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Preliminarily analyses of the regional database of stranded drifting FADs in the Pacific Ocean

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Executive Summary

Drifting Fish Aggregating Devices (dFADs) are reaching coastal areas where they can become stranded, adding to pollution and/or causing environmental damage. To quantify these events and their impacts, several Pacific Island Countries and Territories (PICTs), in collaboration with the Pacific Community (SPC) and international Non-Governmental Organisations (NGOs) have started programmes to collect in-situ data. These data collection programs on stranded and lost dFADs are fully implemented in seven PICTs to date: the Cook Islands, Wallis and Futuna, the Federated States of Micronesia (FSM), the Republic of the Marshall Islands (RMI), French Polynesia, Palmyra and Hawaiʻi, and are starting this year in New Caledonia and Tuvalu.

A total of 1,159 stranding events were identified in the 2009–2022 period in all the PICTs considered; 45.4% were of a buoy alone; 30.0% of a FAD alone and 19.0% of a FAD with a buoy attached (the rest corresponding to entries with unknown presence of buoys and FADs). Most FADs found were dFADs, in whole or in part, although in FSM and RMI anchored FADs (aFADs, "Payao") were commonly found stranded. Most buoys found were dFAD satellite buoys from Satlink, Marine Instruments and Zunibal brands. In the PICTs where the data collection program is implemented, the spatial distribution of stranding events was wide. Higher numbers of stranding events per 1° cell were detected in Wallis and Futuna, the Cook Islands and French Polynesia, though this could be due to higher data collection effort in some locations. In terms of habitat where FADs and buoys were most commonly found, 39.0% were found on a beach, 27.5% had been previously collected by local communities and were recorded as found in gardens or private homes; 7.6% were found drifting in the ocean and 6.8% were stuck on coral reefs. The fate of FADs and buoys was also investigated, though this information often was not recorded (no record for 18.1% of buoys and 61.4% of FADs). For those with a recorded fate, 74.1% of the buoys and 25.7% of the FADs were removed from the habitat; the rest were left where found.

Most FADs were found without submerged appendages attached (60.9%), although this information was often not recorded (18.4% of the findings). When recorded, dFAD flotation materials were i) bamboo; ii) bamboo and floats; or iii) floats. Flotation materials for the aFADs found in FSM and RMI were metal drums or fiberglass. In terms of materials related to raft covering and submerged appendages, when present, they were mostly netting and ropes (53.5%); or a combination of netting, ropes, plastic sheeting, and canvas. Netting was absent in 31.6% of FADs; present in 36.2% of FADs but without details about mesh size; present with a small mesh size (13.3%); present with a large mesh size (10.6%); and present with both small and large mesh sizes (8.3%).

Very little environmental damage was recorded in the stranding FADs database. When damage was noticed, it was coral damage (4.8% of all FADs); pollution (3.3%); turtle body parts (0.5%); and dead birds (0.2%). Most of these were recorded for dFAD stranding events and in particular when the dFAD still retained submerged appendages. In terms of other animals found interacting with the stranded FADs, or the aggregation of fish and fishing occurring near shore when lost and abandoned FADs are still in the water, this also was relatively rare with five fishing sets on dFADs recorded and aggregated fish detected around nine dFADs and three aFADs.

The origin of the FADs and buoys found stranded in the Western and Central Pacific Ocean (WCPO) was investigated by i) using markings on the satellite buoy to determine vessel owner, flag and Convention Area (CA) of fishing; and ii) matching buoy ID number with the PNA FAD tracking database and/or the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical

Tuna Commission (IATTC) observer databases. Where possible, the buoy's last known position and date and flag of origin of the vessel monitoring the buoy were identified. This second method also allowed comparison of the fate of the buoys recorded in the PNA FAD tracking database with their detected stranding event.

Most buoys (and FADs when still attached) found stranded were from vessels fishing in the WCPFC (52.6%), followed by IATTC (38.7%) and both CAs (8.7%); and the last known position was in the WCPFC-CA (65.8%) or the IATTC-CA (34.3%). There was large variability in terms of country of origin for stranding events. Most stranding events in French Polynesia were from the IATTC-CA (Ecuadorian, US, Panama vessels); and in FSM almost only from the WCPFC-CA although from a wide range of fleets. In Wallis and Futuna buoys were mostly from the WCPFC-CA (more than 65.0%), and from vessels flagged US, Korea, Kiribati and Ecuador. In the Cook Islands, buoys presented a last known position in the WCPFC-CA (75.0%), from vessels fishing in the WCPFC-CA (33.3%), both CAs (44.4%) or the IATTC (22.2%) (US, Korean, Ecuadorian and El Salvadorian vessels). The EEZ of the last known position was also investigated to detect potential patterns of origin by stranding areas.

For the 82 stranded buoys that could be matched with the PNA FAD tracking database, the fate of these dFADs, as classified in the PNA FAD tracking data was investigated. First, it was found that many buoys were not classified as stranded in the PNA FAD tracking database because they were on atolls that were not present in the digital map used to define the coastlines. Using a higher resolution map, an updated classification of dFAD fate from the PNA FAD tracking data was compiled. This highlighted that 18.3% of the stranded buoys also found in the PNA FAD tracking data were classified as beached; 3.7% recovered close to shore and 2.4% in port. However, 59.8% and 12.2% were still classified as still drifting or lost at the end of their trajectory, while they were ultimately found beached in one of the PICTs. This highlighted the fact that stranding events using the PNA FAD tracking data only are highly under-estimated, mainly due to deactivation of buoys when they drift outside the main fishing grounds and high rates of FAD (re)appropriation at sea.

We invite WCPFC-SC18 to:

- Highlight the need for in-situ data to be collected to better quantify dFAD stranding events and the impacts of dFADs on marine and coastal ecosystems.
- Note the development and progress of the in-country data collection programmes on stranded and lost dFADs nearshore and of a regional database; as well as the need to explore potential FAD retrieval programs as a measure to mitigate the impacts of lost FADs.
- Note the preliminary results from analyses of the regional database presented in this paper.
- Note the need for trajectory data, including historical periods, from both the IATTC and WCPFC convention areas to better determine the origin of FADs and buoys found stranded.
- Encourage the extension of the in-country data collection programmes to other members of WCPFC.

1. Introduction

Several Pacific Island Countries and Territories (PICTs), together with regional entities (e.g., Parties to the Nauru Agreement (PNA)) as well as international Non-Governmental Organisations (NGOs), have raised concerns regarding the number of drifting Fish Aggregating Devices (dFADs) reaching coastal areas, including coastlines, where they become stranded. This not only contributes to coastline debris but also damages fragile habitats such as coral reefs and can entangle turtles and sharks (Balderson and Martin, 2015; Escalle *et al.*, 2019b).

Concern over stranded dFADs has intensified in recent years due to a general feeling of an increasing trend in stranding events, including in PICTs with no purse seine activities; and by a lack of retrieval plans and solutions to process/recycle these objects on remote islands. However, the number of studies investigating stranding events in the Western and Central Pacific Ocean (WCPO) remains limited. This is largely due to the absence of data available to adequately quantify the number of dFADs arriving in coastal areas, stranding events, and impacts on the ecosystems. Studies based on trajectories from satellite buoys deployed on dFADs operating in the WCPO (i.e., PNA dFAD tracking data, see (Escalle *et al.*, 2021)), estimated that 7% of dFADs end up beached in the WCPO, with some areas more influenced by oceanic currents and others more linked to dFAD deployment strategy (Escalle *et al.*, 2019b, 2021). Based on results from Escalle et al. (2019a), it was recently estimated that 4 to 6 km^2 of coral reef habitat could be affected per year in all the PNA countries (Banks and Zaharia, 2020). The number of stranding events and level of ecosystem impacts are very likely under-estimated, given that the current dataset corresponds mostly to data from PNA member EEZs, but also because satellite buoys are commonly deactivated by fishers when drifting outside the main fishing areas.

In the WCPO, dFAD management has primarily focused on limiting dFAD fishing efforts and the impact that dFAD fishing may have on tuna stocks. This included the implementation, beginning in 2009, of a two to four month dFAD closure during which all dFAD-related activities (e.g., fishing, deploying, servicing) are prohibited. Additionally, a limit of 350 active buoys per vessel, at any given time, was implemented in 2018 (WCPFC, 2018); note this may not actually limit the overall number of dFADs deployed (as buoys may be deployed on dFAD found in the water, many vessels are far from the limit and buoy deactivation and (re)activation may be occurring). More recently in the WCPO, in an effort to reduce the impact of dFADs on sensitive species such as turtles and sharks, and to reduce marine pollution, mandatory use of low entanglement risk dFADs was implemented in 2020, while non-entangling dFAD designs are required from 2024 and the use of biodegradable dFADs is encouraged (e.g. WCPFC, 2018, 2021).

This paper presents initiatives started or under-development by PICTs and in collaboration with the Pacific Community (SPC) and NGOs to collect data on lost dFADs reaching coastal areas and/or stranded, as well as the impacts of these events on ecosystems. Data collection is carried out and stored individually in each PICT. A regional database with data from all PICTs is then compiled at SPC, allowing for future scientific studies to be performed at the scale of the WCPO, as well as the ground-truthing of existing estimates. This paper presents preliminary results from analyses of this regional database.

2. In-country initiatives to collect data

2.1 Collaborations with SPC

In the context mentioned above of recorded events of arrival of dFADs in coastal areas, as well as the need to collect in-situ data to complement available data on dFADs (PNA dFAD tracking and observer data); data collection programmes have started or are in development, as a collaboration between fisheries departments, SPC and NGOs.

The main objectives of the programmes are:

- quantify the number of dFAD stranding events or dFADs drifting nearshore,
- assess the resulting ecosystem impacts, including on species of special interest (SSIs) and on habitats,
- when possible, evaluate how dFAD materials and satellite buoys may be repurposed or recycled locally by communities.
- considering ways to mitigate these impacts and providing scientific-based advice to guide the management of FADs in the Pacific Ocean.

Since 2020, data collection programmes on lost dFADs reaching coastal waters and on stranded dFADs have started in the Cook Islands, Wallis and Futuna, French Polynesia, Federated States of Micronesia (FSM) and Republic of the Marshall Islands (RMI) (Table 1). New Caledonia, Tuvalu, Samoa and the Solomon Islands have also shown interest in joining the data collection effort and contributing to the regional database. These programmes involve local communities reporting their findings to fisheries officers, who enter data on forms and in their country/territory database. Data can also be collected through existing SPC data collection networks within a community-based fisheries management framework. As each programme is based on local communities' engagement, communication and awareness activities are essential. This involves different means, such as posters, radio and TV broadcasts, and public talks (Figure S3). Importantly, to be effective, the development of systematic data collection programmes on stranded and lost dFADs must remain as simple and efficient as possible.

Table 1. Summary of data collected through stranded dFAD data collection programs in the WCPO.

PICT	Start of the program	Events recorded
French Polynesia	2019	536
Wallis and Futuna	2020	160
FSM	2021	139
Cook Islands	2020	96
Hawai'i	2014	83
Palmyra	2009	64
New Caledonia	2022	32
RMI	2021	24
Tuvalu	2022	10
Samoa	Under discussion	1
Pitcairn	Opportunistically	7
Australia	Opportunistically	4
Vanuatu	Opportunistically	3

For the first few months of the program in each PICT, reports included dFADs and buoys previously picked up by the public. This is also important to create a baseline inventory and better capture and identify new events. For this first inventory record, any information is relevant, even if the precise date/location is unknown, as it gives an idea of common levels of dFADs that have historically arrived. If the buoy ID is recorded, this will assist in cross referencing with other databases (e.g., WCPFC-IATTC observer data, PNA dFAD tracking data) to avoid duplication and ensure a reliable representation of database records. Data were also collected through dedicated visits to outer islands by SPC staff, fisheries departments and local staff (fisheries observers). Island coastlines were then surveyed on a specific day, and data were collected for every dFAD found.

When possible, data collected included date, location, environment, materials and size of the dFAD, its fate (e.g., removed, left where it was found, fished), the buoy identification number and any other painted marks on the buoy, as well as any observed environmental impacts (e.g., coral reef damage or entanglement of SSI). Data are then transferred to SPC, who compiles all the data into a regional database.

2.2 Other initiatives

In parallel, other initiatives or opportunistic reports have emerged. This includes data collection at Palmyra Atoll (through The Nature Conservancy TNC) since 2009; Hawaiʻi (through the Center for Marine Debris Research) since 2014, and French Polynesia since 2019 (Marine Resources Authority) (see Table 1). Opportunistic data collection has also been reported to SPC since 2018, including through SPC's existing data collection networks. This includes additional records from Australia; New Caledonia; Pitcairn Islands; Samoa; Tuvalu; and Vanuatu.

At Palmyra Atoll, The Nature Conservancy (TNC) and the U.S. Fish and Wildlife Service (USFWS) have been collecting data on dFAD stranding since 2009. Visual surveys across shallow reefs, lagoon flats and beaches have been opportunistically tied in with other projects but, now that consistent stranding areas have been established, specific surveys are being scheduled across all 12 months of the year. Designs of the stranded dFADs, and type of materials used are described, as well as the impacts on the environment. When a satellite buoy is present and the identification number visible, it is also recorded. A dFAD Watch type program (Zudaire *et al.*, 2018) has also been under development at Palmyra Atoll since June 2021. This involves fishing companies alerting local partners if a dFAD comes close to Palmyra Atoll's shores, so that it can be picked up before causing any environmental damage.

In Hawaiʻi, the stranded dFAD collection was first initiated by Sarah-Jeanne Royer as a member of Nikolai Maximenko's group at the University of Hawaiʻi at the International Pacific Research Center. The program is now being monitored by the Center for Marine Debris Research (CMDR) at Hawaiʻi Pacific University (HPU). The data collection started in 2014 and now involve several collaborators that report the findings to the research group. Depending on the geographical location of the dFADs some buoys are re-directed when possible to the island of Oahʻu and kept in a warehouse with the possibility to repurpose the buoys to tag and track marine debris like fishing nets.

French Polynesia has also started a large project to quantify the number of dFADs drifting within its EEZ, including the number of stranded dFADs and their ecosystem impacts. The programme involves several component: i) data reported by local communities through a form that can be directly downloaded or filled up on the marine resources authority's website (http://www.ressources-marines.gov.pf/dcpech); ii) dedicated surveys in nine islands of the Tuamotu, with visits to local communities, shoreline surveys using a drone, shores cleanings and FAD recycling operations. Data collected through these independent programs were also added to the regional database and analysed in this paper.

