Coastal fisheries and FAD monitoring project in Kadavu, Fiji: An assessment of data collected from 2017–2020

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Background

In Fiji, nearshore fish aggregation devices (FADs) have been deployed by the Ministry of Fisheries (MoF) in various locations along the coasts of Suva, Gau, Kadavu, Savusavu and in the outer islands. The Pacific Community (SPC) supported MoF in implementing the monitoring and evaluation of FADs deployed in Kadavu, with the primary scope of quantifying fishing effort and catches while also providing training to community monitors in collecting landing data. Training and data collection in Kadavu started in September 2017 and have been ongoing since then. To further investigate if and to what extent FADs affected income and food security in communities, household surveys were also planned but have not been implemented yet, mainly because of the COVID-19 pandemic and associated travel restrictions. This article presents an assessment of the landing survey data collected between September 2017 and December 2020 in Kadavu, with a focus on examining the performance of FADs in terms of catch per unit effort (CPUE). It then discusses the results, and critically reflects on possible next steps.

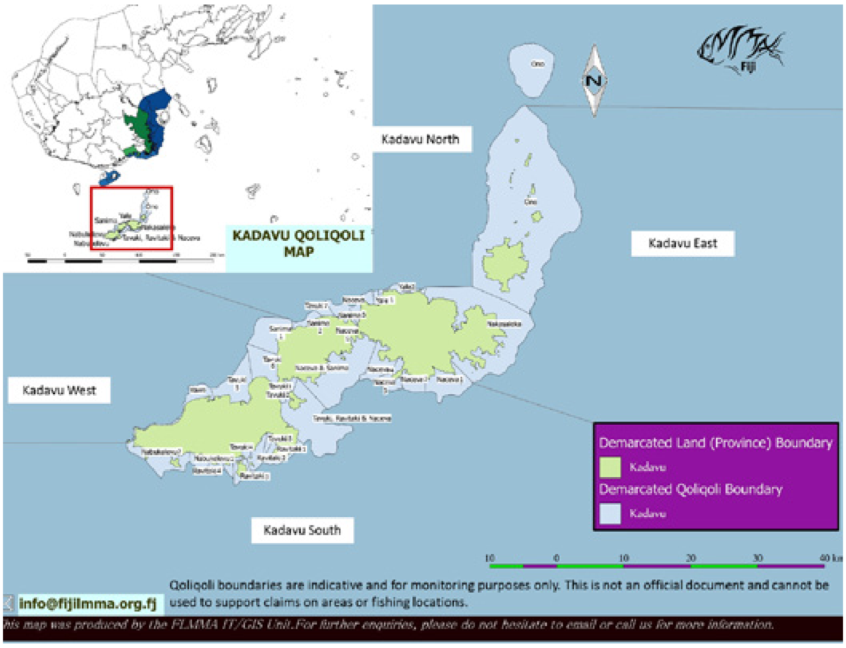

Figure 1. Fishing areas in Kadavu. (Source: LMMA Fiji)

Methodology

A landing survey protocol was developed, and data collectors were trained to use the SPC TAILS application[3] for artisanal fisheries collection and nearshore FAD monitoring by staff from SPC's Oceanic Fisheries and Coastal Fisheries programmes in August 2017. Training included fish species identification. The protocol was updated on several occasions. Landing sites were selected for data collection based on fishing areas defined on the basis of fishing rights areas, called *i-qoliqolis*. A map of Kadavu's *i-qoliqolis* is provided in Figure 1. Each village or site is unique, with different fishing habits and challenges for data collection. The sample protocol[4] was designed to work within the community context and be flexible to capture most of the fishing activity during the sample days.

Catch and effort data were regularly recorded at seven landing sites. Data collection days varied from week to week on a rolling three-day basis. Seven nearshore FADs were covered by the data collection.

The data available includes fishing activity logs and fishing logsheets. Activity logs count, according to a defined protocol, the number of boats, both paddle vessels and motor vessels, that come back from fishing each day during a defined period. Logsheets were gathered from as many fishers as possible on sample days, catch and effort data regarding each fishing trip, including fishing methods, costs, locations and catches, were recorded.

Data analysis was performed using the opensource system R version 4.0.2, installed on R-studio (R Development Core Team, 2005).

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[3] https://oceanfish.spc.int/en/ofpsection/data-management/spc-members/dd/505-tails-application
[4] The detailed protocol is available upon request.

Results

Activity logs

In total, of 5766 activity logs (including zero fishing days) and 4756 fisher logsheets were collected across the seven landing sites in 40 months. Activity log numbers are independent of fishing activity, and these are within the control of data collectors and generally governed by survey protocols; thus, numbers over time should be reasonably stable. Logsheets were collected from fishers who have been fishing, and are directly related to fishing activity and dependent on fisher behaviour; thus, numbers are expected to be less stable. The greatest number of activity logs were collected in the fourth quarter of 2018.

Fishing trips, events and catches

Table 1 provides a summary of the number of fishing trips, events and catch records sampled, as well as the total weight of catches for each landing site. A fishing event is defined by a combination of the fishing area fished and the fishing method used. A fishing trip can, therefore, contain several fishing events if the fisher changes fishing area or fishing method. For each fishing event, catches are then recorded by the species of fish caught (i.e. one catch record per species of fish caught). A fishing event can contain multiple catch records if several different species of fish have been caught during that fishing event.

