Data Collection for Assessing Impacts of FAD Stranding Events

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Abstract

Fish Aggregating Devices (FADs) are widely used in tropical tuna purse seine fisheries around the world. These FADs are tracked using echosounder buoys equipped with GPS. When FADs drift out of the fishing grounds, they can reach coastal areas and become stranded. However, few studies have evaluated the impact of stranded FADs on sensitive ecosystems such as coral reefs.

The objective of this study is to identify the factors contributing to damage caused by FAD stranding, propose methodologies for assessing their impacts on coral reefs, and establish best practices for data collection. To achieve these objectives, fieldwork was conducted on the coral reef on D´Arros Island and Saint Joseph Atoll in the Indian Ocean, where a methodological framework was developed and tested for potential application in similar marine ecosystems worldwide.

The Line Intercept and Photo Quadrat methods were successfully implemented. Based on the in-situ sampling experience, this study presents guidelines for data collection related to FAD stranding events.

1. Introduction

Fish Aggregating Devices (FADs) were introduced into the tropical tuna fishery in the early 1990s. Their use has increased over the last decades until regulatory measures such as FAD limits were adopted in Regional Fisheries Management Organizations (RFMOs) to reverse the trend and mitigate their impacts. These measures were first implemented voluntarily by the EU fleet and progressively adopted in RFMOs worldwide, first in the Indian Ocean, by the Indian Ocean Tuna Commission (IOTC) in 2015, then in the Atlantic area by International Commission for the Conservation of the Atlantic Tuna (ICCAT) in 2016 and finally in the Pacific by Inter-American Tropical Tuna Commission (IATTC) and Western and Central Pacific Fisheries Commission (WCPFC) in 2017. Today, the number of active operational buoys at any given time per large-scale purse seiner ranges between 300 and 425.

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FADs are generally composed of a floating raft and a submerged appendage that tends to be deeper in the Pacific and Atlantic and shallower in the Indian Ocean (Murua et al., 2018). Long-lasting petroleum-based plastic materials (e.g., polyamide nets and polyethylene ropes) have been primarily used for FAD construction (Murua et al. 2018), although in recent years, their components are being replaced by biodegradable and non-entangling materials (Moreno et al., 2023; Murua et al., 2023; Zudaire et al., 2023). Although drifting FADs are tracked by an echosounder buoy, tuna fleets using them do not have the capacity to recover all FADs when they drift out of the fishing areas, resulting in their deactivation and loss and contributing to marine litter. In some cases, FADs can end up stranding in coastal areas of high tourism interests or in sensitive coastal habitats, such as coral reefs. Accurately assessing the true scale of FAD stranding events remains challenging, as most buoys are deactivated once they exit the fishing grounds.

Recognizing the impacts of FAD loss and stranding events, RFMOs continue to promote mitigation and management measures aimed at improving the use of FADs. These efforts include transitioning to biodegradable materials, guided by an established implementation timeline, supporting FAD recovery programs (C ICCAT 24-01[3]; IOTC 24-02[4]; WCPFO CMM 23-01[5]; IATTC 23-04[6]), and enhancing FAD monitoring systems.

FAD retrieval programs are being implemented to recover those that get close to or reach coastal areas, assessing the extent of FAD stranding events, and conduct evaluations of their impacts (Banks & Zaria, 2020; Balderson & Martin, 2015; Escalle et al., 2022; Heile et al., 2023; Kimak et al., 2025; Mourot et al., 2023). However, few studies have focused on quantitatively assessing the impacts of stranded FADs or on establishing standardized guidelines for data collection to support harmonization across programs of such assessments. *In situ* data collection is essential to more accurately quantify the impacts of FADs on marine and coastal environments (Escalle et al., 2022).

The objective of this work is to identify factors contributing to damage caused by FAD stranding, propose methodologies for assessing their impacts on coral reefs, and establish best practice for data collection. To this end, an *in-situ* fieldwork study was conducted in the coral reef island of D´Arros, in the Indian Ocean, where a methodological framework was developed and tested so it could be applied in similar marine ecosystems globally.

2. Damage of FADs on coral reefs

A bibliometric analysis, supported by a literature review, was conducted to identify the main themes addressed in the literature concerning the primary drivers for coral reef impacts in the Indian Ocean. This approach also served as a proxy to better understand the actual threats facing coral reef ecosystems (Uyarra et al., 2023). Climate change (warming and acidification) was the most important threat affecting coral reefs as also noted in the threatened species list published by the International Union for Conservation of Nature and Natural resources, followed by "pollution" and "residential & commercial development" (Burke et al. 2017; Bullock et al., 2021). Projections of climate change scenarios are expected to increase the proportion of threatened

[3] 2024-01-s.pdf
[4] iotc_cmm_2402.pdf
[5] CMM 2023-01 - Conservation and Management Measure for Bigeye, Yellowfin and Skipjack Tuna in the Western and Central Pacific Ocean | Monitoring and Evaluation
[6] C-23-04_FADS boiodegradables

reefs to 85% by 2030, and to 100% by 2050, with 65% being highly or very highly threatened. Among all local threats, fisheries were identified as the most relevant activity negatively impacting coral reefs (Burke et al. 2011; Sauter et al. 2020). It is estimated that overfishing alone affects around 60% of the reefs. Furthermore, coral reefs in certain areas have become threaten because of the fishing activity (Burke et al. 2011).