2.3 Lessons learnt

The data collection programs on stranded and lost dFADs is fully implemented in seven PICTs to date: the Cook Islands, Wallis and Futuna, FSM, RMI, French Polynesia, Palmyra and Hawaiʻi. Given the current development of similar initiatives in other PICTs in the future, some lessons learnt, and challenges faced, can already be summarized. Factors influencing the success of the program, especially in terms of data reporting, as well as how the contribution was made, are described in Table 2. With the extension of the programmes to more PICTs, and the increasing reporting of stranded FADs, systematic standardisation and processing procedures need to be in place when combining the individual data into the regional database.

Table 2. Factors influencing the success of the data collection programs and the challenges faced.

Type	What?	How?
Success	In-country motivation and fishery department involvement. Good knowledge of dFADs, their design and potential impacts.	- A focal person in the fishery department in charge of collecting and entering data. - Frequent email/Skype exchanges or SPC staff visiting at the beginning of the programme and regular updates afterwards.
Success	Significant inclusion of local communities: knowledge of the programme and understanding its objectives and its importance for them.	- Various communication means: posters in English and local languages and dialects, comics, radio and newspaper messages, TV broadcast. Good relationship between fisheries departments and fishermen/ population and public meetings. - Local visit by SPC staff, public presentation.
Success	Centralisation and homogenisation of consistent data collection.	- A form filled in by fisheries officers upon report from the community (Appendices). Depending on the PICT, data collection protocols (e.g., form) could be adapted so it can be used by artisanal fisher's, community-based groups, NGOs, fishing companies and opportunistic data collectors. - Precise description of the data fields (Appendices). - Hosting the form and pictures on Google Drive for easy access and sharing.
Success	Follow-up communications with the general public.	- Communication of results (e.g., presentation, small articles) to the general public, so they can see the results of their efforts and how things are developing.
Challenges	Including outer Islands in the program (communication data transfer, etc.).	
Challenges	Accuracy of found dates and found locations; as well as other information regarding the finding (buoy ID, materials, impact).	

3. Preliminary analyses

a) Summary of stranded events

A total of 1,159 stranded events were identified in the 2009–2022 period in all PICTs considered. Most of the stranding events were of a buoy alone (45.4%), followed by a FAD alone (30.0%) and by a FAD with a buoy attached (19.0%) (Table 3; the remainder corresponded to entries with unknown presence of buoys and FADs). When considering FADs only (583), the most common objects found were dFADs (79.9%), followed by aFADs (9.1%) and dFAD parts (4.5%) (Figures 1 and 2). For the remaining events, the type of floating object was not recorded (6.5%). When considering the buoys only (780), the vast majority were satellite buoys (97.5%), with a few radio buoys and CO_2 monitoring buoys (Figures 1 and 2).

Table 3. Percentages of type of objects found stranded and numbers in brackets. Finding of FADs included dFADs, aFADs and dFAD parts; buoys include FAD satellite buoys, radio buoys and weather buoys.

		FADs (583)		
		Presence	Absence	Unknown
Buoy (780)	Presence	19.0% *(220)*	45.4% *(526)*	2.9% *(34)*
	Absence	30.0% *(348)*	0% *(0)*	0% *(0)*
	Unknown	1.3% *(15)*	0.3% *(3)*	1.1% *(13)*

The number of stranding events recorded in the regional database has been increasing with the development of the data collection programmes and the growing number of PICTs participating. The first stranding events recorded were in 2009 in Palmyra, the only country which has a data collection of more than 14 years (Figure 1). In 2019 and 2020, more than 150 stranding events were recorded, and more than 300 in 2021 and 2022. In many countries, the first stage of the data collection program was an inventory of all buoys and FADs previously collected by the local communities and often accumulating in gardens or ports. Hence, the date is sometimes unknown (7.6% of all stranding events) or could be uncertain. In terms of type of stranding events, satellite buoys, dFADs and dFADs with a satellite buoy dominated the findings (Figure 1). The type of floating objects found stranded was slightly different between the PICTs. In FSM and RMI, respectively, 21.6% and 66.7% of the stranded events were aFADs, respectively (Figure 2). We can also note that in Wallis and Futuna, many of the objects found were dFAD parts (14.4%), likely because they have been picked up by communities previously, brought to private homes and reused for other functions related or not to the fishery.

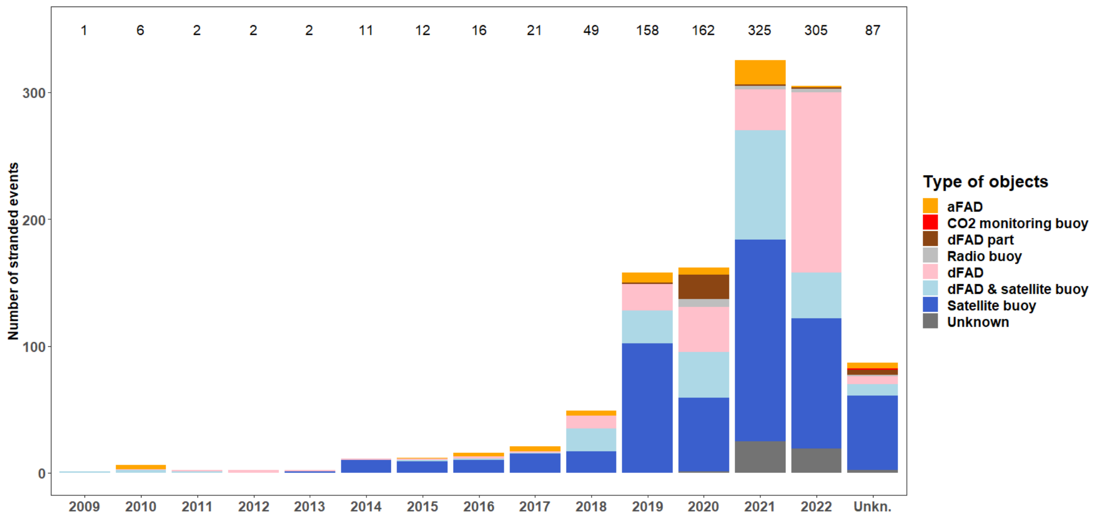

Figure 1. Number of stranded events found by year and type of findings. Numbers on the top of the figure correspond to the number of stranded events per year.

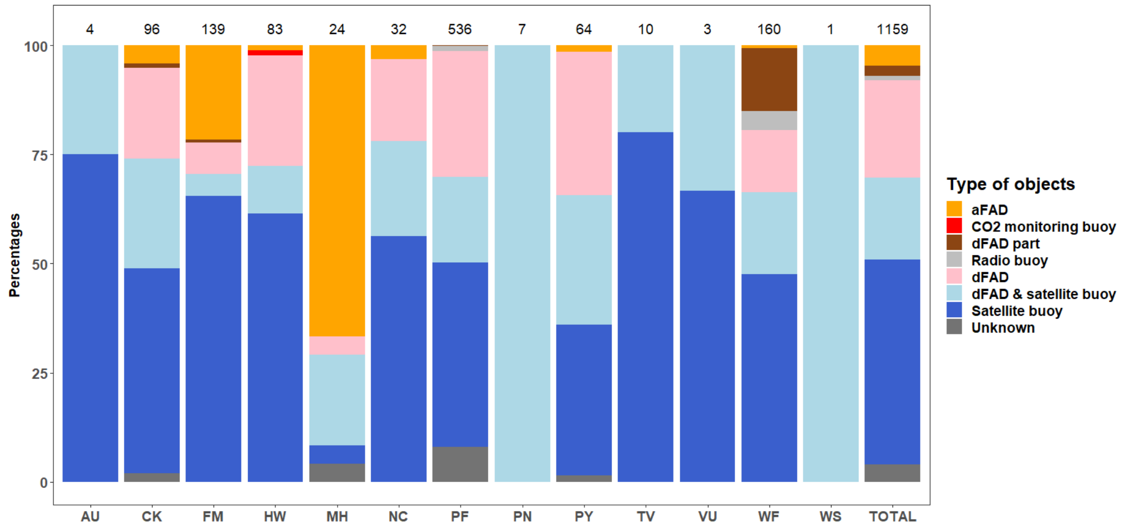

Figure 2. Percentages of stranded events found by country and type of findings. Numbers on the top of the figure correspond to the number of stranded events per country. AU = Australia; CK = Cook Islands; FM = Federated States of Micronesia; HW = Hawaiʻi; MH = Marshall Islands; NC = New Caledonia; PF = French Polynesia; PN = Pitcairn; PY = Palmyra; TV = Tuvalu; VU = Vanuatu; WF = Wallis and Futuna; WS = Samoa.

Most of the buoys found were of the three following brands: Satlink (34.9%), Marine Instruments (22.4%) and Zunibal (15.4%), and a few Ryokusei and Kato (Table 4). Note that the brand was not known for 23.2% of the buoys. It can also be noted than half of the buoys (51.9%) had an echosounder, but this was not known in 41.5% of the buoys (Table 4). Small differences between countries were detected with, for instance, a higher proportion of Zunibal buoys in French Polynesia, or the few Kato buoys found in FSM (Figure 3).

Table 4. Model and type of buoys found stranded.

	Type of buoy		Echo-sounder (Number)		
	Number	%	No	Yes	Unknown
Satlink	272	34.9	1	258	13
Marine Instruments	175	22.4	18	81	77
Zunibal	120	15.4	23	66	31
Ryokusei	17	2.2	0	0	16
Kato	15	1.9	0	0	15
Unknown	181	23.2	6	0	174
Total	780				
% Echosounder			6.2	51.9	41.5

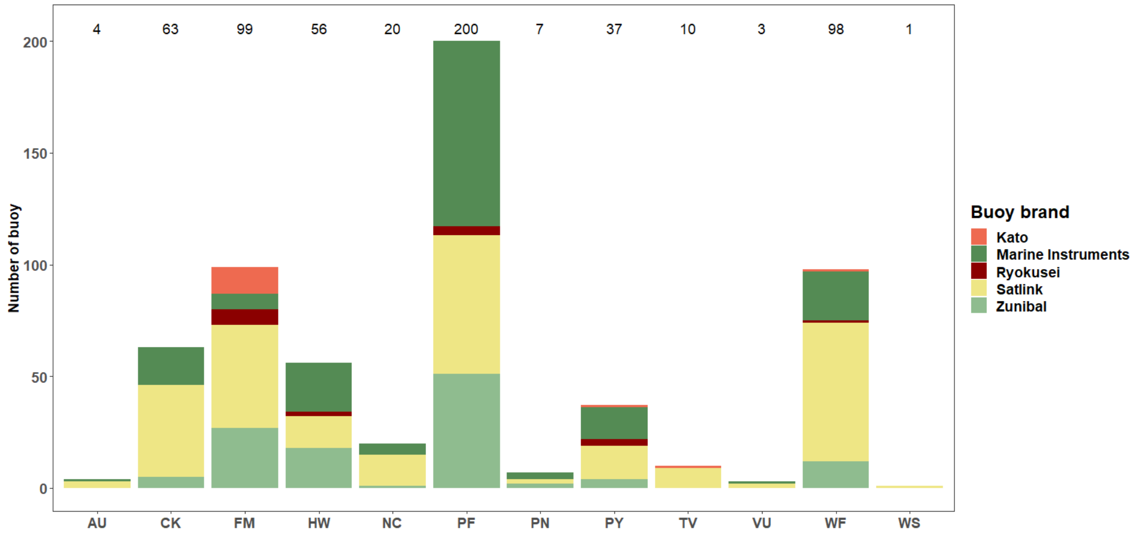

Figure 3. Number of buoys found stranded by buoy brand and country. See Figure 2 for country codes.

b) Spatial distribution of stranding events

The spatial distribution of FAD stranding events in the WCPO shows a large distribution for the countries where the data collection program is implemented (Figures 4 and 5). Higher numbers of stranding events per 1° cell were detected in Wallis and Futuna, the Cook Islands and French Polynesia. It should however be noted that this could be due to higher data collection efforts in particular locations or to actual higher levels of stranding events. Additional years of data and/or accounting for the effort in data collection would be needed to better understand the spatial differences detected here.

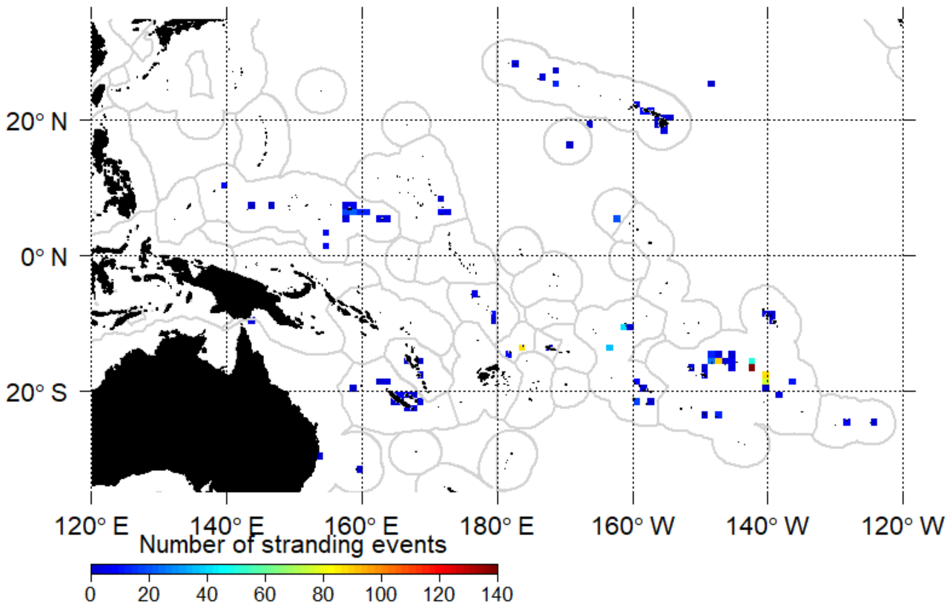

Figure 4. Aggregated map of stranded FADs found in Pacific Island Countries and Territories between 2008–2022.