Catches by categories of fish

Figure 2 presents a breakdown of catches by fish categories, excluding tuna catches, which represent the largest amount at around 51 tonnes. Emperors accounted for most of the reef fish caught (12.3% of the total catch, excluding tunas). Parrotfish, groupers and unicorn fish were the next common reef and lagoon species caught (9.3%, 9.2% and 5.1%, respectively, of the total catch weight, excluding tunas). Reef-associated species such as trevally, Spanish mackerel and barracuda also accounted for a reasonable number of the fish sampled by data collectors (14.5%, 9.4% and 7.7%, respectively, of the total catch weight, excluding tunas).

Trends in average fish weight[5] over time were also analysed for top-landed fish families or species. For most top-fished families and species, the average landed weight changed significantly over time. Despite an important variability, a decrease in average landed fish weight can be observed over time for some species (e.g. mullet, parrotfish, emperors[6]). A sustained downward trend may provide an indication of problems with fish stocks, providing that the associated fishing effort has not decreased as well. This is not the case for reef and lagoon fishing (fishing effort cannot be disaggregated at the species level, only by habitat or method), which has actually increased between 2017 and 2020.

Catch and effort by habitats fished

Table 2 below presents catch and effort data by type of habitat fished[7], including descriptive statistics for CPUE. Differences between FAD mean and others are highly significant according to t-tests (p-value < 2.2e-16). Mean CPUE is much higher for FAD as compared to other habitat fished, highlighting the effectiveness of FADs to increase catch rate. The standard deviations are quite high, reflecting the wide variations and dispersion in the weight of fish caught (e.g. well over 150 kg for some fishing events), and indicating that the median CPUE can also be a good indicator to use.

Changes in mean effort, mean catch and mean CPUE across time were examined by quarter and for each year. Figure 3 compares the mean CPUE for the different fishing habitats across each year, and Figure 4, shows this by quarter.

Table 1. Number of fishing trips, events and catch records sampled and total weight of catches per landing site.

Landing site	No. of trips sampled	No. of events sampled	No. of catch records sampled	Weight of catch sampled (kg)
Kadavu Nabukelevu Babatokalau	842	868	1621	36,520
Kadavu Naceva/Nakasaleka Babaceva	772	772	3286	20,080
Kadavu Naluvea/Galoa	638	643	3201	17,800
Kadavu Nasaila/Ravitaki District	635	688	1873	17,900
Kadavu Kavala Jetty/Fisheries/Ono	461	463	1442	21,260
Kadavu Nabukelevu Babaceva	453	457	853	9750
Kadavu Yawe/Tavuki	186	192	305	8610
Kadavu Market/Vunisea Jetty	11	11	24	250
Kadavu Vunisea Fisheries	1	2	2	10
Total	**3999**	**4096**	**12,607**	**132,180**

5 Total catch weight per species or family divided by number of fish caught from this species or family.
6 Parrotfish and emperors started being exported to Suva shortly after monitoring commenced.
7 Deep water includes seamounts and deep reef slopes. Reef and lagoon sites include coastal reefs, outer reefs, mangroves, and lagoons.

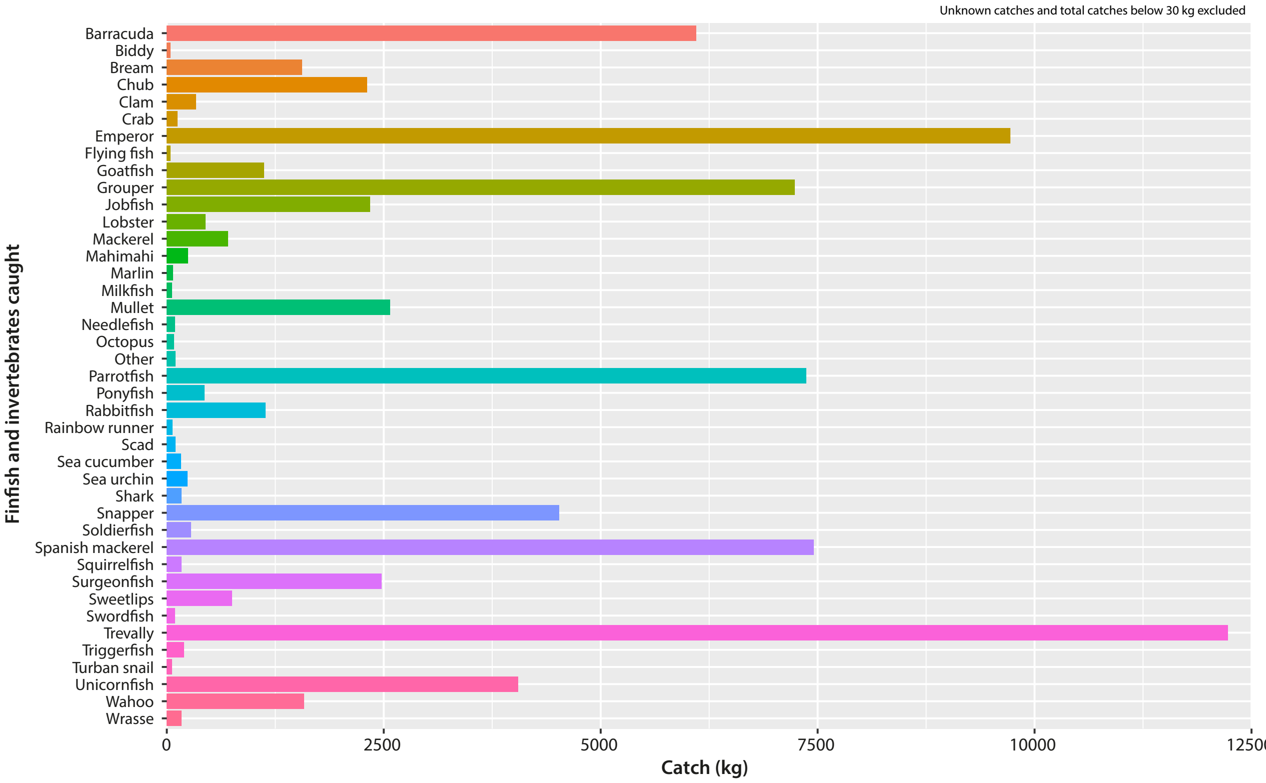

Figure 2. Total catch by categories of fish, excluding tunas. Unknown catches and catches below 30 kg were excluded.

