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Overview of ongoing work on FADs

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Executive Summary

Drifting Fish Aggregating Devices (dFADs) are used in large numbers in the Western and Central Pacific Ocean (WCPO), and their potential impacts in a number of areas are of growing concern. This paper summarises the work from several dFAD-related projects, including: i) a regional database on beached and lost dFADs; ii) updated estimates on the number of dFADs deployed annually in the WCPO and the number of active buoys monitored per vessel; and iii) a Pacific-wide project to define guidelines to reduce the impact of lost and abandoned dFADs on marine turtles.

DFADs that are lost or abandoned by fishing companies are increasingly reaching coastal areas where they can become stranded, adding to pollution and/or causing environmental damage. To quantify these events and their impacts, data collection programmes on dFADs reaching coastal waters and on beaching of dFADs have started in 2019 in French Polynesia (326 records within the program or recorded opportunistically) and in 2020 in the Cook Islands (95 records in the database), Wallis and Futuna (163 records), Federated States of Micronesia (110 records) and the Republic of the Marshall Islands (2 records). New Caledonia, Tuvalu and Solomon Islands have also shown interest in joining the data collection effort and adding to the regional database. Opportunistic reports and other initiatives, such as data collection in Palmyra Atoll and Hawaii have also added records to the database (65 and 77, respectively).

Updated estimates of the number of deployments and active dFADs per vessel and in the whole WCPO have recently been compiled for the last nine years. Average estimates of number of dFAD deployments ranged between 20,000 and 40,000 per year. The median number of active buoys monitored per vessel per day ranged from 45 to 75 between 2016 and 2019 depending on the year, well below the current management limit of 350, and most vessels deployed less than 150 dFADs in a year.

With this extensive use of dFADs in the whole Pacific Ocean, the potential impact of dFADs on sea turtles needs to be evaluated and minimized. A project, in partnership between the International Seafood Sustainability Foundation (ISSF), the Pacific Community (SPC), Hawai´I Pacific University, the National Oceanic and Atmospheric Administration (NOAA) and the Inter-American Tropical Tuna Commission (IATTC), has started in 2020 with the aim of defining guidelines and conservation recommendations to reduce the ecological impacts due to dFAD use, including from lost and abandoned dFADs on sea turtles in the Pacific Ocean. The project has four specific objectives: i) conduct a comprehensive review and host workshops to better understand the current situation regarding dFAD loss and potential impacts on turtles population sizes; ii) conduct simulations of dFAD trajectories arriving at essential habitats for sea turtles, with a special focus on leatherback turtles in and around the Hawaiian Islands; iii) evaluate options to reduce dFAD impacts on sea turtles and their habitats, including the development of best practices guidelines; and iv) provide public outreach of the results to fishers, scientists and managers.

Other dFAD-related projects include analyses of the PNA dFAD tracking data, analyses of echosounder data from satellite buoys deployed on dFADs (Project 88), non-entangling and biodegradable dFAD trials in the WCPO (project 110) and results from a recent dFAD recovery feasibility study, for which stand-alone papers have been submitted. Potential future FAD research areas are also listed.

We invite WCPFC-SC17 to:

- Note the progress made on the different dFAD related projects in the WCPO, to better understand dFAD use and limit related ecosystem impacts.
- Note the development and progress of in-country data collection programmes on beached and lost dFADs nearshore, as well as establishment of a regional database.
- Encourage the extension of the country data collection programme on beached and lost dFADs to other members of WCPFC.
- Note the findings that most vessels in the WCPO deployed less than 150 dFADs per year and very few vessels deployed/redeployed more than 350 dFADs per year. The current limit for the number active buoys an individual vessel can have at any one time is 350 under CMM-2018-01 (paragraph 23). Most vessels actively monitored about 75 buoys at any time. These results indicate that this measure is not constraining dFAD deployments or buoy monitoring.
- Note the estimates of 30,000–40,000 dFADs deployed/redeployed per year in the WCPO.
- Note the objectives of a Pacific-wide project to define guidelines and conservation recommendations to reduce the ecological impacts due to lost and abandoned dFADs on sea turtles.
- Note that there are a number of other interesting avenues of investigation regarding dFAD use that may be of interest if funding can be obtained.