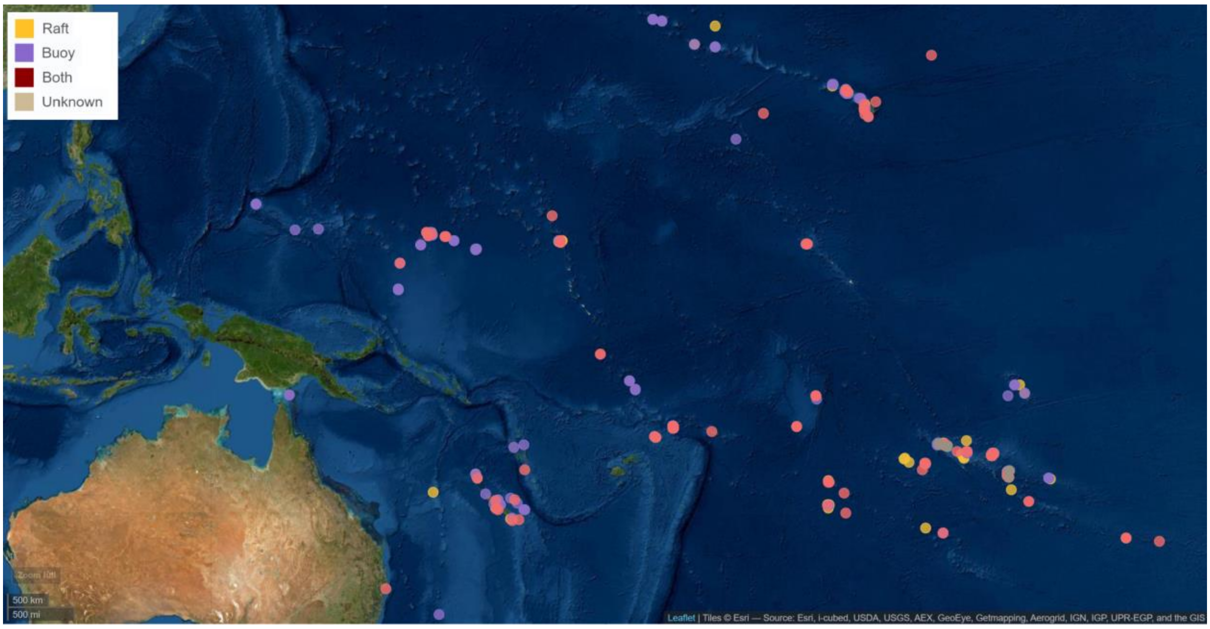

Figure 5. Map of stranding events with known position (1156) found in Pacific Island Countries and Territories between 2009–2022, by type of findings.

The type of stranded objects differed between countries. For instance, French Polynesia is more subject to stranded FADs alone or associated with a buoy than just a buoy alone. However, this could be the result of a higher data collection effort in this PICT. Figures 6.1 to 6.9 indicate locations of stranded FADs and/or buoys (raft, buoy, both or an unknown object) in each PICT with more than five stranding events in the database; as well as the habitat. In some PICTs, stranding events were more numerous on one side of the coast, which is the case for the Hawaiian Islands (Figure 6.3) or Rangiroa Atoll (Figure 6.6). Others, such as Palmyra Atoll (Figure 6.8) or Wallis (Figure 6.9) present high density of coral reefs around their coastlines, making them sensitive locations to stranding events.

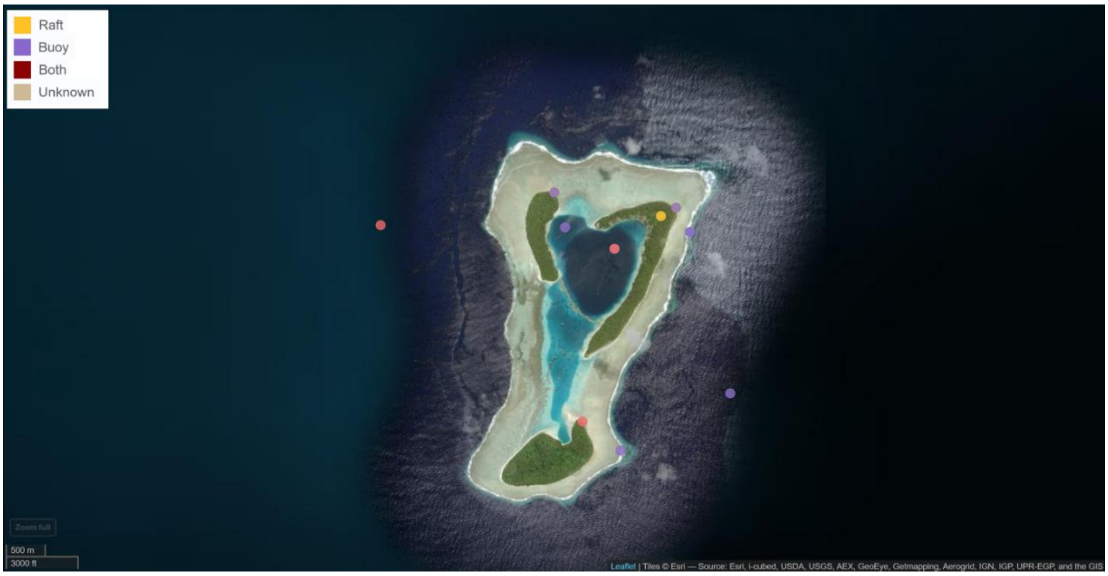

Figure 6.1. Map of stranding events in Mokil Atoll (Federated States of Micronesia).

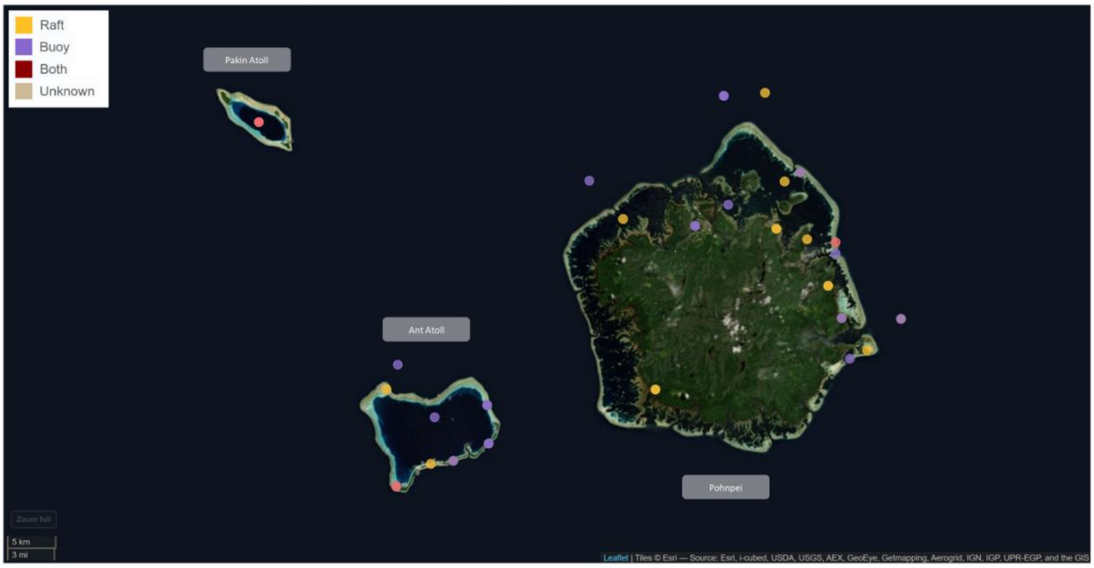

Figure 6.2. Map of stranding events in Pohnpei, Ant Atoll and Pakin Atoll (Federated States of Micronesia).

Figure 6.3. Map of stranding events in the Main Hawaiian Islands (Hawai'i).

Figure 6.4. Map of stranding events in Mili Atoll (Republic of the Marshall Islands).

Figure 6.5. Map of stranding events in New Caledonia and Vanuatu (Southwest Pacific example).

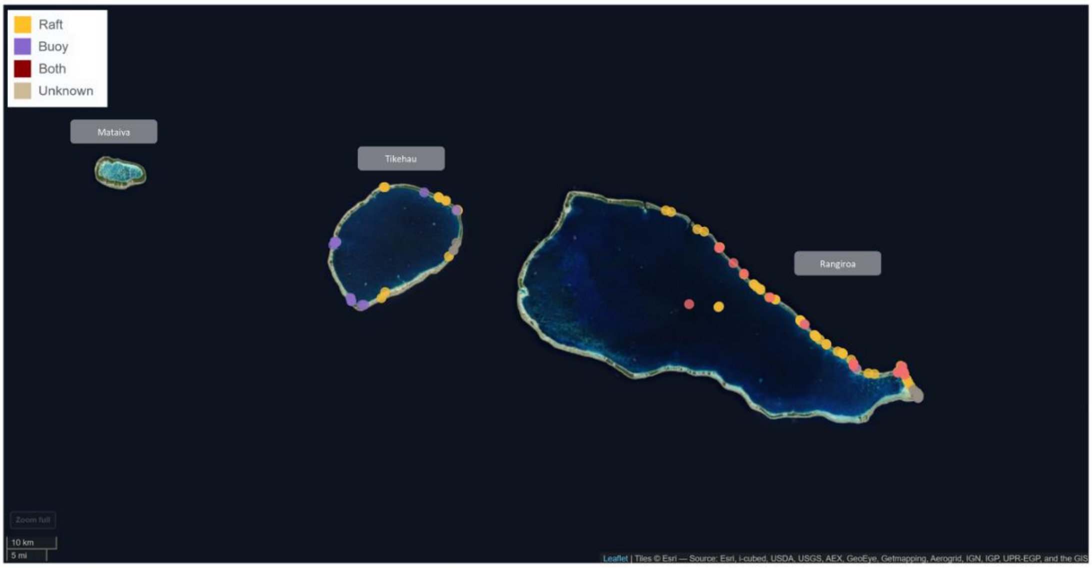

Figure 6.6. Map of stranding events in Mataiva, Tikehau and Rangiroa Atoll (French Polynesia).

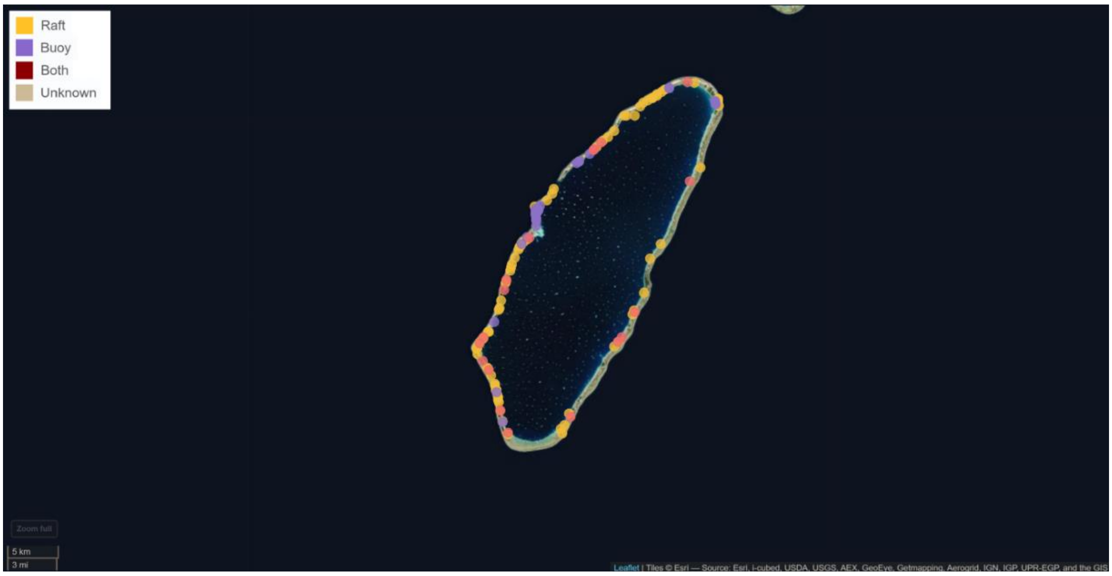

Figure 6.7. Map of stranding events in Raroia Atoll (French Polynesia).

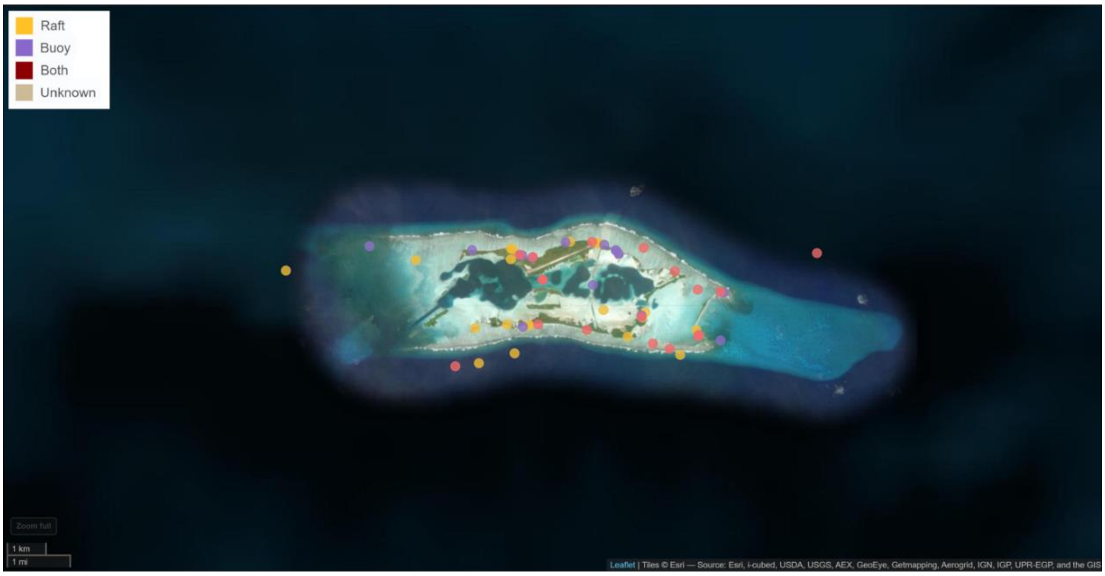

Figure 6.8. Map of stranding events in Palmyra Atoll.

Figure 6.9. Map of stranding events in Wallis (left) and Futuna (right).

c) Habitat impacted

FAD stranding events can occur in sensitive environments and therefore pose a risk to coral reefs and other marine life. Out of the 1159 stranding events recorded, 39.0% were found on a beach, 7.6% were drifting in the ocean and 6.8% were entangled on coral reefs. The second major part of the findings relate to data previously collected by local communities and recorded as found in gardens or private homes, and accounted for 27.5% of the data.