Table 2. Catch and effort data by type of habitat fished.

Habitat type	No. of events sampled (n)	Hours	Fish weight (kg)	CPUE (kg/hour)		
				Mean	Median	SD
Deep water	138	751	6652.5	10.1	6.5	9.4
FAD	1015	2135.7	43,339	24.5	18	21.9
Open ocean	493	1382.1	15,995	12.4	8.1	14.9
Reef and lagoon	2443	12,774.1	66,046.4	6.7	4.3	8.5

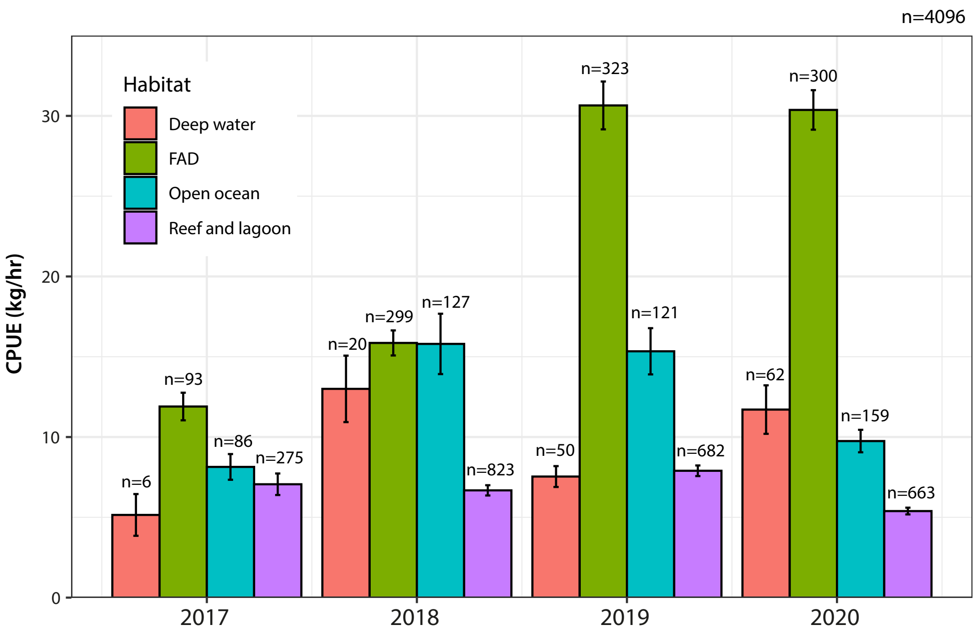

Figure 3. Mean catch per unit effort (kg/hr) by year and area fished, with standard errors. The numbers displayed are the number of fishing events sampled.

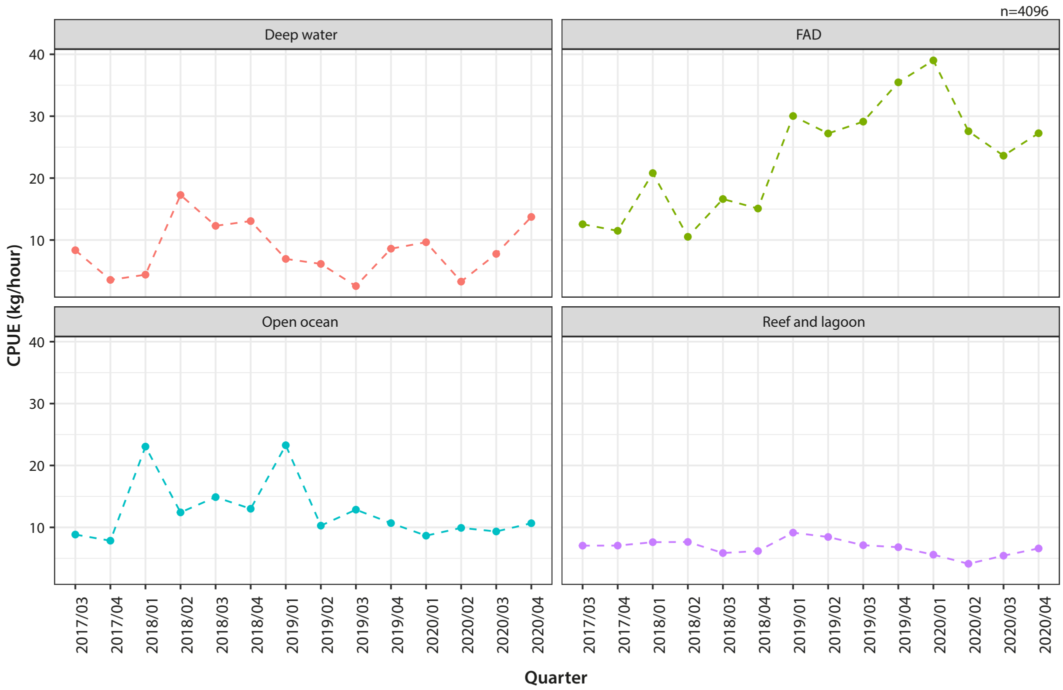

Figure 4. Mean catch per unit effort by quarter and habitat fished.