Marine litter, particularly in relation to FADs, did not show up in the literature review as an important source of damage to coral reef communities (Uyarra et al., 2023). In the Indian Ocean, Duhec et al (2015) studied the characteristics and sources of marine debris in Alphonse Island and concluded that most of the litter found originated from Southeast Asia and Somalia. Only 2% of the total number of marine debris items found in that survey were classified as 'Fishing-related items'. Vogt-Vincent N. & A. Burt (2023) modelled the flow of plastic debris in the Indian Ocean between 1993 and 2019, tracing its origins to specific source regions. They concluded that a significant proportion of the beached marine litter in Seychelles originates from Asia, particularly Indonesia, while the inner islands primarily received debris from India and Sri Lanka. Therefore, understanding these connections in each region could be essential to detect coastal areas significantly impacted by FADs (Escalle et al., 2022).

Understanding the potential physical damage caused by FADs to coral reefs requires considering various factors that influence species-specific responses to such interaction (i.e., conservation status of species, growth type and growth rates). In the case of assessing damage caused by FADs, few studies have focused on assessing and characterizing the impacts of FADs on coral reefs (see Balderson & Martin 2015; Zudaire et al. 2018; Banks & Zaharia 2020; Consoli et al. 2020; Escalle et al., 2022; Mouret et al., 2023; Uyarra et al., 2023). According to those studies, damage to coral reefs is primarily attributed to the submerged appendages of FADs, particularly when nets are used in their construction. However, field observations (see below) have identified additional elements, such as ropes, attractors, and weights, as potential sources of damage (Table 1).

Table 1. Evidence of Impacts of FADs on coral reefs found in the literature review and in field work (*Source: Uyarra et al., 2023*)

Part of equipment	Type of interaction	Type of damage	Bibliographic evidence
Buoys	None		
Structure	Collision Shading Entanglement	Coral injuries	Fieldwork
Nets (e.g., aggregator nets, structure nets, sausage nets)	Shading Entanglement	Coral entanglement / injuries	Balderson & Martin, 2015 Consoli et al. 2020 Banks & Zaharia 2020 Zudaire et al. 2018 Fieldwork
Ropes	Shading Entanglement	Coral entanglement / injuries	Fieldwork
Attractors	Entanglement	Coral entanglement / injuries	Fieldwork
Weight	Collision Shading Entanglement	Coral injuries	Phase 2

The type of impacts that FADs can cause on corals can be classified into three categories (definitions derived and adapted from Burns et al. 2018):

- **Scraping / Abrasion**: scarring to the live coral tissue caused by the collision of FADs with the reef.
- **Breakage:** pieces of broken coral that appear scattered on the benthos caused by the collision of FADs with the reef.
- **Tissue mortality**: any pieces or area of coral tissue that exhibited complete tissue mortality because of a collision, contact, or suffocation caused by the FADs.

The type and severity of damage resulting from interactions between FADs and coral reefs, and consequently, the reef's capacity to recover, depend on several factors. These include the intensity and duration of the interaction, the specific component of the FAD involved, environmental characteristics (e.g., reef structure), the species affected, and additional localized pressures unique to the area.

The severity of the damage increases with the intensity of the interaction, which can be influenced by factors like wind and current speed, wave height, and the exposure time. The longer and forceful the interaction, the greater the potential for reef damage. Forceful interaction may result on removal of the coral's tissue, providing other organisms the opportunity to settle and compete with corals for space. Prolonged direct contact between corals and FADs may prevent the symbiotic zooxanthellae algae of the coral from accessing light; this hinders photosynthesis, which may result in suffocation and ultimately, coral mortality.

Thus, the design of FADs can influence the type and extent of damage they may cause. The reviewed literature and the observations made during our fieldwork (see below) suggest that netting components (e.g., FAD ”cage” nets, tied up nets in to sausages), used in the Indian ocean before 2020 (when the Res. 19-02 banned their used), before 2024 in the west Pacific and to

2025 in the Eastern Pacific and Atlantic Ocean, generally implicated in coral damage (Balderson & Martin, 2015; Banks & Zaharia, 2020; Consoli et al. 2020; Zudaire et al. 2018).

Since the net structure can easily become entangled with the reef, and even continue drifting generating further tension, it may lead to abrasion, breakage, or coral mortality. The permanent contact of the net (or any other part of the FAD) may potentially result in coral mortality. This may occur while beaching if the FAD raft structure sinks over the reef. Other parts of the structure that may negatively interact with corals are the suspended weight, which may collide with corals causing injuries and/or breakage, and attractors elements, which easily entangle on coral reefs (Uyarra et al. 2023).

Environmental conditions such as water currents and wind are determinant to where FADs aggregate and beach (Imzilin et al. 2019; Kahn et al. 2020). In addition, reef structure and zonation may be important factors influencing how reefs may interact and be affected by FADs.