1. Introduction

Purse seine fishing on drifting Fish Aggregating Devices (dFADs) accounts for about 40% of the purse seine tuna catch in the Western and Central Pacific Ocean (WCPO). Fishing on dFADs is thought to have become important for the efficiency of the purse seine fleet targeting skipjack tuna. However, it can have undesirable impacts, such as increased bycatch, including catch of small bigeye and yellowfin tuna, and environmental pollution, ghost fishing and habitat damage from lost or abandoned dFADs. Specific dFAD-related projects have therefore emerged to better characterize and understand dFAD use and the potential ecosystems impacts that they might cause. First, monitoring the number of dFADs deployed annually, and their spatio-temporal prevalence is important for assessing their influence on the tuna fisheries and other environmental and ecological risks. Second, better understanding of the use of dFADs, as well as accessing scientific information on the impacts of dFADs, and fishing on them, are also key for the sustainable management of the fishery. Finally, consequences of the massive use of dFADs on the ecosystems, through marine pollution and beaching, as well as on Species of Special Interest (SSI) also requires investigation. This could be done through accessing alternative data sources to quantify these impacts, or through simulations.

This paper summarises the advances and results from several dFAD-related projects involving or lead by the Pacific Community (SPC). Specifically, we report on; i) a regional database developed to tabulate information on beached and lost drifting dFADs; ii) updated estimates on the number of dFADs deployed annually in the WCPO and the number of active buoys monitored per vessel; and iii) a Pacific-wide project to define guidelines to reduce the impact of lost and abandoned dFADs on marine turtles (an SSI).

2. Ongoing dFAD projects

2.1 Regional database of beached and lost dFADs

DFADs are increasingly 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 SPC and international Non-Governmental Organisations (NGOs), have started programmes to collect in-situ data to help quantify the scale of this issue.

Since 2020, data collection programmes on lost dFADs reaching coastal waters and on beached dFADs have started in the Cook Islands, Wallis and Futuna, French Polynesia, Federated States of Micronesia and Republic of the Marshall Islands (Table 1). 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. When possible, data collected should include 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. Each programme is based on local communities' engagement and therefore communication is essential. This involves different means, such as posters, radio and TV broadcasts, and public talks (Figure S3). Importantly, the development of systematic data collection programmes on beached and lost dFADs must remain as simple and efficient as possible.

The main objectives of the project are:

- To quantify the number of dFAD beaching events or dFADs drifting nearshore,
- Assessing the resulting ecosystem impacts, including on SSIs and on habitats,
- When possible, evaluate how dFAD materials and satellite buoys may be repurposed or recycled locally by communities.

Table 1. Summary of data collected through beached dFAD data collection programs or opportunistically in the WCPO.

PICT	Start of the program	Data collected within the program	Data collected opportunistically before the program
French Polynesia	April 2019	151	175
Wallis and Futuna	Feb. 2020	158	5
Cook Islands	Feb. 2020	17	78
FSM	Feb. 2021	101	9
RMI	June 2021	2	0
Palmyra	2008	65[1]	0
Hawaii	2014	77	0
New Caledonia	Under discussion	-	16
Tuvalu	Under discussion	-	10
Samoa	-	-	1
Pitcairn	-	-	7
Australia	-	-	3
Vanuatu	-	-	1

[1] as of April 8th 2020, no surveys since due to COVID.

In French Polynesia, a scientific program to collect data on beached FADs started in 2019 and collected 151 events so far, with an additional 175 FADs or buoys data collected opportunistically (Table 1). In Wallis and Futuna and the Cook Islands, respectively, 163 and 95 dFADs and/or satellite buoys found beached or drifting nearshore have been reported (Table 1, Figures S1 and S2). In the Federated States of Micronesia (FSM) and the Republic of the Marshall Islands (RMI), programs only started this year, and a total of 110 and 2, respectively, dFADs and/or satellite buoys have been reported. New Caledonia, Tuvalu and Solomon Islands have also shown interest in joining the data collection effort and contributing to the regional database. An SPC internal funding source (Funding with Intent Project, funded by the New Zealand Aid Program) allowed for awareness and data collection activities in FSM and RMI. This also permitted SPC to hire a staff member in their Micronesian Regional Office (MRO), as a FADs Focal Officer. The dedicated staff on the ground has facilitated the activities and allowed for some surveys to be performed on remote islands.