When considering FADs and buoys separately, results differ slightly. First, buoys were mostly found in gardens and private homes (category "previously collected" in Table 5) (36.0%), followed by beaches (26.7%) and then other habitats. They were then often dismantled to recover electronic materials. Second, FADs were found on beaches (55.2%); in gardens (14.2%); and on coral reefs (8.9%). The aFADs were mostly found beached (52.0%) or in gardens (16.0%) whereas dFADs were mostly found on beaches (70.3%). However, when dFADs were found with submerged appendages, they were more often found to stranded on coral reefs (23.1%) compared to dFADs without any appendages (4.3%).

Table 5. Percentages/number of stranded events per habitat type and FAD type/component.

Environment	Total	FADs	Buoys	dFAD with tail	dFAD without tail	aFAD
Beach	39.0% (*452*)	55.2% (*322*)	26.7% (*208*)	50.0% (*26*)	77.8% (*126*)	52.0% (*26*)
Coral reef	6.8% (*79*)	8.9% (*52*)	6.2% (*48*)	23.1 (*12*)	4.3% (*7*)	8.0% (*4*)
Drifting in the lagoon	2.6% (*30*)	3.8% (*22*)	3.1% (*24*)	0.0% (*0*)	1.9% (*3*)	2.0% (*1*)
Drifting in the ocean	7.6% (*88*)	7.9% (*46*)	8.8% (*69*)	21.2% (*11*)	1.9% (*3*)	2.0% (*1*)
Mangrove	0.3% (*4*)	0.7% (*4*)	0.1% (*1*)	0.0% (*0*)	0.6% (*1*)	4.0% (*2*)
Previously collected*	27.5% (*319*)	14.2% (*83*)	36.0% (*281*)	5.8 (*3*)	9.9% (*16*)	16.0% (*8*)
Shore	3.8% (*44*)	3.8% (*22*)	3.5% (*27*)	0.0% (*0*)	3.1% (*5*)	14.0% (*7*)
Unknown	12.3% (*143*)	5.5% (*32*)	15.6% (*122*)	0.0% (*0*)	0.6% (*1*)	2.0% (*1*)

*Found in garden, wharf or landfill.

The type of environment where FADs and buoys were found differed depending on the PICTs considered. Figures 7 and 8 show that a large proportion of objects have been previously collected by local communities, who transformed and recycled materials, especially in the Cook Islands (37.7%) and New Caledonia (16.0%) for buoys, and FSM (35.3 %; 14.6%), French Polynesia (57.3%; 18.0%) and Wallis and Futuna (17.4%; 26.3%), for both buoys and FADs. New Caledonia (28.6%), Palmyra Atoll (22%), FSM (18.8%), Wallis and Futuna (17.1%), Pitcairn Islands (14.3%), and Hawaiʻi Islands (12.9%) also presented higher rates of FADs stranded on coral reefs.

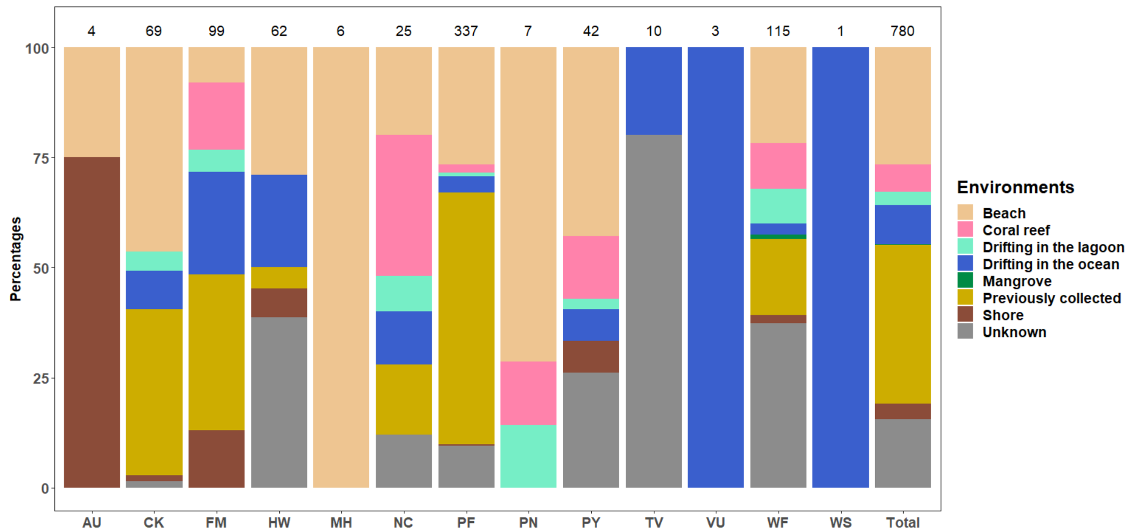

Figure 7. Percentages of stranded buoys per habitat type and country. Numbers on the top of the figure correspond to the number of stranding events per country. See Figure 2 for country codes.

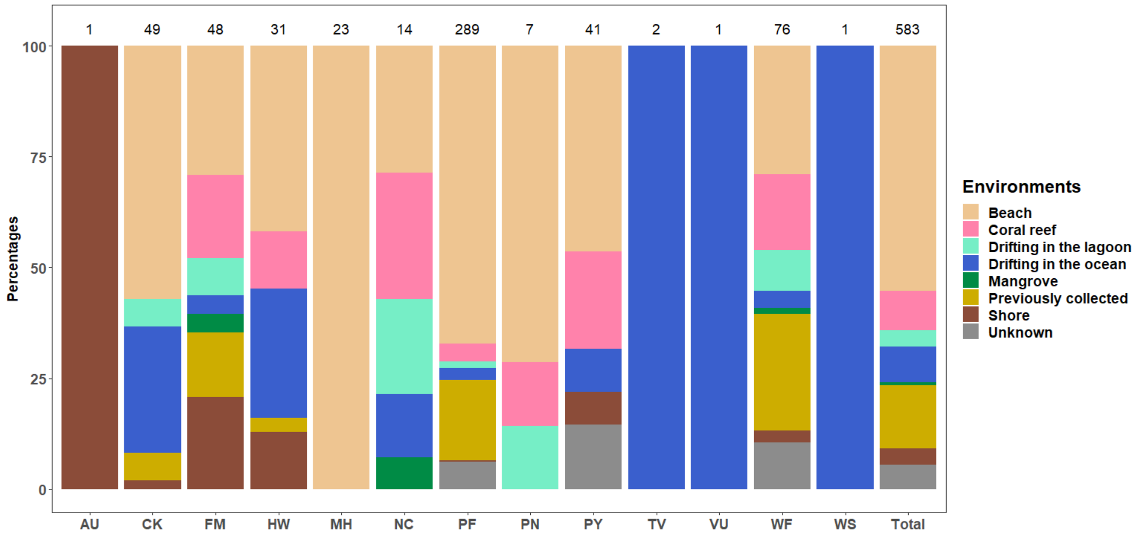

Figure 8. Percentages of stranded FADs per habitat type and country. Numbers on the top of the figure correspond to the number of stranding events per country. See Figure 2 for country codes.

d) Type of FADs found stranded

The type of FADs found stranded was investigated (including dFADs and aFADs); most FADs were found with no submerged appendages still attached (60.9%). 20.8% of the FADs still had submerged appendages attached; and 18.4% of the findings did not have this information recorded (Table 6). The condition of the FADs when found was also investigated, although this information is mostly not recorded (56.6% of the findings). The rest of the FADs were found intact (23.3%), mainly without submerged appendages (i.e. "tail"), followed by mostly fallen apart (12.0%) and finally classified as beginning to break up (8.1%) (Table 6).

Table 6. Number and percentages of stranded FADs with submerged appendages and FADs condition.

Submerged appendages			Condition			
	N	%	Intact	Beginning to break up	Mostly fallen apart	Unknown
Present	121	20.8	8.2	1.0	2.6	8.9
Absent	355	60.9	12.7	5.5	6.0	36.7
Unknown	107	18.4	2.4	1.5	3.4	11.0
Total	583		23.3	8.1	12.0	56.6

Materials were recorded in 301 FAD stranding events (53.5% of total) (Figure 9). Most of the flotation materials detected in found FADs were i) bamboo; ii) bamboo and floats; or iii) floats (Figure 9). In FSM and RMI, a lot of the stranding events were of aFADs, leading to flotation materials recorded as metal drums or fiberglass. The rest of the materials were a mix of bamboo, floats and/or PVC, metal drum and plastic foam (polystyrene or Styrofoam). In terms of raft covering and submerged appendages, 20.3% of the FADs with materials recorded did not present any attachment (Figure 9). This is particularly the case in FSM and RMI, as it corresponds to aFADs. When present, the attachments were mostly netting and ropes (53.5%); or a combination of netting, ropes, plastic sheeting, and canvas. Regarding netting, 31.6% of FADs did not have any netting (mostly aFADs); 36.2% of FADs had some netting, with details about mesh size not recorded (Figure 10). When mesh size was recorded[1], 13.3% of FADs had small mesh netting; 10.6% large mesh netting and 8.3% both small and large mesh netting (Figure 10). Different shapes of FAD rafts were also detected, cylindrical (FSM and RMI; corresponding to aFADs); rectangular, square, or as a "sausage" (corresponding to buoys attached together) (Figure 11).

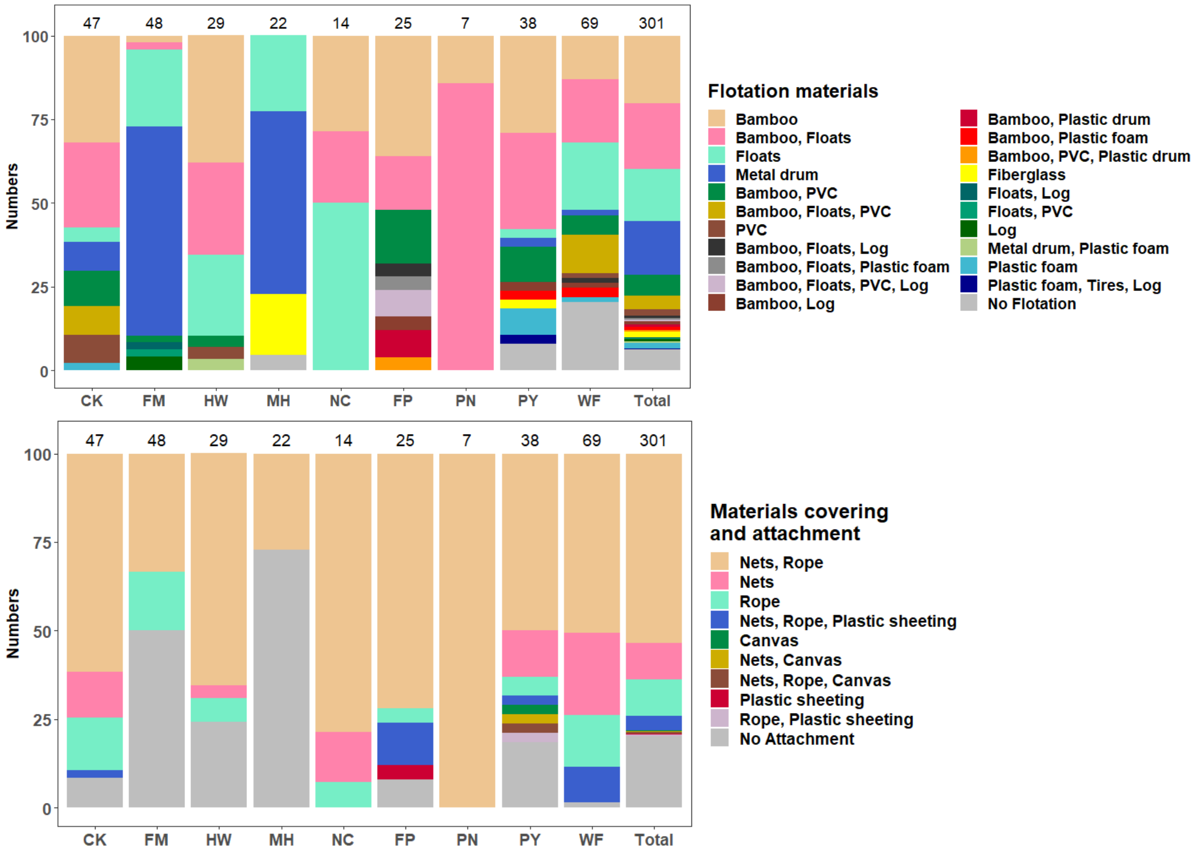

Figure 9. Flotation (top) and covering and attachment (bottom) materials of FADs found stranded with materials recorded per country. Numbers on the top of the figure correspond to the number of stranded events with materials recorded per country. See Figure 2 for country codes.

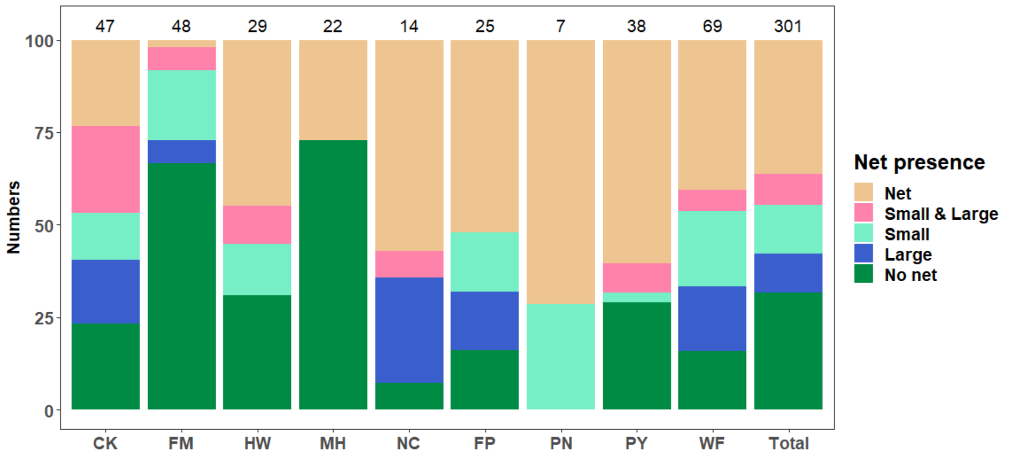

Figure 10. Presence and mesh size (small or large mesh size; visually estimated) of net for FADs found stranded with materials recorded, per country. Numbers on the top of the figure correspond to the number of stranded events with materials recorded per country. See Figure 2 for country codes.

[1] Note that small and large mesh are defined as < or > to 7cm and used in the definition of Low-Entanglement risk dFADs by WCPFC and the International Seafood Sustainability Foundation (ISSF).