Banks & Zaharia (2020) identify the following reef zones:

- **Reef crest** is the highest point of the reef that breaks waves and receives the full impact of wave energy. It can be exposed the atmosphere at low tide, with harsh living conditions for the coral (KSLOF, 2014).
- **Fore reef** is the part of the reef that extends from the reef crest into the ocean. It slopes downward and can reach great depths (KSLOF, 2014). It can be interrupted by terraces or sediment flats. It is exposed to high wave energy in the shallow zone and low in the intermediate zone (5-20 m).
- **Back reef** is the area that slopes into a lagoon. Often shallow, it can be exposed at low tide (KSLOF, 2014). It is exposed to low wave energy.
- **Lagoon and lagoonal reefs:** a pool of seawater highly or partially enclosed within a reef formation (atolls) or between a reef and shorelines (barrier reefs) (KSLOF, 2014)**.** Area exposed to low wave energy, tidal fluctuations, shallow currents, and can have complex bottom structures (coral pillars, pinnacles and boomies) (Barott et al., 2010)
- **Reef flats:** area behind the reef crest that is protected from the wave action. It can extend from meters to kilometres. Low wave energy, low dissolved oxygen, high temperatures and exposed to air at low tides (KSLOF, 2014).

In a study exploring the benefits and costs of FADs in the Western and Central Pacific, Banks & Zaharia (2020) found that FADs primarily beached on reef flats, followed by the fore reef and lagoonal reefs. According to KSLOF (2014), the fore reef is the most sensitive, as in its intermediary zone it has the highest coral growth and species diversity.

Furthermore, the type of coral, whether soft corals (e.g., octocorals or gorgonians / sea plumes) or hard corals (e.g., scleratinians), may determine the type of damage resulting from interactions with FADs. Hard corals may suffer from scaring and breakage, while branching and plate-like corals are more susceptible to breakage (Au et al. 2014). Depending on the soft coral species, they may cope with the interaction or break. Their recovery will depend on growth rates and type, which is specific to species.

3. Methodological approach for conducting underwater surveys.

The impacts of FADs on coral reefs are poorly studied. Scientific research focuses on defining areas were FADs drift, accumulate and beach and on describing the interaction with marine fauna habitat (e.g., marine turtles) (Maufroy et al., 2015; Maufroy et al., 2018; Imzilen et al., 2022; Escalle et al., 2019; Escalle et al., et al., 2024). Building on the work by Uyarra et al., (2023), the present study aims to provide a standardized methodological framework for characterizing the potential impacts of FADs on coral and fish communities. Several methodologies were tested, and those selected are described below. These methodologies are suitable to seagrass, patch reefs and bank reef habitats, thereby allowing the standardization of future studies aimed at assessing the impacts of FADs on reef habitats. The application of this protocol to steep reef habitats and reef cliffs would require adaptation, as it could compromise the diving security of the researchers.

For this exercise, D´Arros Island and Saint Joseph Atoll (Fig. 1) were selected in the Indian Ocean based in the following criteria:

- Localized in the proximity of tuna FAD fisheries grounds.
- The presence of derelict FADs was identified in a first evaluation of beaching events, using GPS position of echosounder buoys attached to FADs.
- Coral reefs were available.
- Diving infrastructure was in place.
- They are virgin areas with other anthropogenic threats kept at minimum levels.

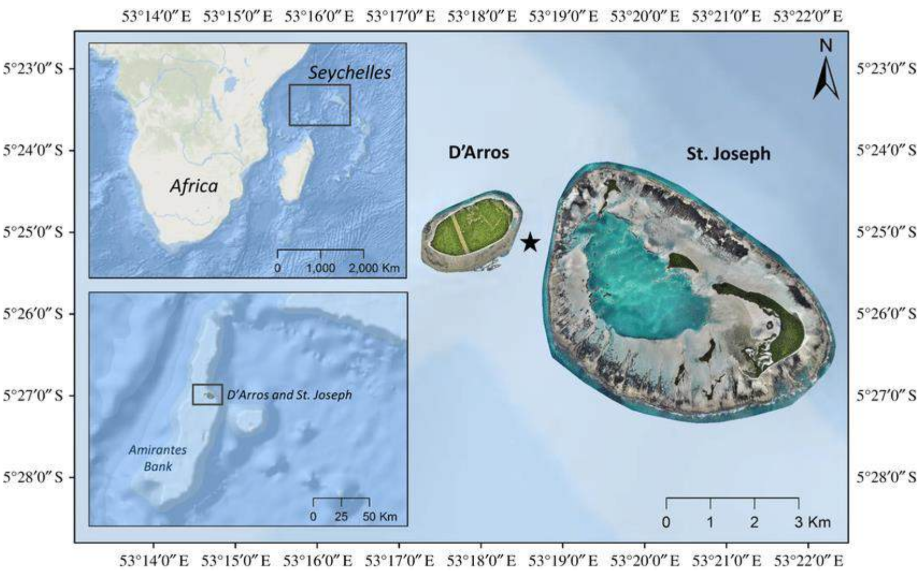

Fig 1. Sampling area: D´Arros Island and Saint Joseph Atoll (*Source: Peel et al., 2019)*

The objective of the sampling was to determine the impact of FADs on coral reefs. To achieve this objective, the team:

- Assessed the potential impact of FADs on corals and fish communities that may result from the tension generated by waves/currents/winds between the floating part and the snagged tail of a derelict FAD.
- Analysed changes in live and dead coral cover, scaring, and breakage by comparing "FAD" *versus* "control" sites.
- Explored differences in fish species richness and abundance between "FAD" and "control" sites.

The pilot project was conducted using four existing stranding FADs, each paired with a corresponding control site, located approximately 100 meters away and characterized by having a similar coral community and depth at which each beached FAD was found.