In parallel, other initiatives or opportunistic reports have emerged. This includes data collection at Palmyra Atoll (through The Nature Conservancy TNC) since 2008 and Hawaii (through the Center for Marine Debris Research) since 2014, where a total of 65 and 77 dFADs and/or satellite buoys have been found. At Palmyra Atoll, the data collection program is part of a larger dFAD Watch Program currently being developed. In Hawaii, the Center for Marine Debris Research is currently investigating the possibility to repurpose buoys to tag and track marine debris like fishing nets. Opportunistic data collection has also been reported to SPC since 2018, including through SPC's existing data collection networks. This includes an additional 45 records, mostly from 2019 and 2020, from Australia; New Caledonia; Pitcairn Islands; Samoa; Tuvalu; and Vanuatu.

The data currently available to quantify beached dFADs (i.e., the PNA dFAD tracking data) have been shown to under-estimate total numbers (given frequent deactivation of dFADs when drifting outside the main fishing areas) and do not provide any information regarding ecosystem impacts (Escalle et al., 2021d). Hence, in-situ data collection and observations are important to complement fisheries data. Additional countries and territories may therefore wish to consider implementing a data collection programme and participate in this regional initiative. Relevant quantification of the scale of dFADs beaching or drifting nearshore, as well as assessment of resulting ecosystem impacts, will be possible through data collection over several years and covering the largest area possible, and will help guide management of dFADs in the WCPO.

2.2 Quantifying dFAD use in the WCPO

Updated estimates of the number of deployments and active dFADs per vessel and in the whole WCPO has recently been compiled for the last nine years (Escalle et al., 2021b). Estimates were derived using two different approaches combining observer and logbook data with the PNA dFAD tracking data to evaluate trends in dFAD use across the entire WCPO between 2011 and 2019 (details of the methods can be found in Escalle et al. (2020) and in Escalle et al. (2021a)).

The objectives of the analyses were to:

- estimate the total number of buoys or dFADs currently deployed per vessel, as well as across the entire WCPO per year.
- estimate the number of active buoys (on constructed dFADs or logs) monitored by individual vessels over certain periods of time.