While the mean CPUE for reef and lagoon habitats remains relatively stable (Fig. 4), the mean CPUE for other habitats shows some strong variations across quarters, in particular for FADs, where an increase in the mean CPUE was observed between 2017 and 2020, with multiple peaks observed in the first quarters of every year. The sharp increase of mean CPUE in 2019 could be partly explained by the deployment of an additional FAD in Talaulia in mid-2018, following cyclone Keni, showing a particularly high mean CPUE (see Section "Catch and effort by FAD"). An examination of weight categories of yellowfin tunas caught between 2018 and 2020 shows that mostly small fish were caught in 2018, whereas much bigger fish were caught in 2019 and 2020. The different peaks of mean CPUE at FADs corresponds with tuna seasonality, with tuna being the main fish caught at FADs (see Section "Catch and effort by FAD" below).

Catch and effort by FAD

Catch and effort data were analysed for each FAD and compared to non-FAD areas. Over 30% of the catch by weight was sourced from FADs, highlighting the significance of FAD fishing in Kadavu. Nearly 90% of the fish caught at FADs were tunas, the vast majority being yellowfin (88% of tuna caught), followed by skipjack (11%). The remaining 11% of fish caught mostly consisted of barracuda (5%), wahoo (2%), snapper (1%) and emperors (1%).

Over 92% of recorded FAD fishing events occurred on two FADs, both of them located on the south side of Kadavu, with most fishing events occurring from just two landing sites. The reasons why other FADs have not been fished include their location, or the fact they were lost shortly after data collection started.

The main fishing method used at the FADs was trolling (937 fishing events). The highest mean CPUE was for trolling (26 kg/hour) followed by mid-water handlining (12 kg/hour), the latter being the cheapest fishing method used at FADs in terms of Fijian dollars per hour (costs include fuel, baits and ice). This highlights the potential interest to further develop mid-water fishing at FADs.

End use of fish

Data collectors asked fishers what the intended end use of each fish was. This allowed a characterisation of the relative importance of certain types of fish within community food security and livelihood support. The end use of marine products was split into five possible outcomes: eaten, given away, sold in the community (in the village or by the roadside), sold at a provincial market (i.e. Vunisea or similar), or sold at a urban market (i.e. Suva or export). In total, across the sampled catches, 22% of fish were eaten, 8% were given away, and the remaining 70% sold (33.5% at community level, 33.5% at a provincial market and 3% at urban markets).

End use varies significantly across species, highlighting heterogeneous contributions to both food security and livelihoods. For instance, while many reef fish species were eaten by fishers, oceanic species were predominantly sold at community or markets. This concurs with findings in Figure 5, which presents end usage of fish caught from FAD and non-FAD fishing. Most of the fish caught at FADs were sold, predominantly to the community (more than 50% of reported use). On the contrary, for non-FAD fishing, only around 20% of catches were reported to be sold to communities, and 25% were reported to be eaten by fishers. A larger proportion of non-FAD catches were also given away.

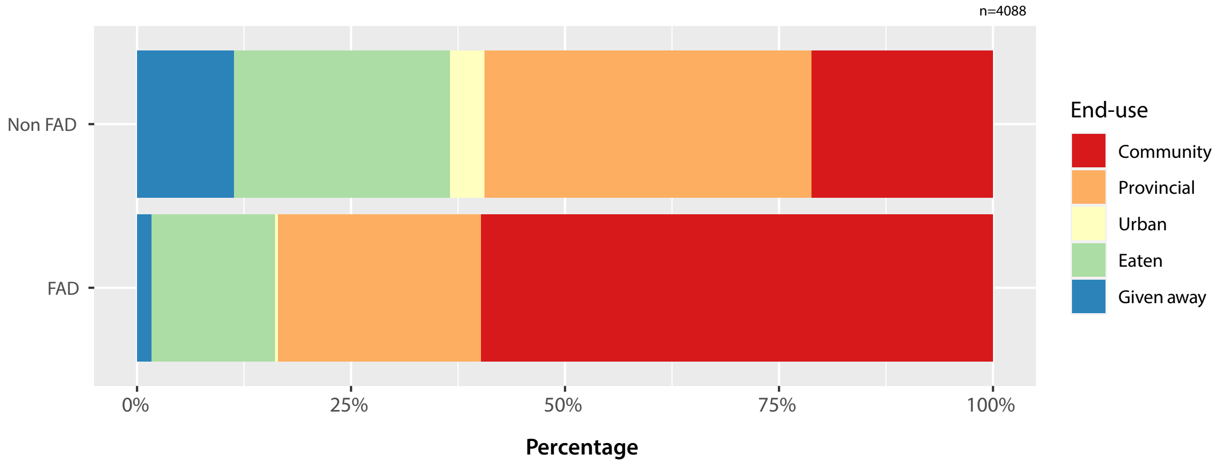

Figure 5. Proportions of reported end use of fish for FAD (three mostly fished FADs) and non-FAD fishing.