The assessment of the impacts of FADs on coral reefs was conducted using data from four FADs. Corals and fish composition were compared between FAD sites and their paired control sites. Due to the high variability in habitat types where FADs were found (i.e., one on seagrass, two in patch reefs, and one on the reef) and survey conditions (the entry to the lagoon was determined by the tides, effecting the survey timing and potentially influencing fish abundance and richness) and the limited number of FADs (N=4), results of this study cannot be integrated or used to draw conclusions or extrapolate findings. Therefore, the results are presented independently for each FAD and its paired control site. Consequently, the impact evaluations obtained in this study should be considered as observations rather than definitive conclusions. These are presented as examples of the results obtained through the application of the proposed methodological approach.

3.1. Coral reef benthic surveys

The objective of the survey was to define the best methodology to study potential impacts of FADs and have preliminary results of what their impacts could be on coral reef communities. This was achieved by:

- Assessing coral conditions using different methodologies (i.e., transects and photo quadrats), to allow identifying the performance of both methodologies for this type of studies. Both methodologies were applied across all FAD sites and control sites.
- Recording and comparing benthic cover composition (i.e., live coral, dead coral, rubble, rock, sand, algae, other) between FAD and control sites; whenever possible, live coral identification was carried out to genera/species level.

Underwater surveys were conducted by three divers. The control site was selected at a minimum distance of 60m from the FAD site, in an area with the same habitat type and characteristics (e.g., depth). It would be recommendable to increase the minimum distance from the paired FAD to 150m, especially if the habitat area is flat, as the impact area of the FAD could change and expand due to the FAD moving and even re-beaching as a result of currents, and winds from different directions.

Once the FAD and/or the control sites were identified, the following steps were carried out to complete the coral reef benthic survey:

- Step 1. Record the GPS coordinates.

- Step 2. Mark the FAD/control site using a marking buoy in the centre of the study site. The following cases were possible:
    - FAD available and raft floating: the marking would be located at the point where the weight (i.e., FAD's anchoring element) or the furthest extreme of the subsurface structure (when the weight is not available) contacts with the substrate.
    - FAD available and surface structure laying on the substrate: the marking would be placed in the middle of the surface structure. This would be normally facilitated by the presence of ropes.
    - FAD not present due to previous removal to avoid further potential damage on the reef: in this case, it was suggested to mark the point where the FAD contacted the reef, so this point can be used for marking the central point for the surveys.
    - Control site: at control sites, the buoy mark would be placed in a similar habitat, substrate type and depth to that of its corresponding paired FAD site.
- Step 3. Note the general characteristics of the area, including habitat type, dominating species, depth, visibility, and any interesting feature of the location.

- Step 4. Line intercept transect (Fig. 2). To implement this methodology, it was determined that 10 m transects was an adequate length size. Due to the expected trajectory of the FAD it was considered that rather than placing parallel transects at a continuous depth, they should be placed considering how to best capture any potential damage. To do so, a first transect was laid down starting from the centre of the study site, following exactly the main trajectory of the FAD. This trajectory was determined either by the presence of the FAD tail or visible damage. The direction of this first transect would be noted. Then, three additional 10m transect would be laid down following at 90º, 180º and 270º from the first transect line. In total, four 10m transects were laid down at each study site (FAD and control), starting at the centre using one single transect line that would be moved after finishing each transect survey.

  For each transect, the presence of benthic type (e.g. sand, rubble, dead coral, algae, seagrass, sponges, soft coral, hard coral, other organisms, etc.) immediately under the transect line, as well as the length of the intercept point (the point where the substrate changes) would be noted. When transferring this information into an excel file, these data could be transformed into percentage cover of each substrate type. For hard coral, whenever possible, identification was carried out to the species level. To support *in situ* identification, the transects were also filmed using underwater cameras (Go Pro Hero). This allowed researchers to reexamine transect data if in any doubt (i.e., coral reef species identifications).

Figure 2. Line intercept method for the status of Coral reef. A) Data Collection; b) Transect line deployment. (*Photo cretid: Ekaitz Erauskin; Source: Uyarra et al., 2023*)

- Step 5. Photo quadrat methodology (Fig 3). In addition to the line intercept method, photo quadrats were used to assess the extent of the potential damage. Quadrats of 50cm x 50cm were placed along the transect line (leaving the transect line always at the same side of the quadrat) at 0m, 2,5m, 5m, 7,5m and 10m fix distances. Photos of each quadrat were taken using an Olympus T6 in an underwater housing. These photos were later processed in the computer to calculate the percentage cover of the different substrate types. After applying both the line intercept method and the photo quadrat method, the transect lines would be removed.