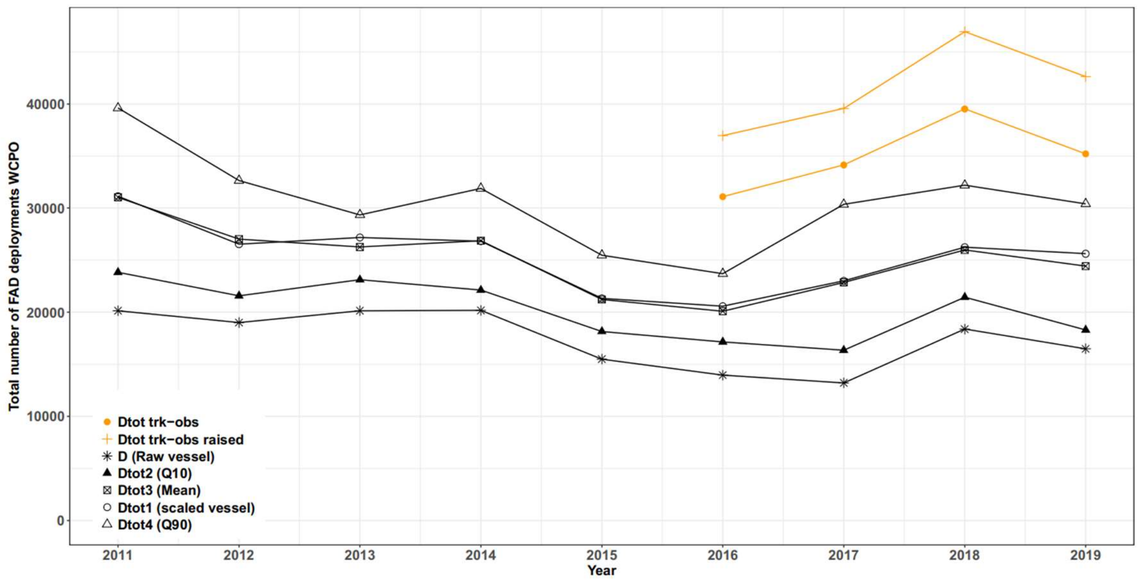

Figure 1. Estimates of the total number of deployments per year in the WCPO for all vessels. Different estimation metrics were used based on fishery data only (black line, with D represent the raw number of deployments recorded by observers; Dtot1 and Dtot3 represents the estimates per vessel and the average across vessels and Dtot2 and Dtot4 an 80th-percentile range of uncertainty around these values) and a combination of PNA dFAD tracking and observer data (orange line, with total and raised estimates). Figure from Escalle et al. (2021a).

Average estimates of number of dFAD deployments ranged between 20,000 and 40,000 deployments per year, depending on the estimation methodology, with the total number of deployments appearing relatively stable over the last decade (Figure 1). The median number of active buoys monitored per vessel per day ranged from 45 to 75 between 2016 and 2019 depending on the year (Figure 2), well below the current management limit of 350. Our results contrast with other oceans, having fewer buoys monitored per vessel as well as a unique stable trend in total number of deployments, but overall numbers of deployments are two times higher than any other ocean.

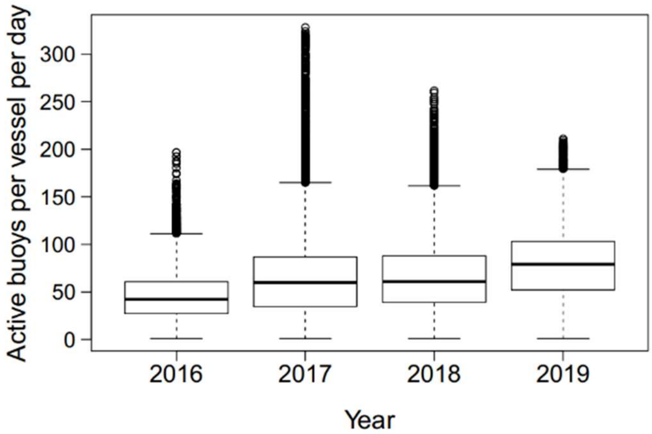

Figure 2. Annual variability in the raised number of active buoys per vessel and per day in the PNA dFAD tracking data for the top 50 vessels deploying the highest number of dFADs. Figure from Escalle et al. (2021a).

The method and results compiled provide a baseline to monitor dFAD use in the WCPO. In 2020, however, the limited observer placement due to the COVID-19 pandemic, greatly decreased the dFAD related data collected by observers and this limited our ability to update the analyses. This study nevertheless provides a basis for improved monitoring and management of dFAD use in the WCPO.

2.3 Impact of lost and abandoned dFADs on marine turtles

Fishery management strives to maintain best practices through time, and those best practices should be updated with new available data and whenever fishing tactics and strategies change. To date, the impact of purse seine fishing on sea turtles (i.e., mortality in purse seine gear, entanglement in active or lost gear) is believed to be quite low. However, due to the increased use of dFADs in the Pacific Ocean, the potential impact of dFADs on sea turtles needs to be evaluated and minimized. In this context, a project in partnership between the International Seafood Sustainability Foundation (ISSF), SPC, Hawai´I Pacific University (HPU), the National Oceanic and Atmospheric Administration (NOAA) and the Inter-American Tropical Tuna Commission (IATTC), has recently started. The project will run over 20 months from December 1th 2020 to July 31th 2022 with the aim to define guidelines and conservation recommendations to reduce the ecological impacts due to dFAD use, including from lost and abandoned drifting dFADs on sea turtles in the whole Pacific Ocean. These guidelines will identify means to reduce the interaction and mortality associated with entanglement in dFADs, ghost fishing and by protecting turtles' essential habitats from the impacts caused by dFAD stranding events.