Fishing costs

Data were collected on the costs of fishing, which were largely due to fuel, ice and baits. The costs of fishing from motor vessels only were compared in the following ways: cost per hour of fishing effort by method (Fig. 6), cost per weight of fish caught by fishing location (Fig. 7) and cost per hour of fishing effort by fishing location (Fig. 8). All costs are in Fijian dollars (FJD).

The comparison by method shows that the mean cost per hour of fishing on motor vessels varied significantly from around FJD 3.5/hour for scoop nets, to FJD 24.6/hour for trolling. The relatively high mean cost of collecting by boat (only 22 motorised fishing events) can seem surprising, and is mostly due to lobster, urchin and giant clam fishing. Fishing in the open ocean was the most expensive in terms of how much it costs to obtain a kilo of fish (Fig. 7). The cost per hour of fishing in the open ocean and around FADs are higher than the cost of fishing on reefs, lagoons or deep-water grounds (100–450 m depths) (Fig. 8), which is intuitive as open ocean and FAD fishing require the motor to be running most of the time.

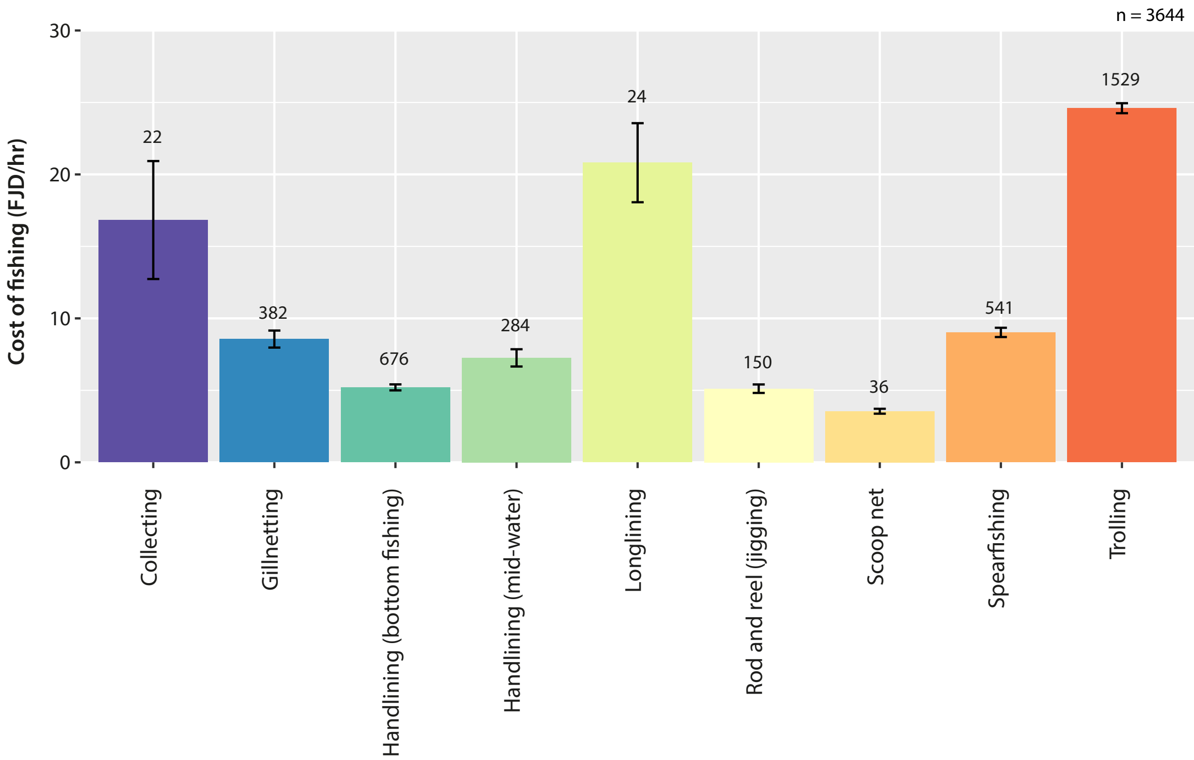

Figure 6. Relative mean costs of fishing by method for motor vessels, in FJD/hour fished, with standard errors. The numbers displayed are the number of fishing events sampled.