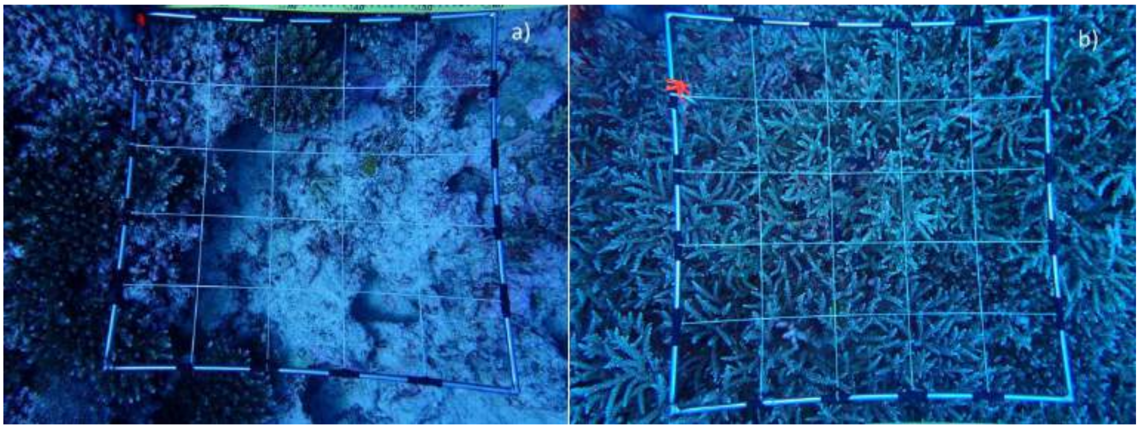

Figure 3. Implementation of the photo quadrant method to caral reefs. Photo credit: Maria C. Uyarra; Source: Uyarra et al., 2023)

- Step 6. Damaged area: To estimate the overall extent of the damage the furthest points where damage was visible from the marking buoy (central point) were localized. Using type measures the damaged area (in m2) could be measured and later calculated.

The outputs obtained from the implementation of both methodologies are presented in Figure 4 (line intercept method) and Figure 5 (photo quadrat method). Overall, both figures highlight the diversity of habitats in which the study was carried out. While the dominant benthic component at the patch reef was sand (both in FAD and control sites), at the seagrass habitat, it was the seagrass itself, and on the reef site, the dominant benthic component was hard coral.

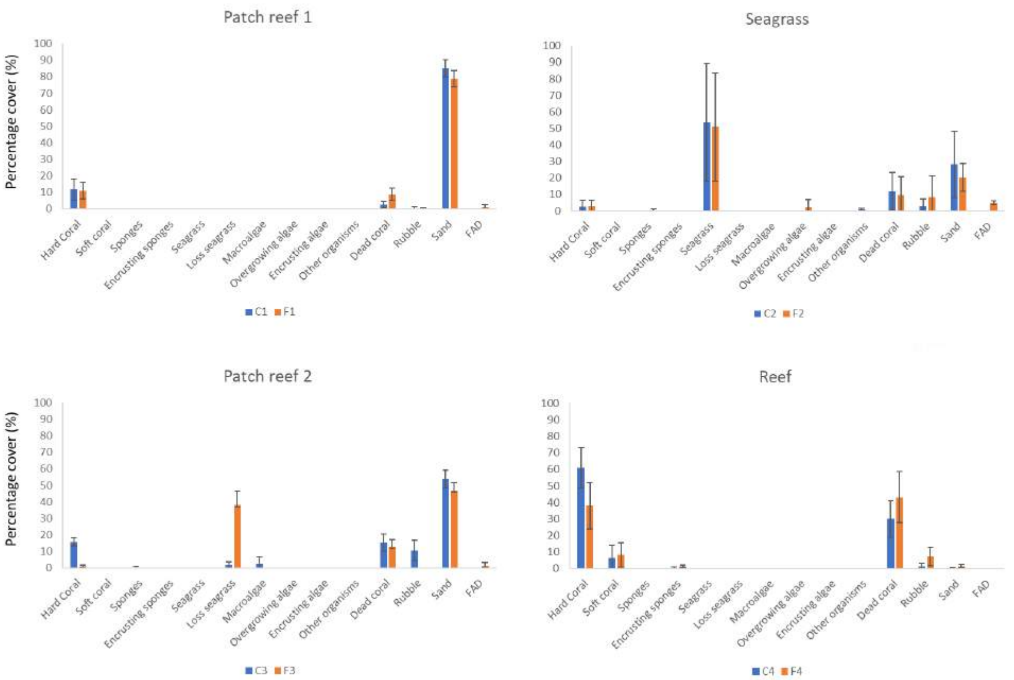

Fig 4. Benthic composition (measured in percentage cover) obtained through the implementation of the line intercept method. Blue bars correspond to values for the control sites, and orange bars are values for the FAD site. error bars represent the standard error. (Source: Uyarra et al., 2023) **loss seagrass refers to floating seagrass that is detached from the substrate.*