The project expects to achieve this main aim through four specific objectives distributed throughout the two-year project.

Objective 1. Evaluation of the status quo

Information will be gathered on current dFAD loss, stranding events and dFAD interactions with turtles:

- Current knowns and unknowns about potential impacts of dFADs both by entanglement and by the active catch of purse seine fishing gear.
- The knowledge on dFAD stranding events in the Pacific Ocean, with a specific focus on Hawaiian Islands stranding events.
- The research and data needs to better understand the impacts of dFADs on sea turtles.
- Current management measures by tuna RFMOs to reduce those impacts.

Objective 2. Modelling dFAD trajectories

Two complementary lagrangian simulations of drift trajectories of dFADs will be implemented:

- *Simulation 1* (backwards)- Determining origins of dFADs arriving in Hawaii or other important coastal sea turtle habitats: this simulation will focus on determining the potential origins of dFADs that arrive in important sea turtle habitats and Hawaiian islands over a long time-scale. This simulation will focus on a limited number of sea turtle key habitats (1° by 1° grid cells) in order to maximize the duration aspects of the simulation backwards over a long period of time.
- *Simulation 2* (forward)- Determining the probability of dFADs arriving in the Hawaiian EEZ or within important oceanic or coastal sea turtle habitats: this simulation will cover the whole tropical Pacific and different ENSO periods and will investigate the probability of dFAD arrival in different areas of the whole Pacific (including potential sea-turtles' coastal and oceanic habitat). Particles will be released throughout areas of the tropical Pacific Ocean where dFADs are typically deployed, and their drift trajectories will be simulated forward in time for a maximum of 18 months.

Objective 3. Evaluate options to reduce the impact

Workshops with the main fleets in the Pacific Ocean will be organised to discuss potential best practices guidelines to minimize dFAD impacts on marine turtles and their habitats.

Objective 4. Reporting and outreach

This objective, simultaneous to all the previous objectives, will be devoted to disseminating progress and results of this project with fishers, scientists and managers.

2.4 Other projects

Another project involves the monitoring of dFAD use in the WCPO, through the PNA dFAD tracking programme and observer data. This allowed the quantification of dFAD use in the WCPO, as described in section 2.3, but also to study the spatio-temporal variability in the type of satellite buoys used, dFAD deployments, dFAD density and the fate of dFADs. These results are detailed in an independent paper (Escalle et al., 2021d).

Additionally, two dFAD-related WCPFC projects are also currently ongoing. The first (Project 88) focusses on analysing acoustic data from satellite buoys deployed on dFADs, with the aims to assess the potential for data from acoustic buoys to provide novel and fishery-independent indices of abundance for stock assessments; as well as investigate the proportion of small bigeye and yellowfin tuna under dFADs that have a large estimated biomass beneath them. Results from this project can be found in Escalle et al. (2021c). The second project (Project 110) aims to conduct trials, in collaboration with fishing industry partners, of non-entangling and biodegradable dFADs in the WCPO. Following the first trials in the WCPO (Moreno et al., 2020), this will provide essential information to the tuna fishing industry on the designs, types of materials, performance and cost-effectiveness of non-entangling and biodegradable dFADs in the WCPO context, and support industry to increase uptake of more ecologically sustainable dFAD designs. Updates regarding project 110 are found in Escalle et al. (2021b).

Finally, another study, in partnership with fishing companies, satellite buoy providers, and funded by The Nature Conservancy (TNC), explored and evaluated options for reducing dFAD loss and beaching in the whole Pacific Ocean (Escalle et al., 2021a).

2.5 Potential future dFAD research areas

Additional work could include further investigation of operational use of dFADs by owner vessels or other fleets. For instance, looking at the number of dFADs actually set on and the frequency of setting on individual dFADs with the related catch per vessel or fleet, in relation to the overall array of dFADs available and environmental variables. The influence that the presence of echosounder, single and multi-frequency may have on the realized catch and the catch composition could also be investigated. Echosounder data, in particular the new avenue of data from double frequency echosounders, could also be used to study schooling behaviour, and investigate whether dFADs stimulate productivity or just concentrate natural productivity. This could also be used to further investigate the potential for an independent index of biomass to be used in stock assessments, or to look at potential mitigation measures to reduce the catches of small bigeye and yellowfin tuna.