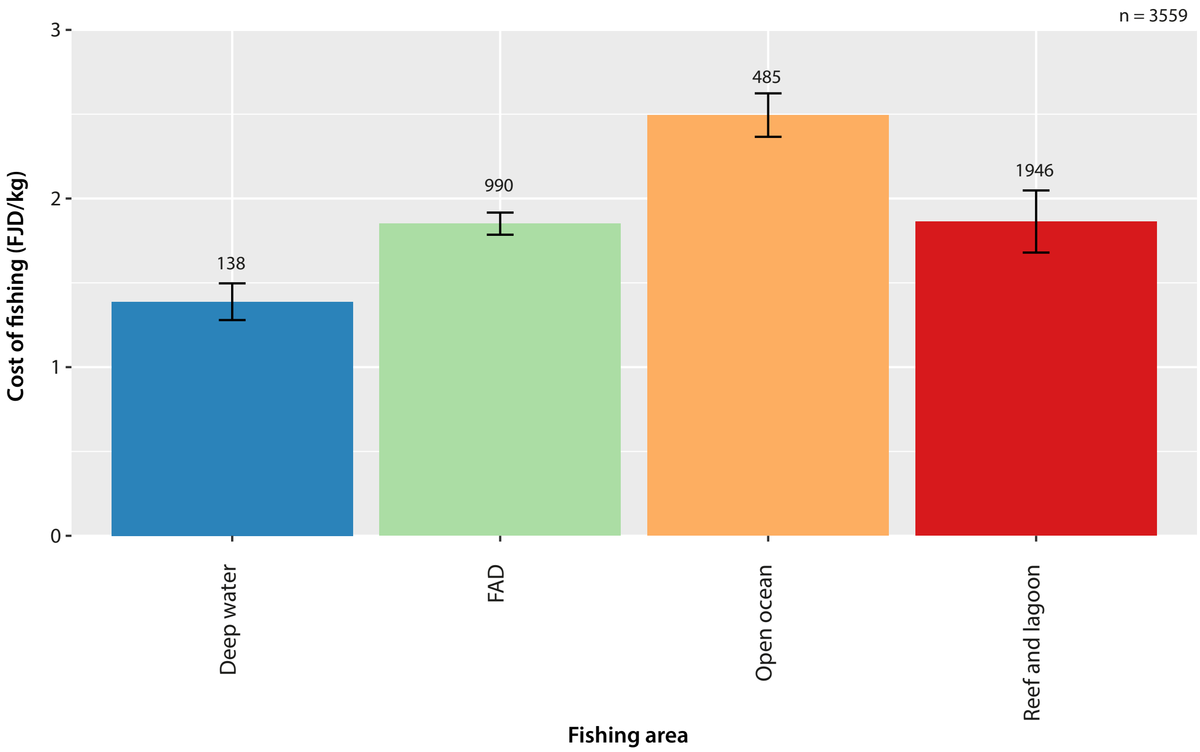

Figure 7. Relative mean costs of fishing by location for motor vessels, in FJD/kg of fish caught, with standard errors. The numbers displayed are the number of fishing events sampled.

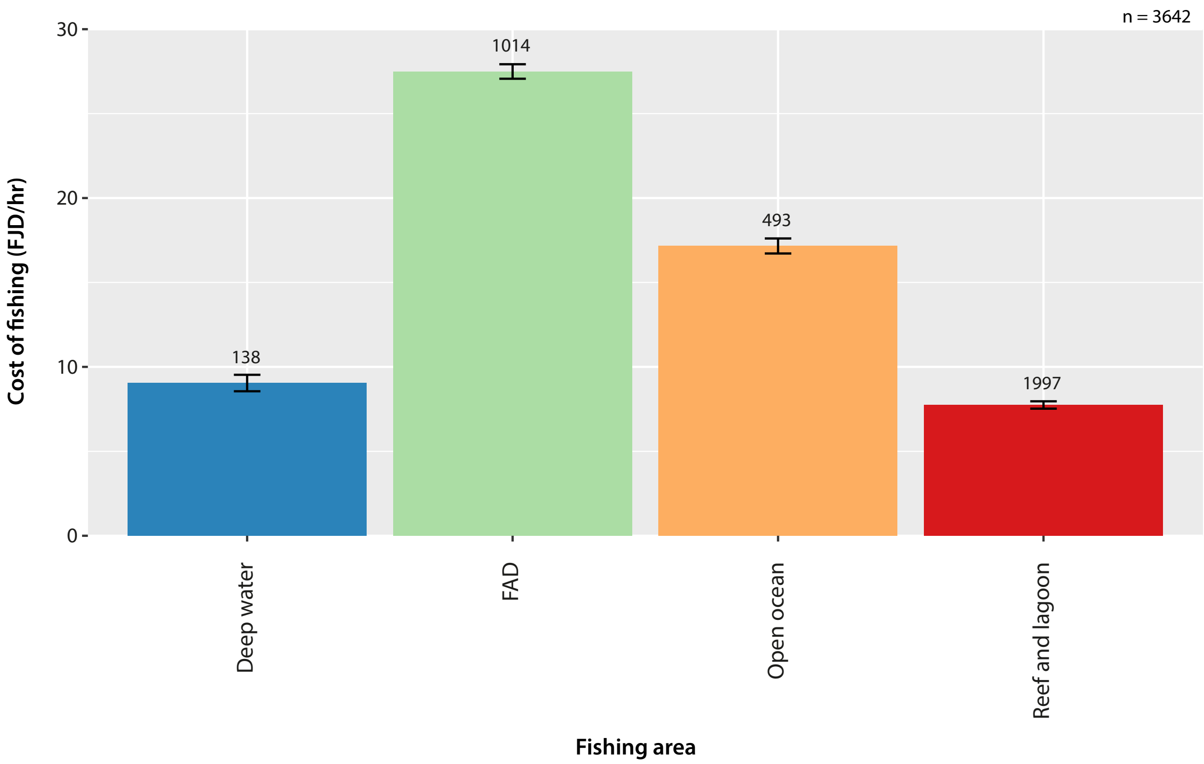

Figure 8. Relative mean costs of fishing for motor vessels by location, in FJD/hour fished, with standard errors. The numbers displayed are the number of fishing events sampled.

Gender

Table 4 presents catch and effort data by gender, including descriptive statistics for CPUE. An important point to consider when interpreting the data on gender is that 97% of the data collection on female fishers was done by one single data collector (one of two women collecting data[8]) at just one landing site.

There are almost 10 times as many records of male fishing events as there are of female fishing events. The observed fishing effort may not be representative of the actual balance between male and female fishing effort as there could be a bias induced by the difficulty of collecting data on female fishing activity. Indeed, men tend to fish from a boat and are, therefore, easy to spot when they land their catch at defined landing sites. This is not the case for women who mostly fish on foot on the reef.