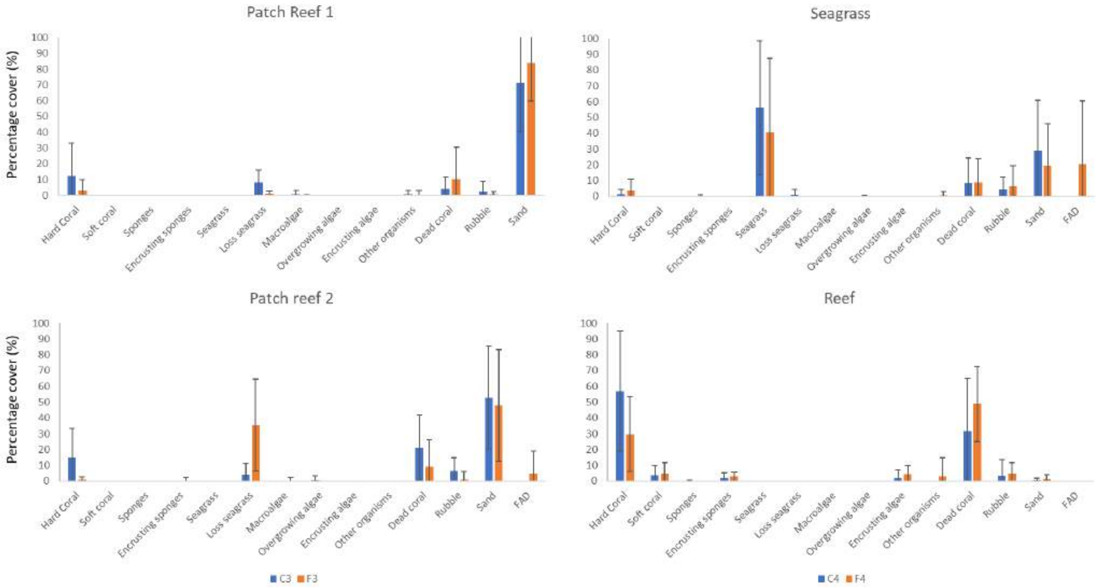

Figure 5.: Benthic composition (measured in percentage cover) obtained through the implementation of the photo quadrat method. Blue bars correspond to values for the control sites, and orange bars are values for the FADs site. Error bars represent the standard error. Loss seagrass refers to floating seagrass that is detached from the substrate. *(Source: Uyarra et al., 2023)*

From all benthic components, generally high cover of hard and soft coral, seagrass, coralline algae, sponges, indicate healthy habitats. On the contrary, high amounts of dead coral, rubble, overgrowing algae, are associated with poorer quality habitats. In this context, it is evident from both figures that there was a higher amount of hard coral at the control sites compared to the FAD sites. The cover of dead coral or rubble did not consistently follow the expected pattern, with higher cover observed at FAD sites than at control sites.

Despite the similarities in the results obtained using the two methodologies, those obtained through the photo quadrant method exhibited higher variance. This can be attributed to the fact that, in the line intercept method, the transect functions as a unit, integrating all the information from the whole transect into one single value per benthic component. In contrast, with the photo quadrats, in this structured designed, it was possible that some of the photos would be in an area with high coral cover, and other photos on sand. Since each photo is a replicate, the variability largely increases.

The idea behind testing two methodologies was to identify which methodology reflected best what was observed *in situ*. At the level of benthic components composition, it can be concluded that both methodologies are suitable for this kind of study, as the outputs are similar.

The benefit of using photo quadrats is that it allows performing damage extent analysis more easily. Furthermore, taking photos to quadrats is easier than filming the transect line in case that either of those are needed for posterior species identification.

The intercept transect method would be the preferred methodology for steep and cliff reefs since the quadrat is difficult to place in those zones. Furthermore, the standard error reduces, and minimizing underwater equipment (e.g., not carrying the quadrat) is always a bonus. Under all circumstances it is recommended, that, whenever possible, carrying out *in situ* identifications, for which high coral identification expertise is required. Otherwise, both photo and video processing can be employed but it is time consuming.

3.2. *Fish surveys*

These surveys focused on evaluating fish community abundance and richness o both at FAD and control sites, by making *in situ* observations and recordings. *In situ* recordings were complemented with underwater camera recordings to help later with identification of some fish species (Fig 6). For fish counts the following steps were taken:

Figure 6. Fish surveys. a) fish data collection; b) fish community at the control reef site. Photo credit: Ekaitz erauskin. (*Source: Uyarra et al., 2023*)

- Step 1. Determine the correct distance for the survey. The underwater visibility determines largely the distance at which the survey can be carried out successfully. In the case of the lagoon (i.e., patch reef and seagrass sites), where the visibility was very poor, the adequate distance to maintain with the reference point (the buoy mark) was 2.5m. In contrast, at reef sites, where the visibility was much better, the adequate distance for the survey was established at 5m. Thus, after having marked the study site with a line and a buoy, the divers would place themselves at the specific distances and wait 3-5 minutes for fish to re-establish their normal activity.

- Step 2. Fish counts. For 3 minutes one diver would count and identify all the fish living at or passing between the diver and the reference point, considering a visual angle that covered 2.5m on each side of the reference point. Both swimming and benthic fish were noted. After this, the divers would get close to the substrate for another 150 seconds to count and identify those fish living in the crevices/FAD within this same area. This procedure was repeated from the opposite side of the buoy mark. Thus, the total time counting and identifying fish would be 10 minutes in total, plus additional time allowed for fish to re-establish their normal activity after diver movement in the area at the start of the survey and after changing side. An additional diver would film the fish activity using an underwater camera (GoPro Hero 8) as a means to double check any doubt that may emerge during fish identification.

- Step 3. Abundance and species richness were recorded on a spreadsheet (i.e.., Excel file) for analysis.

The fish surveys carried out at each FAD/control site turn into a unique value of fish abundance and fish species richness for each site. That is, there were no replicates and therefore, no error bars were provided. Since a major source of variability on fish abundance and fish species richness are the tide and the time of the day at which the surveys are carried out, and it was not possible to control for this variability in the field (i.e., the time of entry into the lagoon was dependent of many other factors, but especially wind and shifting tides), the outputs obtained should be considered with caution .