Further work on dFAD density is also needed, either by i) reconstructing dFAD tracks with missing sections in the PNA dFAD tracking data, using simulation methods; or ii) complementing dFAD trajectory data with other fishery data in joint analyses; or iii) accessing complete trajectories. This would allow us to further investigate the link between dFAD densities and occurrence of dFAD and free school sets, CPUE standardisation, effort creep and tuna behaviour.

Further work on the ecosystem impacts linked to lost and abandoned dFADs is also needed to: i) better characterise potential ghost fishing; ii) quantify beaching events and potential ecosystem impacts linked to them; iii) investigate ways to track dFADs that have drifted outside fishing areas and are no longer used by fishers; and iv) evaluate dFAD recovery options at a regional scale.

We invite WCPFC-SC17 to:

- Note the progress made on the different dFAD related projects in the WCPO, to better understand dFAD use and limit related ecosystem impacts.
- Note the development and progress of in-country data collection programmes on beached and lost dFADs nearshore, as well as establishment of a regional database.
- Encourage the extension of the country data collection programme on beached and lost dFADs to other members of WCPFC.
- Note the findings that most vessels in the WCPO deployed less than 150 dFADs per year and very few vessels deployed/redeployed more than 350 dFADs per year. The current limit for

the number active buoys an individual vessel can have at any one time is 350 under CMM-2018-01 (paragraph 23). Most vessels actively monitored about 75 buoys at any time. These results indicate that this measure is not constraining dFAD deployments or buoy monitoring.

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- Note that there are a number of other interesting avenues of investigation regarding dFAD use that may be of interest if funding can be obtained.

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World Wildlife Fund (WWF) provided funding to print and ship posters in the Cook Islands and Wallis and Futuna; activities are organised by Tiare-Renee Nicholas and Chloé Faure. The New Zealand Aid Program provided funding for the awareness and data collection program in FSM and RMI, with James Wichman and Beau Bigler organising the awareness and data collection activities. Mainui Tanetoa, Margot Boval, Jean-Claude Gaertner, Charles Daxboeck, Marie Soehnlen and Anne-Marie Trinh are part of the data collection projects in French Polynesia, which are funded by the Direction des Ressources Marines, the University of French Polynesia/ Institut de recherche pour le développement (IRD) and TNC. Palmyra Atoll data collection is part of a larger dFAD Watch Program currently being developed and is funded by TNC and lead by Kydd Pollock. Sara-Jeanne Royer from the Center for Marine Debris Research is organising the data collection in Hawaii. The authors are grateful for the assistance provided by the fisheries department and officers in the field in each of the PICT involved. The authors would also like to thank the local communities, fishermen and general public, involved in data collection in the PICTs part of the programme. The authors are also grateful for any opportunistic report transferred, including findings in Australia; Cook Islands (Te Ipukarea Society); New Caledonia (Association Hô-üt); Pitcairn Islands (The Pew Charitable Trusts); Samoa; Tuvalu; and Vanuatu. The authors would like to thank the members of the Parties to the Nauru Agreement for giving us access to their data for this analysis. The project "Definition of guidelines to reduce the impact of lost and abandoned Fish Aggregating Devices (FADs) on Marine Turtles" received funding under award NA20NMF4540142 from NOAA Fisheries Pacific Islands Regional Office; and involve Victor Restrepo and Gala Moreno (ISSF) as principal investigators and Lauriane Escalle, Joe Scutt Phillips (SPC), Jennifer Lynch (HPU), Yonat Swimmer (NOAA), Alexandre Aires da Silva and Jon Lopez (IATTC), as principal science partners. We thank Sam McKechnie for valuable comments on an earlier version of the paper.

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Appendix 1. Images of communication products and in-country support work for the beached and lost dFAD data collection program.

Figure S1. Pictures of some dFAD rafts and submerged appendages and satellite buoys found in Wallis and Futuna since March 2020. Photos: Wallis and Futuna beached dFAD data collection database.