Mean CPUE is much higher for male fishers than female fishers, reflecting the relative efficiency of power vessels and the differing fishing methods used by men and women.[9] Male fishers allocated 96% of their effort to using a motor vessel to fish, and only 3.5% to fishing on foot and 0.5% to using a paddle vessel. Female fishers, however, mostly fish on foot (69%), followed by using motor vessels (31%). Female fishers only targeted reef and lagoon habitats and use fewer types of methods when fishing, mostly handlining and collecting[10] (see Fig. 9 for fishing methods used by gender). This suggests that female fishers are less diverse and, therefore, potentially more vulnerable to disturbances to certain types of ecosystems. However, many of the methods logged as used by females are low technology, which could also possibly make them less vulnerable to socioeconomic impacts.

Table 4. Catch and effort data by type of habitat fished.

Gender	No. of events sampled (n)	Habitats targeted	Hours	Fish weight (kg)	CPUE (kg/hour)		
					Mean	Median	SD
Male	3567	Reef and lagoon; open ocean; deep water; FADs	15,305	6652.5	12.5	6.5	16.4
Female	391	Reef and lagoon	1344	43,339.0	6.4	4.5	7.8

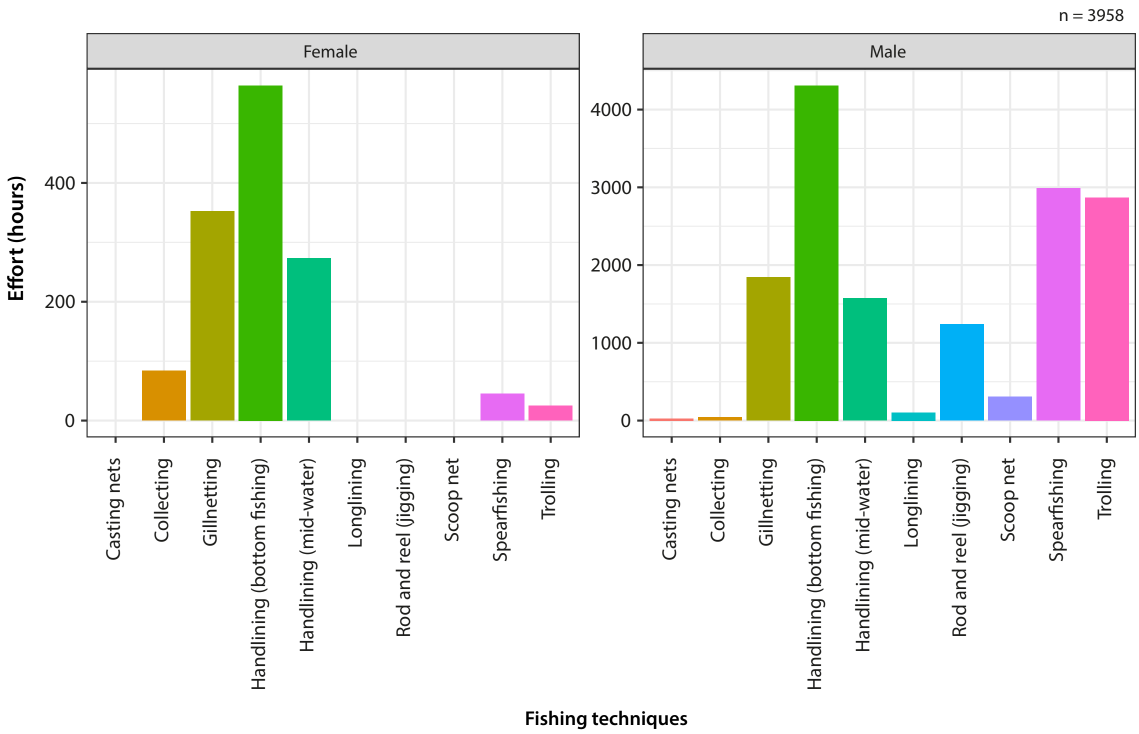

Figure 9. Fishing effort by method and gender.

[8] The other female data collector only collected data at one landing site from male fishers (mostly spearfishermen) who sell their fish for export to Suva.
[9] Mean CPUE data were also computed by fishing method. The fishing method with the highest CPUE is trolling (around 20 kg/hour), which is mostly used by male fishers.
[10] Collecting includes gleaning and collecting underwater from a motor vessel.

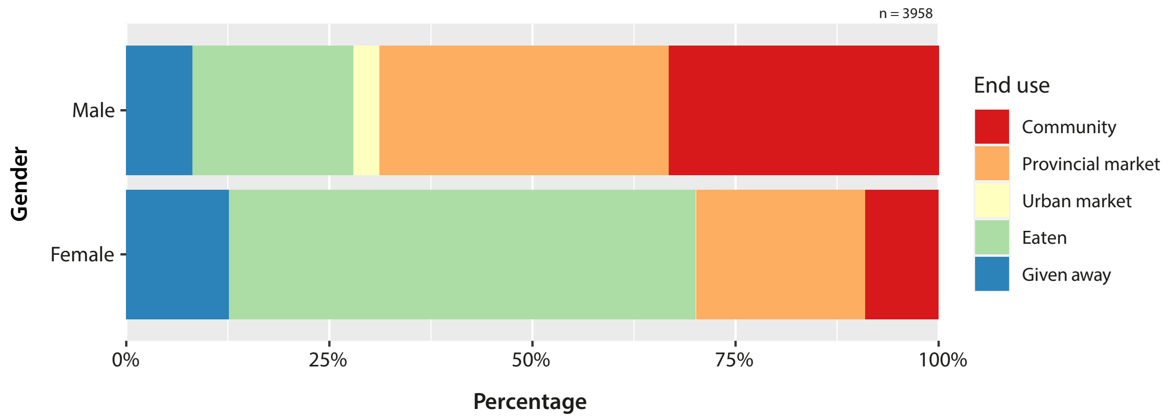

Figure 10. Proportions of reported end use of fish caught by gender.