In total, 86 species of fish were detected, of which 75 fish were assigned to the species level, and 11 were distinctively identified but not found in the reference guide. It is possible that this number could be higher. At the seagrass site, a high number of juvenile fish were found, and the identification of those fish was not possible due to limited information in the classification guides.

Overall, the reef site was the habitat with the highest species richness (N = 33), and the seagrass the lowest (N = 10) (Fig. 7). No clear pattern was found when comparing fish species richness in FAD *versus* control sites. Patch reef 1 and Reef had higher species richness at the control than at the FAD (in absolute values), Patch reef 2 and Seagrass had higher species richness at the FAD site than at their corresponding controls.

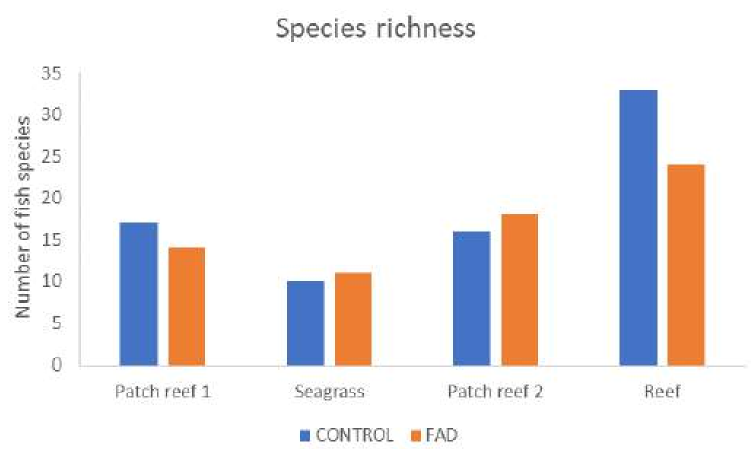

Figure 7. Fish species richness at control (blue bars) and FAD sited (orange bars)

In the case of fish abundance, for all sites the abundance of fish was lower at the FAD site than at its corresponding control site (Fig. 8). The highest abundance of fish was available at the Seagrass site (N = 323), followed by that at the Reef site (N = 285). The lowest abundance was found at the FAD site of Patch reef 2 (N = 90).

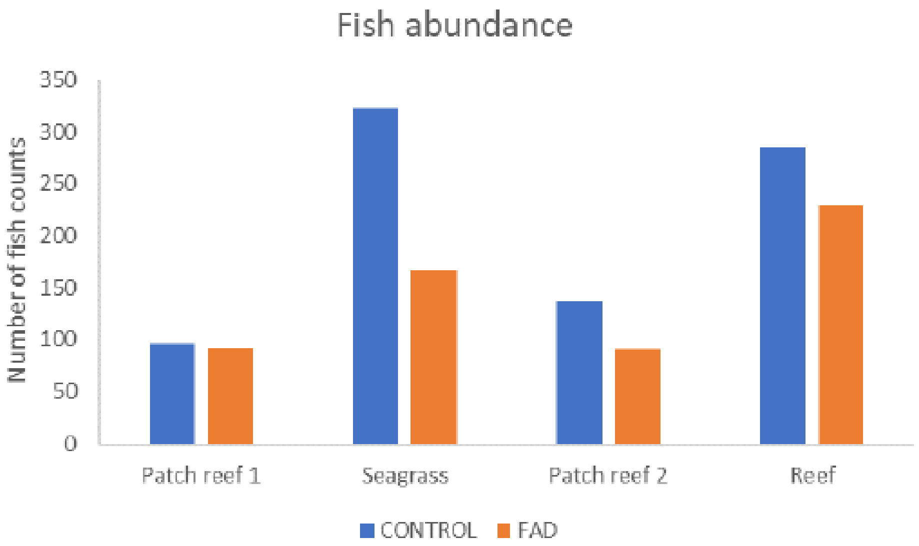

Fig. 8. Fish abundance at control (blue bars) and FAD sited (orange bars).

It would be necessary to expand sampling in this experiment to be consistent with the habitat type (i.e., reef sites), and time of day, to arrive at more robust conclusions on the effect of FADs on fish in this area. The results are shown as illustrative examples of the implementation of the proposed methodology.

4. Data Collection guidelines for FAD stranding events.

In recent years, RFMOs have been establishing guidelines for data collection aimed at evaluating the potential impacts caused by FADs during stranding events. To assess these impacts the data being collected includes general information regarding to the position, FAD and buoy ID, information about the type of FAD structure, FAD dimension and materials, and details of the habitat (Escalle et al., 2022). Considering the data collection initiatives proposed at RFMOs, as well as the factors contributing to coral damage, the data requirements for planning visits to FAD stranding sites, and the insights gained from underwater observations, the following data are proposed for collection during FAD stranding events. In this sense, underwater surveys have proven instrumental for identifying necessary data for FAD retrieval operation planning and for highlighting valuable information that can be systematically collected. Table 2 summarizes the type of information that is being proposed.

Table 2. Type of information to be collected in FAD retrieval events.