Figure S2. Pictures of some dFAD rafts and submerged appendages and satellite buoys found at Palmyra Atoll since 2008. Photos: Kydd Pollock-TNC.

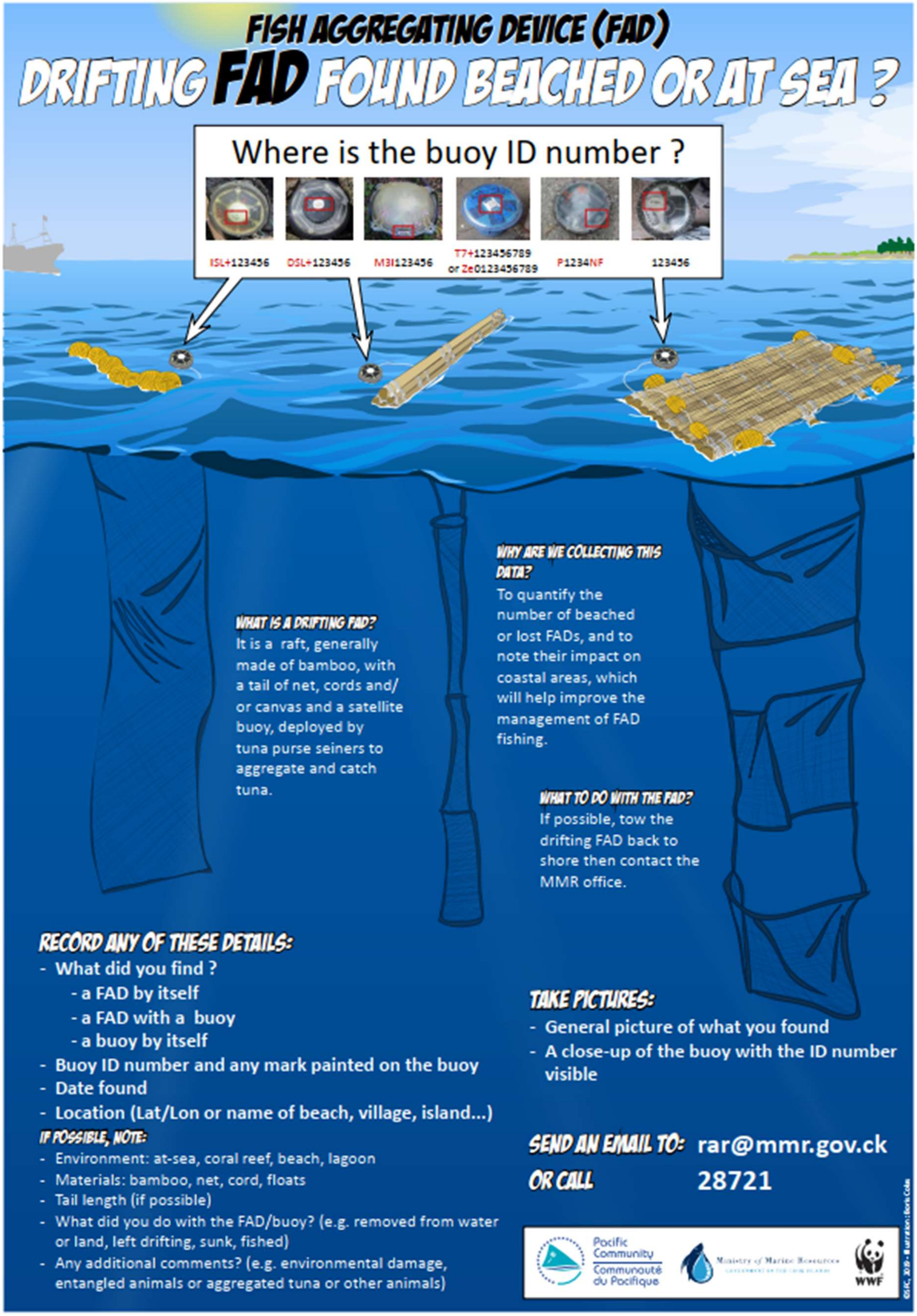

Figure S3. Poster presenting the data collection program for the Cook Islands in English.