Among policy-makers and fishery managers there is an assumption that women fishers largely fish for household consumption, while male fishers tend to fish for income and livelihood support. The data from Kadavu Province provides evidence to support this assumption (Fig. 10): 57% of the marine products fished by females were eaten at home, whereas males only used 20% of their landed catch for household consumption. Females also sold 30% of their catch locally within the community (10%) or at a provincial market (20%). Overall, this highlights the important role of female fishers in terms of food security for their own households but also on the island. As male fishers tended to sell most of their catch, they could be more vulnerable to market fluctuations over which they have no control.

Discussion and recommendations

An important point to note before discussing the monitoring results associated with the performance and effectiveness of FADs is that 98% of the monitored FAD fishing events over the four years were from only two landing sites, with 80% of them from just one site. The reasons why almost no FAD fishing occurred at the remaining five landing sites should be further investigated by the data collectors and the Ministry of Fisheries. The survey protocol may need to be amended as needed to capture information from more FAD fishing trips on the island.

The results show that FADs are effective in improving catch rate for fishers at the two landing sites where FAD fishing occurred. FADs are also less costly to fish to per kilogram of fish caught than other habitats. The results regarding reported end use suggest that FADs allow communities to access more pelagic seafood. Further assessing the effectiveness of FADs in terms of fishing profitability and overall return on investment (see Tilley et al. 2019; Sharp 2013), should it be deemed appropriate by the Ministry of Fisheries, would require further data collection on FAD costs[11] (e.g. pre-deployment scoping and survey, materials, assembly, deployment, maintenance), fishing training costs (if any), fishing costs (e.g. vessel costs, including maintenance, gear and other appropriate running costs that have not been collected) as well as fish price by species and market.

The sample protocol was designed to capture most of the fishing activity during the sample days at each landing site, which enabled the extrapolation and estimate total production, mean catch rate and reported end use for each of the landing site for the years 2018, 2019 and 2020. The protocol provides some very cursory indications on the possibility for extrapolation, and notes that scaling would need to be done carefully for most landing sites. Some additional information on the total number of vessels in each area, and discussions with data collectors and the Ministry of Fisheries on the fishing activity outside hours of monitoring would be needed to allow for robust extrapolation.

It is also not possible to know the extent to which the data is representative of coastal fisheries: 1) in areas where landing sites are located, and 2) for the entire island. Data collectors themselves log their own fishing activities (around 30% of all fishing trips are from six of the data collectors), so they are over-represented in the samples. Social connections can also be leveraged in the data collection, which can be biased towards the close contacts of the data collectors. For instance, almost all data collection on female fishers comes from one female data collector at only one landing site. These are important limits that can be dealt with through additional training and regular feedback.

To better assess representativity and extrapolate some of the results, additional information is needed on fishing activities and practices at both the landing sites and around the entire island (including number and types of operating vessels, fishing effort, catch, fishing location, gear type, end-use of catches, fish consumption). Some information, such as the number of vessels or fishers, could be obtained or

[11] Costs of FAD materials can be found in a 2018 report from the Ministry of Fisheries on FAD deployment in Kadavu.

approximated by the Ministry of Fisheries staff in Kadavu. The remaining information could be obtained in various ways, such as conducting a literature review or through existing data analyses (e.g. University of the South Pacific marine resource value assessments in Kadavu[12] or household income and expenditure surveys), focus group discussions, key informant interviews and representative household surveys at the provincial level.

In addition, ongoing monitoring does not enable the situation to be assessed prior to the deployment of FADs,[13] and does not differentiate impact versus control sites. This limits the scope of the monitoring and does not allow enable an assessment of changes due to FAD deployment. Ideally, to assess and monitor impacts from an intervention (FAD deployment in that case), indicators of interest would be sampled at multiple sites to be affected by the intervention (impact sites), and at multiple control sites, on two or more occasions before and after the intervention (Bell et al. 2015). This means that ongoing monitoring does not make it possible to assess changes due to FADs in terms of livelihood or food security. It also does not make it possible to assess whether there has been any displacement of fishing efforts, from the reef to FADs.

Most of the points raised above are important limits to using the results for assessing FADs' financial performance and effectiveness at the provincial level, and more broadly for fisheries management purposes in Kadavu. For instance, the introduction of size measurements could help to better detect possible overfishing of targeted species, which can then be used as a basis for management decisions such as minimum size limits or bans on specific species. A key recommendation is for SPC and the Ministry of Fisheries to collectively re-examine and discuss the objectives of the Kadavu FAD monitoring project to better link them with management ones, based on the ministry's needs. It could also be an opportunity to discuss how the monitoring project fits in with Fiji's FAD management plan, which is under development.

References

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[12] https://www.usp.ac.fj/index.php?id=23550
[13] This would only be possible for one of the FADs: Kadavu Talaulia, which was deployed in 2018 several months after monitoring started. However, 67 of the 68 of the fishing events recorded at this FAD are from the same landing site where most of the other FAD fishing events have been recorded (including prior to the Talaulia FAD deployment). This makes a before and after analysis much more challenging.