General information	
Type of FAD	Anchored/drifting/log
FAD ID	Identification in the FAD, independent to the buoy ID
ID of the instrumented buoy	Alphanumeric code including the model and numerical series
Date	Date of first sighting
Latitude	Latitude in decimals
Longitude	Longitud in decimals
Habitat type	Beach, lagoon, mangrove, estuary, open ocean, rocky, sea grass, sand, patch reef, coral reef, unknown, other
Depth	Aproximate depth in meters
FAD information	
Type of FAD designg	Cage type, tail shape, other
Floating elements	Material of the floating devices Number Length of the rope
Raft	Shape Dimension Materials of the structure (e.g., metal, canes, etc.) Material in the coverage if present Mesh size (if mesh present) Location (floating on the surface, floating on the water column, laying on the surface)
Submerged structure	Type of structure Materials Length Mesh size (if mesh present) Type of atractors Location (floating on the surface, floating on the water column, laying on the surface) Length laying in the substrate
Weigth	Materials Dimensions Weigth
Evaluation of the impact	
Type of substrate	Beach, lagoon, mangrove, estuary, open ocean, rocky, sea grass, sand, patch reef, coral reef, unknown, other
Reef zone (in case of coral reefs)	reef bank, reef slope, reef cliff
Type of corals	soft or hard
Type of damage	e.g tissue mortality (bleaching of corals), Abrasion (scars on the reef), breakage
Area affected	Estimation of the area affected
Species of corals affected	If the damage is observed in coral reef identify the species if possible
Part of the FAD causing the damage	raft, tail, weight, unknown, other
Entanglements	Species Number Location in the FAD

In each FAD encounter general information to be collected includes date of the encounter, latitude, longitude, FAD type (anchored; drifting or log), FAD ID (different from buoy ID if present), environment or substrate type, and depth.

The depth information is not collected at proposals made at RFMOs while we include it in our data collection proposal. We consider it is essential, as it can help to plan and prioritize the FAD retrieval actions. Prior works highlight the need to promote FAD retrieval before FADs reach coastal areas (Escalle et al., 2022). And in that case, the work plan would depend on the depth in which the FADs are encountered.

Specific information of the FAD structure, dimension and material should also be collected. Details should be specific for each component of the FAD (i.e. floating components, raft, submerged structure and weight) if possible. It should identify if the FADs 'components are floating or laying in the substrate. This could help to plan de FAD retrieval give priority for example to those moving elements still floating or partially floating and collecting after those static ones that have already stranded. Furthermore, the retrieval of FADs may be completely different depending on whether they have any part entangled and/or laying on the substrate, as in that case, careful processing may be needed to avoid further damage to the seabed.

In addition, identification, if possible, of the materials used for FAD construction (i.e. entangling character and type of material such as plastic, metallic or biodegradables (organic, bio-based) are essential to assess the potential damage (in terms of marine litter generation) and prioritize the FAD retrieval.

Regarding the classification of substrate types or habitats, discrepancies were observed among the habitat classification schemes outlined in various guidelines. In relation to impact assessment, in addition to identifying the substrate type, it is valuable to estimate the extent of the affected area. In cases involving corals, distinguishing between coral types—such as hard and soft corals, and if possible, identifying the species—can provide further insight into the nature and severity of impacts.

To quantify and characterize the impacts, the information collected should have the highest resolution as possible. Typically, participants in FAD retrieval programs are not scientists, so the data collection guidelines should be adapted to the people involved. The data could be easily collected with a mobile application, such as one based on FORMS.

5. Conclusions

This study builds upon the work conducted by Uyarra et al. (2023) in the Indian Ocean. While the results obtained do not allow for definitive conclusions regarding whether the observed patterns in benthic composition are directly attributable to FAD impacts, they are presented primarily as illustrative examples of the type of outcomes that can be generated through the application of the proposed methodological approach. This limitation is largely due to the small number of observations collected during the survey, which prevents a representative assessment. However, very importantly, this study allowed testing an in-depth sampling strategy and making *in situ* observations of the behaviour of FAD on coral reefs, identifying how the different parts of FADs interact with fish and benthic communities, which can be instrumental to provide advice on alternative FAD designs, materials, and management. In summary, key points include:

- The outputs obtained from implementing two different fieldwork methodologies (i.e. the line intercept and the photo quadrant method) were showed to be similar.
- The line intercept method for the study of the impacts of FADs on coral reefs was faster and could be adapted to variable topographies, required less equipment and generated lower standard error among samples.
- Photo quadrats methods are the preferred option when aiming to identify the extent of damage.
- The use of four transects, situated at 90º of each other, is adequate to best capture the damage caused by FADs. However, since it implies ascending and /descending in the water column, careful design of the sampling is important to avoid risks for divers. Furthermore, it would not be suitable for FADs stranded at depths deeper than 21m with pronounced slopes.

For data collection during FAD stranding events, with the aim of understanding how different components of FADs interact with benthic communities, assessing their impacts, planning FAD recovery, and identifying potential improvements in FAD design, we propose recording the following information:

- Spatiotemporal information (date, and position) and depth.
- Identification of FAD type, FAD ID, Buoy ID.
- Information about the FAD design, dimension, entangling character of materials (mesh size) and nature of the materials (i.e. biodegradable or synthetic materials).
- Position of the FAD components (raft, submerged appendage-main tail and attractors- and weight) in the water column (floating on the surface, floating on the water column, laying on the surface).
- Type of substrate
- Reef zone
- Type of corals (soft or hard), and species if possible.
- FAD parts interacting with biota.
- Presence of entangled animals, including species, number and location in the FAD.
- Area affected

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