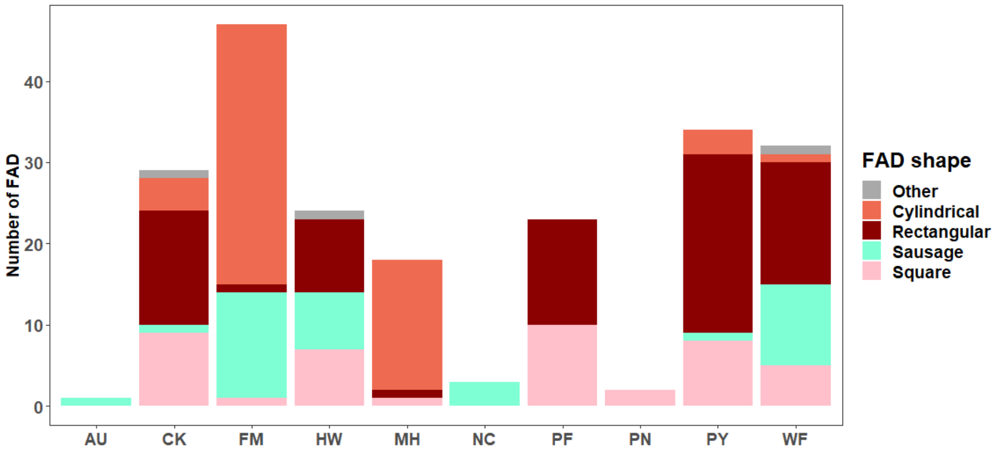

Figure 11. Shape of FADs found stranded per country. See Figure 2 for country codes.

e) Environmental impacts

The fate of buoys and FADs found stranded was investigated (Table 7). 74.1% of the buoys and 23.8% of the FADs were removed from the habitat. It should however be noted that in a large portion of the stranding events, the fate was not recorded (18.1% of buoys and 64.3% of FADs).

Table 7. Fate of buoys and FADs found stranded.

	Buoy		FAD	
	Number	%	Number	%
Left	60	7.7	69	11.8
Removed	578	74.1	150	25.7
Removed partly	0	0	4	0.7
Fished and removed	1	0.1	0	0
Fished and left	0	0	2	0.3
Unknown	141	18.1	358	61.4

When the buoy purpose was known (21.4%), the buoy was mostly considered as used for research (38.2%) or stored (37.4%) (Figure 12). The rest were used by PICT communities, with electronic components such as solar panels or batteries repurposed (1.6%) or transformed as house furniture (8.9%). When considering individual PICTs, most of the satellite buoys in Hawaiʻi and Palmyra were classified as used for research (69.4% and 100.0%, respectively). In other countries, communities were more inclined to transform buoys, such as in Wallis and Futuna (4.8%), FSM (40.0%) and in RMI (100.0%). Fate of buoys in French Polynesia was rarely recorded, as we did not have the complete data at time of analyses.

Regarding the purpose of the FADs, when known (63.5%), in Wallis and Futuna and FSM, FADs were often transformed into another object (64.7% and 46.7%), whereas in RMI most of them were just removed for environmental purposes (77.8%) (Figure 13). In FSM, some of the FADs were also reused as aFADs (33.3%). As previously found for the buoys, most of the FADs in Hawaiʻi and Palmyra were classified as collected for research purposes (52.2% and 83.3% respectively). Fate of FADs in French Polynesia was again rarely recorded. It should be noted that the type of fate recorded is highly variable between PICTs and would not necessarily be classified the same way everywhere.

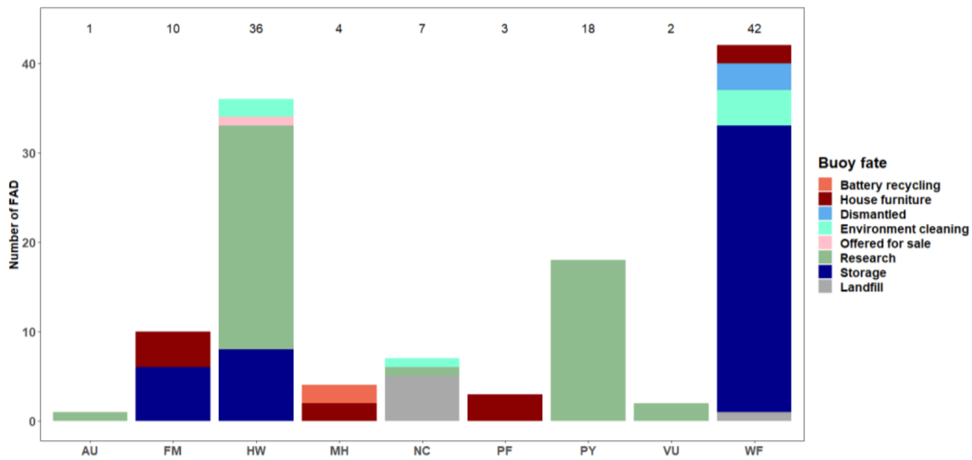

Figure 12. Purpose of buoys removed for the stranded location (total of 125 buoys with purpose recorded). See Figure 2 for country codes.

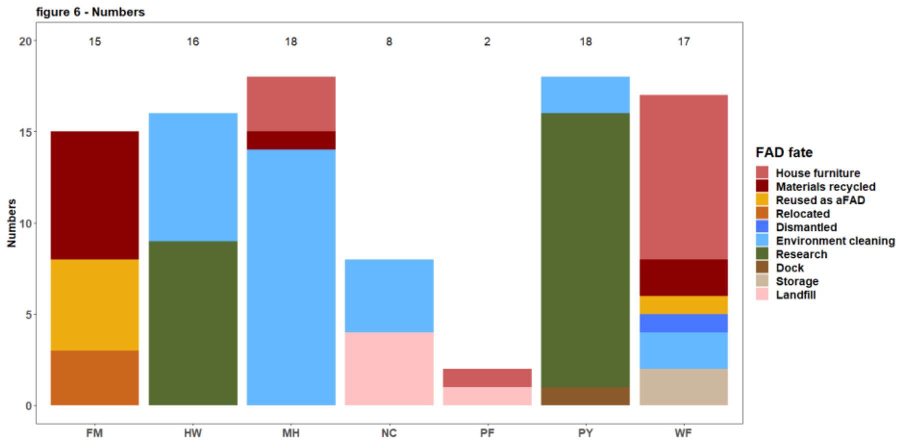

Figure 13. Purpose of FADs removed for the stranded location (total of 125 buoys with purpose recorded). See Figure 2 for country codes.

Very little environmental damage was recorded in the stranding FADs database, with 34.6% of all FADs stranded with no damage recorded and 56.6% with unknown damage (Table 8). When damage was noticed, it was coral damage (4.8% of all FADs); pollution (3.3%); turtle body parts (0.5%); and dead birds (0.2%). Most of these were recorded for dFAD stranded events and in particular when the dFAD still had submerged appendages attached. It should be noted that the damages recorded are at time of finding, but these are certainly underestimated, as ghost fishing, marine pollution or coral damage can occur throughout the lifetime of dFADs (at-sea or on coastal habitats). Marine pollution can also occur through microplastics from dFAD parts, but this would be very hard to quantify.

Table 8. Environmental damage caused by stranded FADs recorded in the database.

	FADs - total	dFAD	dFAD with tail	dFAD without tail	aFAD
No damage recorded	202 *(34.6%)*	148 *(35.5%)*	35 *(32.1%)*	0 *(0.0%)*	32 *(60.4%)*
Coral damage	28 *(4.8%)*	26 *(5.9%)*	22 *(20.2%)*	1 *(1.6%)*	2 *(3.8%)*
Dead birds	1 *(0.2%)*	1 *(0.2%)*	1 *(0.9%)*	0 *(0.0%)*	0 *(0.0%)*
Turtles body parts	3 *(0.5%)*	3 *(0.7%)*	0 *(0.0%)*	0 *(0.0%)*	0 *(0.0%)*
Sperm whale	19 *(3.3%)*	2 *(0.5%)*	1 *(0.9%)*	1 *(1.6%)*	16 *(30.2%)*
Unknown	330 *(56.6%)*	262 *(59.3%)*	50 *(45.9%)*	62 *(96.9%)*	3 *(5.7%)*
TOTAL	583	442	109	64	53

In terms of other animals found interacting with the stranded FADs, or the aggregation of fish and fishing set when FADs are still in the water, this also remains relatively rare with 94.2% of FADs without any interaction recorded (Table 9). It was recorded that artisanal fishing occurred around five dFADs and that aggregated fish were detected at nine dFADs and three aFADs.

Table 9. Aggregated, interacting, or caught animal detected in the vicinity of the FADs.

	FADs - total	dFAD	dFAD with tail	dFAD without tail	aFAD
Aggregated fish	11 *(1.9%)*	9 *(2.0%)*	6 *(5.2%)*	2 *(0.8%)*	3 *(5.7%)*
Caught fish	5 *(0.9%)*	5 *(1.1%)*	4 *(3.4%)*	0 *(0.0%)*	0 *(0.0%)*
Barnacles	15 *(2.6%)*	13 *(2.9%)*	11 *(9.5%)*	1 *(0.4%)*	1 *(1.9%)*
Seabirds	2 *(0.3%)*	2 *(0.4%)*	2 *(1.7%)*	0 *(0.0%)*	0 *(0.0%)*
Monk seal	1 *(0.2%)*	1 *(0.2%)*	1 *(0.9%)*	0 *(0.0%)*	0 *(0.0%)*
Unknown	553 *(94.2%)*	417 *(93.3%)*	92 *(79.3%)*	237 *(98.8%)*	49 *(92.5%)*
TOTAL	587	447	116	240	53

f) Origin – Matching with observer and FAD tracking data

To determine the origin of the FADs and buoys found stranded in the WCPO, two approaches were undertaken. First, when markings were detected on the satellite buoy, the vessel owner was identified (when possible) using the Western and Central Pacific Fisheries Commission (WCPFC) and Inter-American Tropical Tuna Commission (IATTC) online vessel registry. Flag and Convention Area (CA) of fishing were then derived. Second, an investigation of the unique buoy ID number recorded on the satellite buoys found stranded was implemented in three different fishery databases: i) the PNA FAD tracking database; ii) the WCPFC observer database; and iii) the IATTC observer data. In each database, if the buoy ID number was detected, the last known position and date was selected, as well as, when possible, the flag of the owner vessel originally deploying/monitoring it along with the fate of the buoy recorded in the PNA FAD tracking database (Escalle *et al.*, 2021).

In regards with the flag and CA of fishing of the vessel monitoring the satellite buoy (attached to a dFAD or not), which was determined as the vessel name written on the buoy, or flag of vessel from last known position of the buoy in the WCPFC observer and PNA FAD tracking data, a large variability of origin was detected (Figures 14 and 15). From the mark painted on the buoy, 26.6% of buoys were from Ecuadorian vessels; 20.8% from US vessels; 12.1% from Korean vessels and the rest from 13 other flags (Figure 14). Similar patterns were detected using the method matching buoy IDs with observer and trajectory data, however no flag information was available from the IATTC database. Most FADs found stranded were from vessels fishing in the WCPFC (52.6%), followed by IATTC (38.7%) and both CAs (8.7%) (Figure 15). The last known position was in the WCPFC CA in 65.8% of the matched buoy IDs and in the IATTC CA in 34.3% of the matched buoy IDs (Figure 15).

In terms of country of stranding events, most of the buoys found in French Polynesia were from the IATTC-CA (Ecuadorian, US, Panama) (Figures 14 and 15). The buoys found in FSM were almost only from the WCPFC-CA although from a wide range of fleets. The buoys found in Wallis and Futuna were mostly from the WCPFC-CA (more than 65%), and from vessels flagged US, Korea, Kiribati and Ecuador (Figure 14 and 15). Most of the buoys found in the Cook Islands presented a last known position in the WCPFC-CA (75%), from vessels fishing in the WCPFC-CA (33.3%), both-CAs (44.4%) or the IATTC-CA (22.2%) (Figure 15). In this particular case, most of the buoys were from US, Korean, Ecuadorian and El Salvadorian vessels (Figure 14).

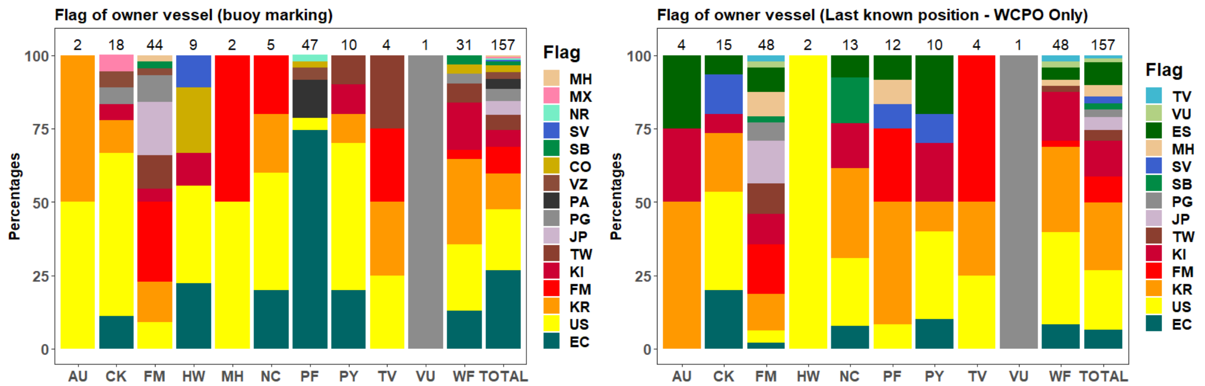

Figure 14. Flag of owner vessel identified using marks painted on the satellite buoys (left) and from the last known position in the PNA FAD tracking data and the WCPFC observer data (right), by stranded location. Note that vessel and flag from the last activity recorded with each buoy ID was not available from the IATTC database. AU = Australia; CK = Cook Islands; CO = Columbia; EC = Ecuador; ES = Spain; FM = Federated States of Micronesia; HW = Hawai'i; JP = Japan; KR = Korea; MX = Mexico; MH = Marshall Islands; NC = New Caledonia; NR = Nauru; PF = French Polynesia; PA = Panama; PG = PNG; PN = Pitcairn; PY = Palmyra; KI = Kiribati; SV= El Salvador; SB = Solomon Islands; TV = Tuvalu; TW = Chinese Taipei; US = USA; VU = Vanuatu; VZ = Venezuela; WF = Wallis and Futuna; WS = Samoa;

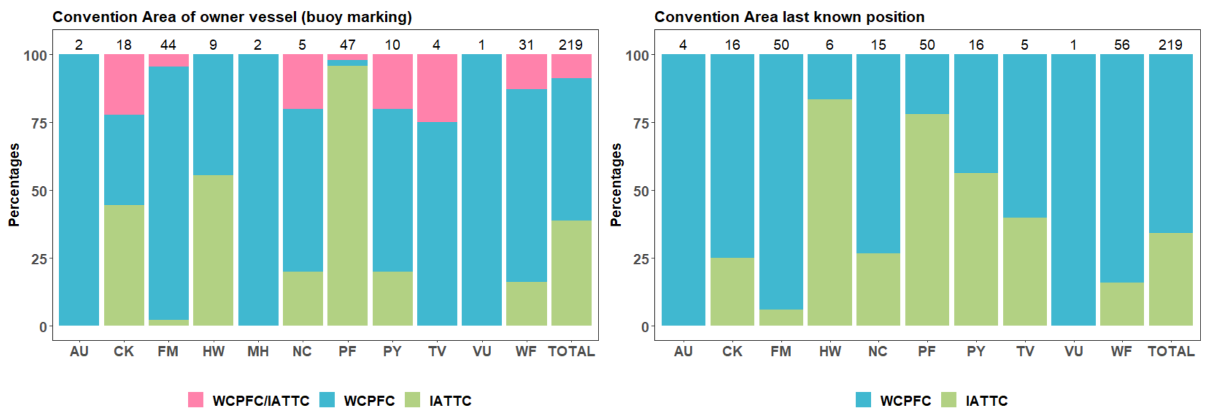

Figure 15. Convention area of owner vessel identified using marks painted on the satellite buoys (left) and from the last known position in the PNA FAD tracking data, the WCPFC and IATTC observer data (right) by stranded location. Positions found in the IATTC/WCPFC overlap area were considered in the IATTC convention area. See Figure 2 for country codes.

