regarding the FOB classifications.

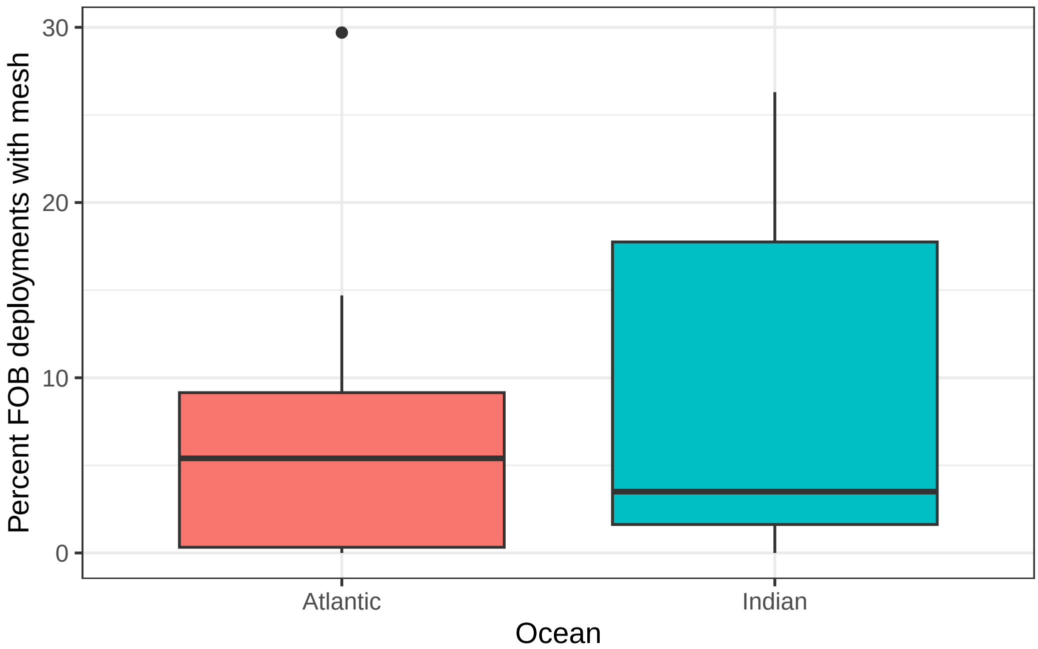
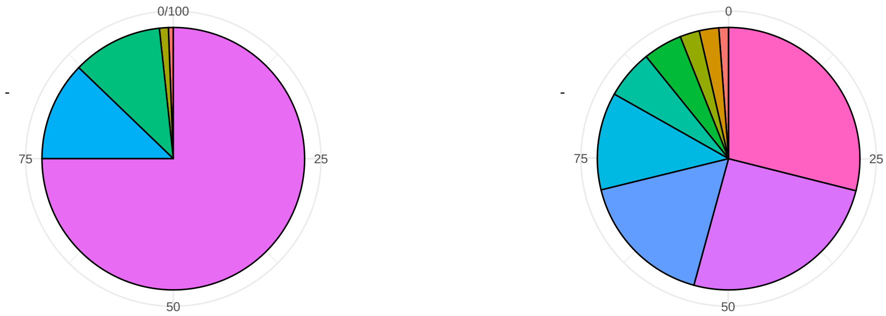


Figure 3: Boxplot of the fraction of observed FOB deployments with mesh materials for each PS vessel by ocean for the period 2021-2022.



(a) Atlantic (36 observers total)

(b) Indian (28 observers total)

Figure 4: Pie charts of the fraction of observed FOB deployments with mesh materials by ocean that correspond to individual observers for the period 2021-2022. Each color corresponds to a different individual observer. Note that, over this time period, there are 36 observers total in the Atlantic Ocean, and 28 observers total in the Indian Ocean.

(a) No. 2: 23/11/2021

(b) No. 21: 23/01/2023

(c) No. 27: 12/10/2022

(d) No. 30: 14/09/2022

Figure 5: Photos of dFADs found in coastal environments of the Indian Ocean reported by and reproduced from IPNLF (2023). The images are in the numbering of that report: (a) #2, (b) #21, (c) #27, and (d) #30. Dates in the header of each image are the dates cited in the report and are not necessarily indicative of the deployment or stranding dates. Note that (a) #2, (b) #21 and (c) #27 were reported by IPNLF (2023) to have tracking buoys of French-flagged or -associated vessels, and that IPNLF (2023) classified all of these objects as entangling, though many would debate this classification for some of these objects.

Figure 6: Example of a FALOG classified as `Large mesh` observed by an observer aboard a French PS vessel in the Indian Ocean on 2022-10-19. ©IRD