The second method, which consisted of identifying buoy ID numbers from the stranded database within the WCPFC and IATTC observer data, and/or the PNA FAD tracking data allowed investigation of the time difference between the last known date and the date found stranded. For each buoy with a match at least in one of the databases, the last known position in the PNA FAD tracking data, or the last activity recorded in the observer data from WCPFC and IATTC was identified for each buoy. The time difference between the last known date and the date found stranded was then calculated and categorized in five classes: less than six months; between six months and one year; between one and 1.5 years; between 1.5 and two years; and more than two years.

As previously identified, certain PICTs received satellite buoys from one CA only (Figures 16 to 19). For instance, French Polynesia, Hawai'i and Palmyra Atoll have stranded buoys mostly from vessels fishing in the IATTC-CA and few from the WCPFC-CA (Figures 17 and 22). It was also found that buoys were mainly drifting between one year and more than two years before being found stranded. Buoys found in FSM, Wallis and Futuna and New Caledonia were mostly matched with data from the PNA FAD tracking program. For FSM, stranded buoys were mostly coming from the Southwest to Southeast and coming from the Northeast for Wallis and Futuna and New Caledonia (Figure 19).

It can be noted that similar patterns of origin were detected for buoys matched with the PNA FAD tracking data and the WCPFC observer data (Figures 18 and 19). However, in the WCPFC observer data, positions correspond to the last time the buoy was recorded by observers, compared to the actual last transmitted position of the buoy in the PNA FAD tracking database. In some cases, this position from the observer data completed the last known position found in the PNA FAD tracking data, particularly with the additional position in international waters.

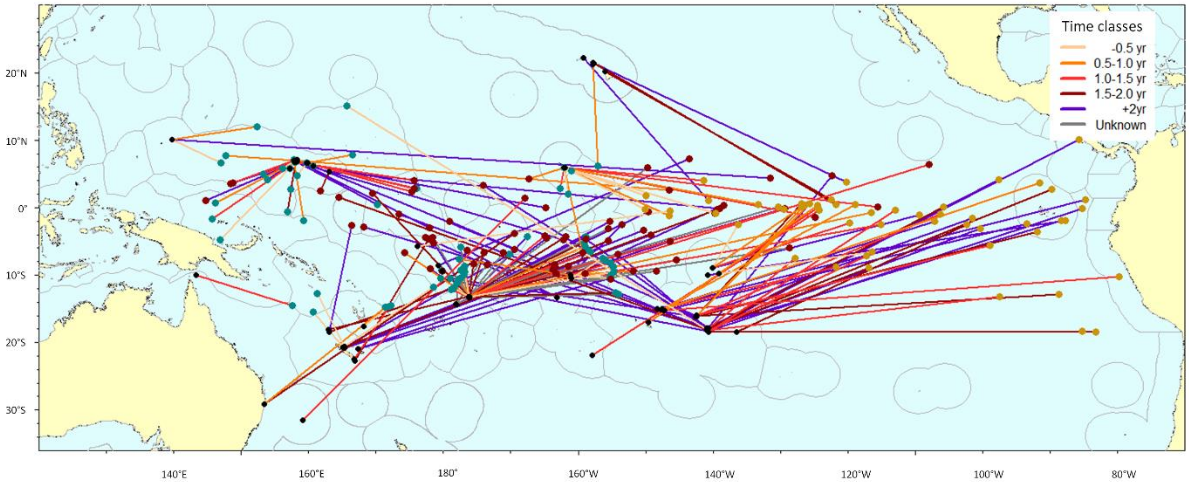

Figure 16. Map with the stranding position (black dots) and the last known position of buoys from the three fishery databases: the PNA FAD tracking data (blue dots); the WCPFC observer data (red dots) and the IATTC observer data (orange dots). The color of the lines indicates the time between last known position and date found stranded.

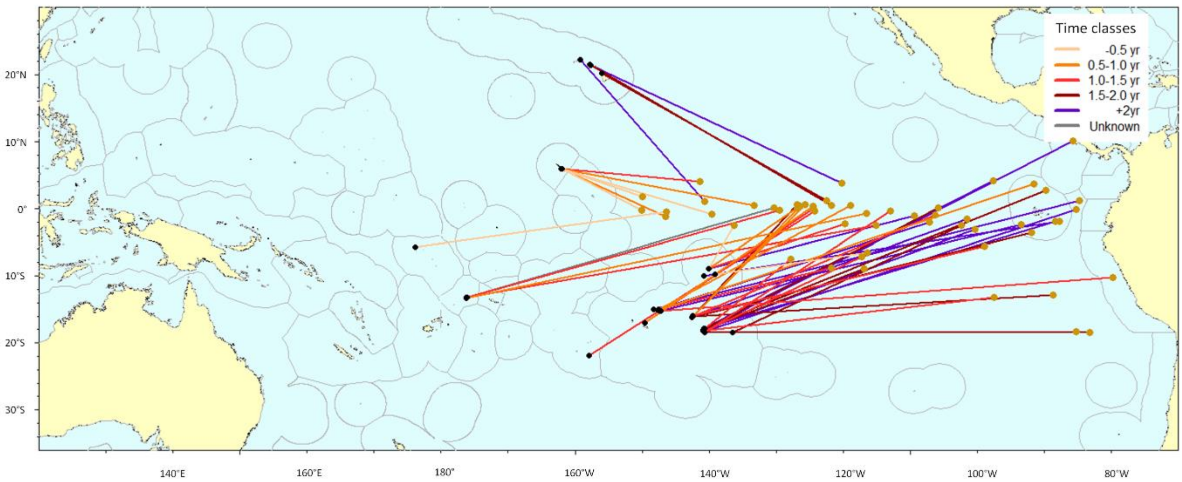

Figure 17. Map with the stranding position (black dots) and the last known position (orange dots) of buoys from the IATTC observer data only. The color of the lines indicates the time between last known position and the date found stranded.

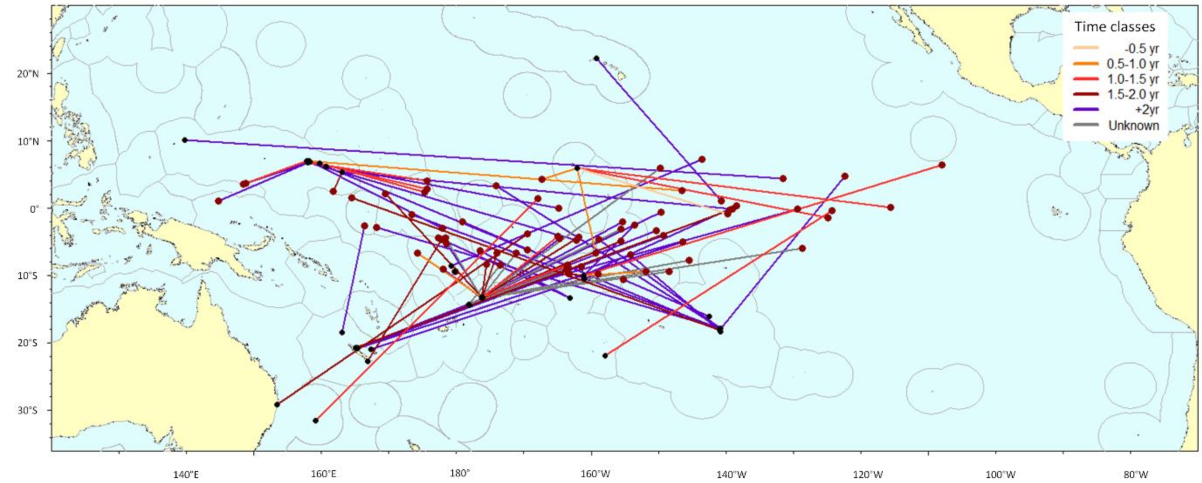

Figure 18. Map with the stranding position (black dots) and the last known position (red dots) of buoys from the WCPFC observer data only. The color of the lines indicates the time between last known position and the date found stranded.

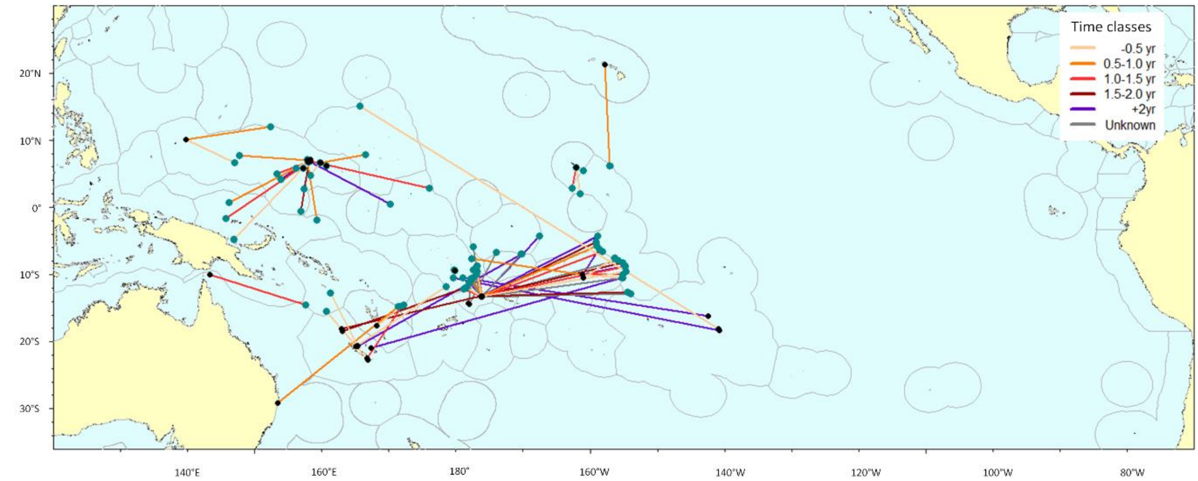

Figure 19. Map with the stranding position (black dots) and the last known position (blue dots) of buoys from the PNA FAD tracking data only. The color of the lines indicates the time between last known position and the date found stranded.

The EEZ of the last known position was investigated to detect potential patterns of origin by stranding areas (Figure 20). In the Cook Islands, most stranded FADs were last detected in the Line Islands (43.8%), the high seas in the central Pacific Ocean (I2), Tuvalu and the Cook Islands. In FSM, most stranded FADs were last detected in FSM, Kiribati Gilbert Islands, and PNG. In French Polynesia, most stranded FADs were last detected in the IATTC-CA, in the high seas in the central and eastern part of the Pacific Ocean (I2 and I3). In Hawaiʻi and Palmyra, most stranded dFADs were last detected in the IATTC, high seas in the central part of the Pacific Ocean (I2) and the Line Islands. In Wallis and Futuna, most stranded dFADs were last detected in the WCPFC-CA, in Tuvalu, the Line and Phoenix Islands; as well as the IATTC high seas areas in the central part of the Pacific Ocean (I2).

Stranding areas \ Origin areas	CK	FM	GL	JV	LN	MH	NR	PG	PX	PY	SB	TK	TV	WF	I1	GP	CR	PU	I2	I3
	WCPFC CA														IATTC CA					
AU	0	0	0	0	0	0	0	0	25	0	50	0	0	0	25	0	0	0	0	0
CK	12.5	0	0	0	43.8	0	0	0	6.2	0	0	0	12.5	0	0	0	0	0	18.8	6.2
FM	0	53.8	15.4	0	0	2.6	0	12.8	2.6	0	0	0	0	0	5.1	0	0	0	7.7	0
FP	0	0	4	0	6	2	2	0	0	0	0	0	4	0	4	12	2	2	20	42
HW	0	0	0	0	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0	83.3	0
NC	6.7	0	0	0	13.3	0	6.7	0	6.7	0	20	0	20	0	0	0	0	0	26.7	0
PY	6.2	0	6.2	6.2	12.5	0	0	0	0	6.2	0	0	0	0	6.2	0	0	0	50	6.2
TV	0	0	0	0	0	0	0	0	0	0	0	0	33.3	0	0	0	0	0	66.7	0
VU	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
WF	5.4	0	0	0	25	1.8	0	0	10.7	0	0	3.6	28.6	3.6	5.4	0	0	0	12.5	3.6

Figure 20. Matrix of EEZ of origin FADs found stranded: stranding country (left) and EEZ or origin (top), derived from the stranding position and the last known position in the PNA FAD tracking data, the WCPFC observer data or the IATTC observer data. AU = Australia; CK = Cook Islands; FM = Federated States of Micronesia; HW = Hawaiʻi; MH = Marshall Islands; NC = New Caledonia; PF = French Polynesia; PN = Pitcairn; PY = Palmyra ; TV = Tuvalu; VU = Vanuatu; WF = Wallis and Futuna; WS = Samoa; GL = Gilbert Islands; JV = Jarvis; LN = Line Islands; NR = Nauru; PG = PNG; PX = Phoenix islands; SB = Solomon Islands; TK = Tokelau; GP = Galapagos; CR = Costa Rica; PU = Peru; I1 = Internal waters between Gilbert, Phoenix and Line Islands (174°–202°); I2 = International waters East of the Line Islands and North of French Polynesia (202°-240°) and I3 = Eastern part of the Pacific Ocean (east of 240°), see Figure 21.

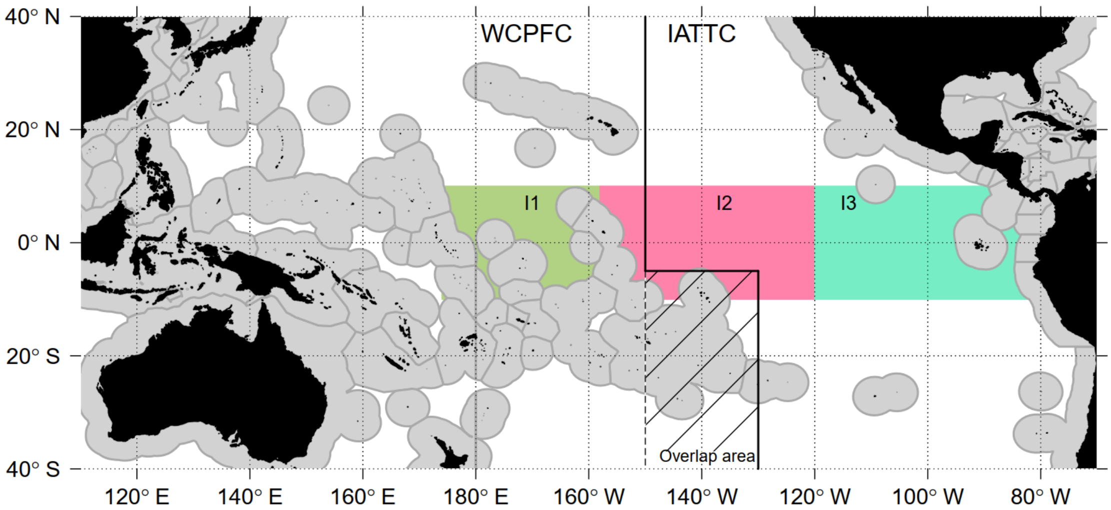

Figure 21. Map of the WCPFC and IATTC Convention Area, including the overlap area. Areas of international waters I1, I2 and I3, as used in Figure 20 are indicated in green, pink and light green.

The time difference between the date buoys (and FADs) were found stranded and their last known position was investigated where 16.0% of buoys were found less than six months after the time of their last known position and 30% were within two years of the last known position (Figure 22). Most of the buoys found within six months after the last known position (73.5%) were matched with data from the PNA FAD tracking database. The proportion of buoys found in the PNA FAD tracking program decreases as time difference increases. This is not surprising given that the PNA database could include positions until deactivation by fishers, while the observer databases include positions on buoys visited by fishers only. Buoys matched with the IATTC and WCPFC observer programs presented a larger time difference, WCPFC observer data being the greatest (Figure 22). This is potentially due to a more direct trajectory towards stranding areas from the IATTC fishing grounds, compared to PICTs located more in the western part of the Pacific Ocean and receiving buoys last detected in the WCPFC observer database. Time series or levels of information recorded may also be different between WCFPC and IATTC observer data, for instance IATTC introduced a new form to record buoy information more accurately. Many of the buoys with an unknown stranding date were matched with the PNA FAD tracking program (50%). It might be possible than these buoys have drifted for less than six months to one year (as most buoys found matched with this database had drift times within this range; Figure 22).

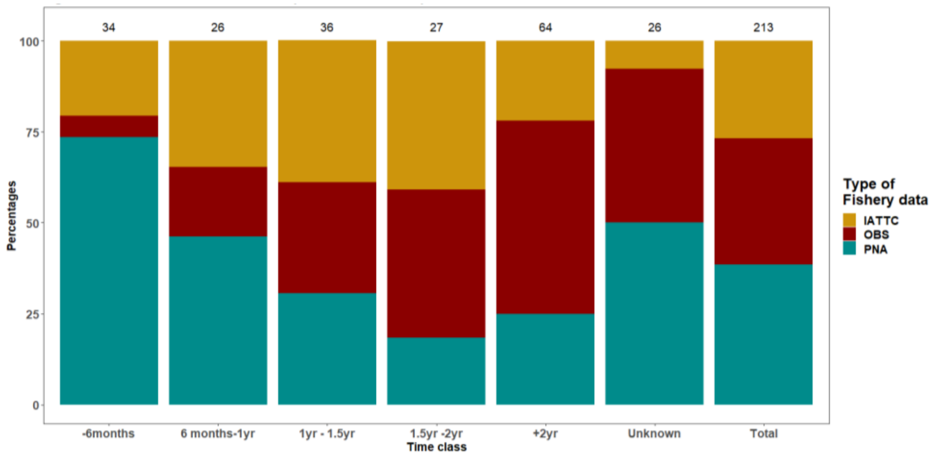

Figure 22. Time difference between the date found stranded and the last known position in the fishery databases: the PNA FAD tracking data, the WCPFC observer data and the IATTC observer data.

Time difference between the date buoys (and FADs) were found stranded and the last known position was investigated by PICT (Figure 23). In most PICTs, the data collection programmes started recently but could have recovered FADs and buoys found years ago. In addition, data on stranded events have been collected between 2009 (Palmyra only) and 2022. Hence, the range of years between date found stranded and last known position presented a high variability in some PICTs. For example, it reached more than 3,000 days (about 8.2 years) for some buoys found in French Polynesia. It can also be noted that the time differences differed depending on the database used, for instance higher time differences were detected for matches with the WCPFC observer's database, which recorded the last activity in the observer data; and smaller time differences for matchings with the PNA FAD tracking data, which is closer to the real date of last transmission. In FSM, more than 75% of the matches with the WCPFC observers' data are under 2,000 days (less than 5 years) between the last record and the stranded position whereas matches with the PNA tracking data were less than 2 years. Similar patterns were found for the Cook Islands, New Caledonia, French Polynesia and Wallis and Futuna (Figure 23).

WCPFC and IATTC observer programs do not transmit the very last position from a satellite buoy, but the last activity on the buoy that has been recorded by observers. Thus, it can overestimate the time difference between the actual last transmission and the stranded position, while fishers could potentially still have used the buoy and associated FAD, with this information not available to the observer. In addition, a floating object can have been stranded for a long period of time before being found by local communities. Consequently, the time difference can, again, be overestimated.

Another point to note is that the PNA FAD tracking program started in 2016. No matching could therefore be found with buoys found stranded before 2016. Moreover, the PNA tracking database does not include the full trajectories of buoys, with some buoy trajectories having been "geo-fenced" (Escalle *et al.*, 2021) with the part of trajectories outside PNA country EEZs removed. Complete trajectories from both the WCPFC and the IATTC would therefore be needed to identify more accurately the origins of buoys, and time buoys have been drifting before reaching coastal areas. Note that high-resolution buoy data is not available for the IATTC until 2022 but is now mandatory for the whole fleet under Resolution C-21-04.

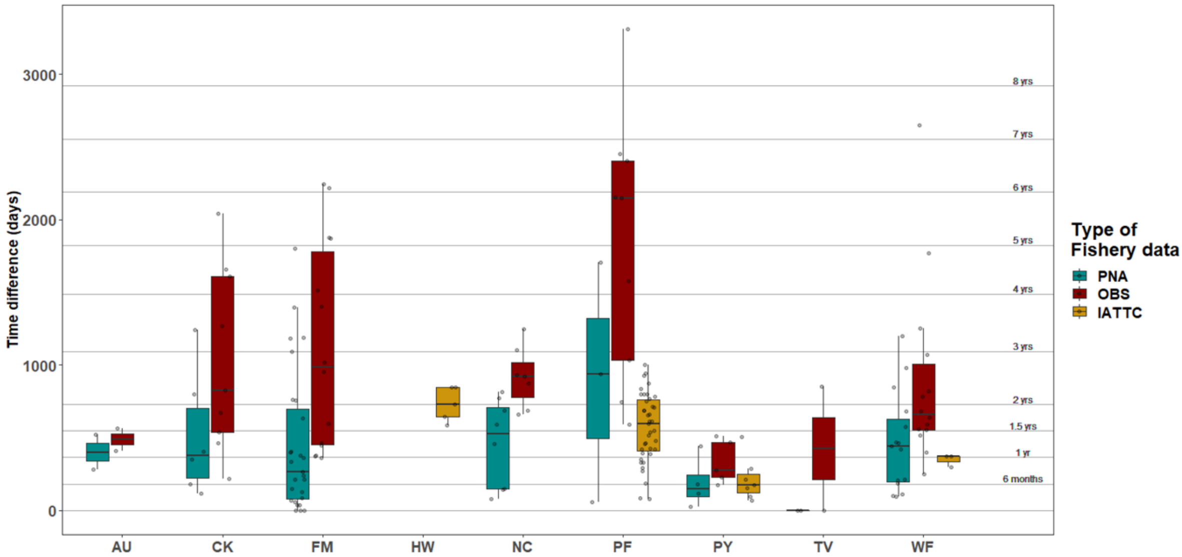

Figure 23. Time difference between the date found stranded and the last known position in the fishery databases: the PNA FAD tracking data, the WCPFC observer data and the IATTC observer data; by PICT of stranding event. See Figure 2 for country codes.

For the 82 stranded buoys that could be matched with the PNA FAD tracking database, the fate of these dFADs, as classified in the PNA FAD tracking data (Escalle *et al.*, 2021) was investigated (Table 10). It was found that very few buoys were classified as stranded (3.7%); recovered close to shore (2.4%); or in port (2.4%). The majority of stranded buoys were classified in the PNA FAD tracking database as still drifting (74.4%); lost (12.2%); or recovered at-sea (4.9%) (Escalle *et al.*, 2021). Additional investigation highlighted that some were not classified as "stranded" because they were on atolls (e.g. Palmyra Atoll or Nukuoro or Kapingamarangi in FSM), that were not present in the map used to define the coastlines and hence whether a dFAD was stranded or not. A higher resolution map was therefore used and an updated classification of dFAD fate from the PNA FAD tracking data was compiled. This highlighted that 18.3% (+14.6%) of the stranded buoys also found in the PNA FAD tracking data that were classified as beached in the tracking data (Table 10). However, 59.8% and 12.2% were still classified as drifting or lost at the end of their trajectory respectively, while they were ultimately found beached in one of the PICTs. This highlighted the fact that stranding events assessed using the PNA FAD tracking data only are highly under-estimated, mainly due to deactivation of buoys when drifting outside the main fishing grounds and high rates of FAD appropriation at sea. Additional work to determine FAD fates using tracking data and the FAD stranding database are needed to better determine the stranding rates at the scale of the WCPO.

Table 10. Fate of dFADs estimated in the PNA FAD tracking data for the 82 buoys found stranded that could be matched with this database, using the initial (Escalle *et al.*, 2021) and updated high-resolution map.

Fate from PNA FAD tracking data (82 buoys matched)	Initial classification	Updated classification (better land definition)
Stranded (or "beached")	3.7%	18.3%
Recovered close to shore	2.4%	3.7%
Port	2.4%	2.4%
Recovered at-sea	4.9%	3.7%
Drifting	74.4%	59.8%
Lost	12.2%	12.2%

Buoy fates estimated in the PNA FAD database were compared to the actual fate recorded in the FAD stranded database. Buoys estimated as "beached" in the PNA FAD tracking database were mostly found on a beach (20%), on shore (26.7%) or previously collected (13.3%). Regarding the buoys registered as still "drifting" in the PNA FAD tracking database, 42.8% was already found on coasts (which includes beach, shore and previously collected), and 14.2% were actually still drifting close to shore.

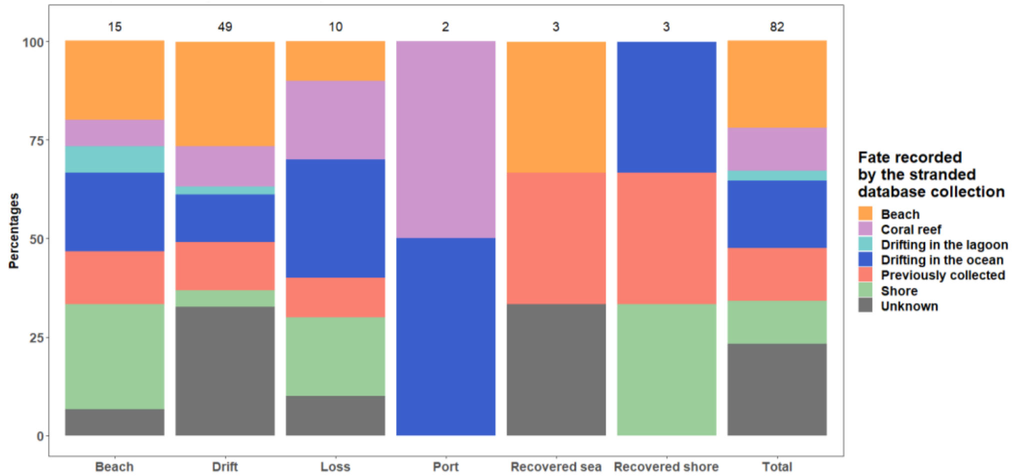

Figure 24. Fate of buoys estimated in the PNA FAD tracking data using updated high-resolution map for the 90 buoys found stranded that could be matched with this database compared to the fate of buoys and dFADs recorded in the stranded database.

4. Discussion and next steps

This paper presents the in-country data collection programmes related to dFADs found in coastal waters and on coastlines, as well as the development of a regional database. Data collection is now in place in nine PICTs: French Polynesia; Wallis and Futuna; FSM; Cook Islands; Hawai'i; Palmyra; New Caledonia; RMI and Tuvalu. More than 1,100 stranding events have been identified, with data collected as far back as 2009. When compiling data from all the different programmes, an extensive step of compiling, processing and cleaning the data was necessary to standardise the data collected, while the database also includes links to supplied pictures that were sometimes used to complement the data entered. We can also note that the data collection effort is likely uneven throughout the region, as most programs are based on voluntary reports from communities, while others used dedicated surveys (e.g., French Polynesia). In addition, in many places, the first step in the data collection effort was an inventory of all the buoys and FADs that had been stranded on the coastline. Future data collection will allow identification of the rate of stranding events in a given time period.

Data collection and transfer are currently made via a paper form and Google Drive spreadsheets. With the anticipated increase in reporting and PICT involvement in the project, the use of an app could be considered (potentially through Tails[2], and/or through the PNA FAD logsheet application with a specific section related to data collected in the coastal environment. Data standardisation will

[2] Tails is a mobile and tablet application (https://play.google.com/store/apps/details?id=spc.ofp.tails&hl=en) that collects fishing logbook data from artisanal and small-scale fishers. The data collected in Tails is used by Pacific countries for fisheries management and scientific analyses and is a critical source of data in a fishery that is usually data-poor.

therefore be needed between coastal and oceanic data collection efforts. This could be facilitated through a coastal and oceanic joint subcommittee as part of the tuna Data Collection Committee, which would identify key priority areas for dFADs on data standards and communicate these to SPC members. The Tails network of data collectors currently submit reports on stranded dFADs to SPC via existing communications protocols. In the future, specific dFAD stranding officers or coordinators may be needed to deal with the amount of data received.

As mentioned previously, some of the data collection programmes are independent initiatives in specific PICTs. Other independent initiatives may also be occurring throughout the Pacific Ocean. In addition, in oceanic waters, some fishing companies likely collect lost or abandoned dFADs from other fleets and store them in port storage areas to be returned or traded back to company owners. Such collaboration between companies (with or without fees upon retrieval), as well as recovery programs before dFADs reach coastal areas will help reduce the environmental impact of dFADs.

In this paper, we presented preliminary results on the data collected in the stranded FAD regional database. This highlighted the extent of FAD and buoy stranding events in the WCPO. The type of stranding events, materials of the FADs found beached, as well as the habitat impacted, and the environmental damage detected were studied. Information collected through the data collection programmes and analysed here could also help prioritizing and exploring potential FAD retrieval programs in the future, as a measure to mitigate the impacts of lost FADs in the environment.

A comparison with existing dFAD-related databases in the Pacific Ocean (e.g., WCPFC and IATTC observer data, PNA dFAD tracking data) was implemented and helped identify the origin (deploying/monitoring vessel/flag, CA) and life history of the dFADs (area and date of last known position, drift patterns). Some buoys found stranded could not be matched with the fishery data investigated. This could be due to the fact that i) we did not have access to all the buoy trajectories in the Pacific Ocean (incomplete and modified trajectories from the PNA FAD tracking program in the WCPO and no trajectory data for the IATTC-CA); ii) observers cannot always record the buoy ID (or not the full ID or accurately) from dFADs set on or visited by vessel; and iii) not all dFADs are set on or visited during their lifetime. In addition, this study also compared the fate of dFADs from trajectory data (i.e., PNA FAD tracking data, (Escalle *et al.*, 2021)) with the stranded events detected in the regional database. This highlighted a general underestimation, as expected, of stranding events in the WCPO using the PNA FAD tracking data. This was firstly due to an error in the classification of stranding events, with some atolls not considered as “land” where stranding could be occurring. Secondly, the fact that buoys are commonly deactivated when drifting outside fishing grounds limits our ability to classify fate using trajectories only. Under-estimation cannot be excluded with in-situ data as well, with not all the records or events being reported. However, communication and involvement of a large portion of the public, including fishermen, could help increase reporting.

Additional countries and territories could consider implementing a data collection programme and participation in this regional initiative. Relevant quantification of dFAD stranding or drifting nearshore, as well as assessment of ecosystem impacts will be possible through data collection over several years and covering the largest area possible, including countries and territories with low or no purse seine effort. Although the WCPFC is currently moving forward in terms of non-entangling and biodegradable dFADs, such designs can still have an impact on the environment, making this programme relevant and timely. This could ultimately help inform dFAD management options in the WCPO.

We invite WCPFC-SC18 to:

- Highlight the need for in-situ data to be collected to better quantify dFAD stranding events and the impacts of dFADs on marine and coastal ecosystems.
- Note the development and progress of the in-country data collection programmes on stranded and lost dFADs nearshore and of a regional database; as well as the need to explore potential FAD retrieval programs as a measure to mitigate the impacts of lost FADs.
- Note the preliminary results from analyses of the regional database presented in this paper.
- Note the need for trajectory data, including historical periods, from both the IATTC and WCPFC convention areas to better determine the origin of FADs and buoys found stranded.
- Encourage the extension of the in-country data collection programmes to other members of WCPFC.

Acknowledgments

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Appendices

- Supplementary figures.
- Description of data collection for dFADs found stranded or at-sea
- Poster presenting the data collection program for the Cook Islands in English
- Data collection form for fisheries officers

Figure S1. Pictures of some dFAD rafts, submerged appendages and satellite buoys found in Wallis and Futuna since March 2020.

Figure S2. Pictures of some dFAD rafts, submerged appendages and satellite buoys found at Palmyra Atoll since 2009.

Description of data collection for FADs found stranded or at sea

For any information contact laurianee@spc.int

Why are we collecting these data?

We are collecting these data in order to quantify the number of lost and beached FADs, and to note their impact on coastal areas, which will help improve the management of FAD fishing. FADs are always deployed with a satellite buoy, so that fishers know the position of their FAD. FADs are usually also equipped with an echosounder to estimate the amount of tuna aggregated underneath. Fishing companies have started sharing data both of the FAD's position, as well as the echosounder data from the satellite buoys deployed on FADs. These data are used in scientific studies that guide management of FAD fishing. When FADs are found at sea or beached, it is therefore very important to record the unique buoy ID number, to potentially match found FADs with these existing datasets.
In addition, fishers commonly remotely deactivate satellite buoys when FADs drift outside fishing areas. The dataset transmitted by fishing companies hence only gives a partial image of the FAD trajectories and the number of beaching events is underestimated in this dataset. Therefore, having access to additional information on beaching events, but also on FADs drifting in coastal areas (with the buoy ID number, if still attached to the FAD) will help complement the existing dataset and better estimate the impact that FAD may have on coastal areas.

Description of the fields in the spreadsheet

- **Entry number**
  (Internal use only. Number of FAD and/or satellite buoy found (1 to n). Used to rename the pictures.)

- **Entered by**
  Name of the person entering the data.

- **Date entered**
  Date of data entry.

- **Found by**
  Name of the person who found the FAD and/or satellite buoy.

- **Contact**
  Enter contact detail (email address, number) of the person who found the FAD and/or the satellite buoy.

- **FAD present**
  Was a FAD present (i.e., FAD by itself or FAD with a buoy)? Yes/No.

- **Buoy present**
  Was a satellite buoy present (i.e., buoy attached to a FAD or buoy by itself)? Yes/No.

- **Buoy ID number (very important if a buoy is present)**
  Enter the satellite buoy ID number, see poster for how to find it (depends on the buoy brand and model).
  Examples of satellite buoy ID number:
  DL+123456 ; **ISL+**123456 ; **DSL+**123456 ; **SLX+**123456
  M3I123456; **M3+**123456; **M4+**123456
  T07123456789; **Te7**123456789; **T7+**123456789; **T8X**123456; **F8E**123456789 ; **Z07**123456789

P1234**NF**; **P1**234**N**; **WF**1234**N**; **CN**123**N**
123456

- **Date found**
Date that the FAD and/or satellite buoy was found. Could be an approximate date if not known, e.g., August 2019.

- **Location**
In particular if the lat/lon were not recorded, note where the FAD and/or satellite buoy was found, e.g., name of beach, town, island, etc.

- **Environment (if provided or visible on the pictures)**
Where the FAD has been found: drifting at-sea in the lagoon or the ocean, on a beach, a coral reef, a beach, a rocky shore, a mangrove; or previously found and reported from a garden, a wharf, etc.

- **Latitude and longitude (If provided)**
Record latitude and longitude in decimal.

- **Painted marks (if provided or visible on the pictures)**
Record any marks painted on the satellite buoy. Could be a vessel name, or the abbreviation of a vessel names, just a letter, a number, a number and a letter, and sometimes the buoy ID number.

- **Mark on the FAD (if provided or visible on the pictures)**
Record any mark attached to the FAD or painted on it.

- **FAD condition (if provided or visible on the pictures)**
What is the condition of the FAD when found? Intact with the submerged tail, intact without the submerged tail, beginning to break, mostly fallen apart.

- **Raft materials (if provided or visible on the pictures, can be multiple entries)**
List all the materials making the raft of the FAD: bamboo, wood, floats, drum, net, cord, canvas, etc.

- **Tails materials (if provided or visible on the pictures, can be multiple entries)**
List all the materials making the tail of the FAD (underwater appendages): bamboo, wood, net, cord, canvas, etc.

- **Size of the raft (if estimated)**
Estimates of the size of the FAD raft, Length (m) x Width (m).

- **Tail length (if estimated)**
Estimates of the length of the FAD tail, i.e., the materials (rope, net, etc.) hanging under the FAD raft (could be absent, then put 0) in meters.

- **Fate of the FAD (if provided)**
What has been done with the FAD: removed from the water, removed from land, left drifting, left on shore, sunk, fished, etc.

- **Purpose if FAD removed**
If the FAD has been removed from the location it was found, mention why it has been removed: avoid pollution, landfill, burned, recycled (to do what?), etc.

- **Fate of the buoy (if provided)**

What has been done with the satellite buoy: removed from the water, removed from land, left drifting, left on shore, sunk, etc.

- **Purpose if buoy removed**
  If the buoy has been removed from the location it was found, mention why it has been removed: avoid pollution, recycling (use battery, solar panels…), etc.

- **Environmental damage (if provided or visible on the pictures)**
  Any environment damage recorded: e.g., tail of the FAD caught up on corals.

- **Entangled animals (if provided or visible on the pictures)**
  Record if any animals were found entangled on the net hanging beneath the FAD and/or the net used to cover the raft. If possible, record the species and the number of individuals.

- **Aggregated fish and/or fished (if provided)**
  Record if any fish (or other animals) were seen aggregated under the FAD and/or if any fishing was performed. If it was the case, mention the species (if know), the number and/or the catch in kg.

- **Other comments**
  Any other comments: e.g., some tuna were aggregated under the FAD, the FAD could not be removed because too heavy, materials reused as fishing gear, etc.

- **Number of pictures received**
  Record how many pictures have been received.

- **Pictures name**
  Rename the pictures using a unique identifier containing, country, date and the entry number (first field).
  <CountryCode>_<Seq. No.>_<Date:YYYYMMDD> Ex: CK_1_20190923
  Add another number if more than one picture: e.g., CK_1_20190923_P1; CK_1_20190923_P2; CK_1_20190923_P3. Then copy the pictures in the folder in google drive.

- **Buoy ID number verified**
  Has the satellite buoy ID number been verified by the fishery officer on a picture or directly: Yes/No.


FISH AGGREGATING DEVICE (FAD)
DRIFTING FAD FOUND BEACHED OR AT SEA ?
Where is the buoy ID number ?
ISL+123456
DSL+123456
M3I123456
T7+123456789
or Ze0123456789
P1234NF
123456
WHY ARE WE COLLECTING THIS DATA?
To quantify the number of beached or lost FADs, and to note their impact on coastal areas, which will help improve the management of FAD fishing.
WHAT IS A DRIFTING FAD?
It is a raft, generally made of bamboo, with a tail of net, cords and/ or canvas and a satellite buoy, deployed by tuna purse seiners to aggregate and catch tuna.
WHAT TO DO WITH THE FAD?
If possible, tow the drifting FAD back to shore then contact the MMR office.
RECORD ANY OF THESE DETAILS:
- What did you find ?
- a FAD by itself
- a FAD with a buoy
- a buoy by itself
- Buoy ID number and any mark painted on the buoy
- Date found
- Location (Lat/Lon or name of beach, village, island...)
IF POSSIBLE, NOTE:
- Environment: at-sea, coral reef, beach, lagoon
- Materials: bamboo, net, cord, floats
- Tail length (if possible)
- What did you do with the FAD/buoy? (e.g. removed from water or land, left drifting, sunk, fished)
- Any additional comments? (e.g. environmental damage, entangled animals or aggregated tuna or other animals)
TAKE PICTURES:
- General picture of what you found
- A close-up of the buoy with the ID number visible
SEND AN EMAIL TO: rar@mmr.gov.ck
OR CALL 28721
Pacific Community
Communauté du Pacifique
WWF

FAD Sighting form

Entered in the database ☐

Data collected by a Cook Islands fishery officer regarding FADs, FAD debris and/or satellite buoys found beached or at-sea. Contact 28721 or rar@mmr.gov.ck

Form

Completed on: **Form number (if more than one on the same day, 1 to x):**

Completed by: Name:

Observer/ person who found the FAD

Name: **Phone number:** **Email:**

Sighting information

(Tick one or several) ☐ **A FAD** ☐ **A buoy - ID Number:**

Date: **Island:**

Location (*If no GPS, write name and/or describe it*):

Environment: ☐Beach ☐Coral reef ☐Drifting in the lagoon ☐Drifting in the ocean ☐Rocky shore ☐Mangrove ☐Garden (found previously) ☐Wharf (found previously) ☐Other:

Latitude: **Longitude:**

Comments:

Number of pictures - taken locally: **- taken by the fishery officer:**

FAD Information

Painted marks on the buoy: **Mark on the FAD:**

FAD condition: ☐Intact with submerged tail ☐Intact without submerged tail ☐Beginning to break ☐Mostly fallen apart

The following details should be completed by the fishery observer if the FAD was seen, or if transmitted by the observer:

Raft materials: ☐Bamboo ☐Wood ☐Plastic or metal drums ☐Floats ☐PVC tubes ☐Cords ☐Nets ☐Steel ☐Cotton canvas ☐Plastic sheet ☐Palm leaves ☐Other:

Submerged tail materials: ☐Net ☐Net tied as a "sausage" ☐Cord ☐Plastic sheet ☐Palm leaves ☐Other:

Estimated size of the raft *(Length x Width)***:**

Estimated depth of submerged tail (m)**:**

Any additional information to complete the FAD description:

Fate of the FAD/ the buoy

FAD removed? ☐Yes ☐No **If so, why?** ☐Avoid pollution ☐Landfill ☐Burned ☐Recycled:

Other fates:☐Unknown ☐Left ☐Fished, species and catch (kg): ☐Sunk ☐Other:

Buoy removed? ☐Yes ☐No **If so, why?**

Impact on marine life

Entangled animals? ☐None ☐Turtle ☐Shark ☐Coral ☐Fish ☐Marine mammal ☐Other:

Status: ☐Dead ☐Alive ☐ Unknown **Species** (if known): **Number of individuals:**

Fish aggregated under the FAD ☐Yes ☐No **Species** (if known):

If FAD is entangled on coral reef please state the approximate size of the area impacted: