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WESTERN CENTRAL ATLANTIC FISHERY COMMISSION (WECAFC)

Guide for the improved monitoring of Anchored Fish Aggregating Device (aFAD) catches and improved assessment of aFAD impacts on stocks in the WECAFC region

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GUIDE FOR IMPROVED MONITORING OF ANCHORED FISH AGGREGATING DEVICE (aFAD) CATCHES

AND IMPROVED ASSESSMENT OF aFAD IMPACTS ON STOCKS IN THE WECAFC REGION

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GUIDE FOR IMPROVED MONITORING OF ANCHORED FISH AGGREGATING DEVICE (aFAD) CATCHES

AND IMPROVED ASSESSMENT OF aFAD IMPACTS ON STOCKS IN THE WECAFC REGION

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1. Background

Since the late 1960's, when anchored Fish Aggregating Device (aFAD) fisheries were first introduced in the Western Central Atlantic Fisheries Commission (WECAFC) region, there has been a steady increase in the number of WECAFC states (or their overseas territories) supporting aFAD fisheries, most of which are located in the insular Caribbean (Wilson et al. 2020). A recent survey indicates there are currently about 3 500+ aFADs across the WECAFC region, exploited by 5 000+ small-scale fishers using 3 000+ small (<9 m long) fishing vessels and various highly selective fishing techniques (Vallès, in prep).

The rapid development of this small-scale, but largely unregulated, fishery has led to increases in the exploitation of straddling stocks of large pelagics in the region, raising concerns about the impacts of the fishery on these stocks (CRFM 2015). Such c1. oncerns include the use of aFADs to target species currently considered overfished regionally such as blue marlin (FAO 2016; Bealey et al. 2019; CRFM 2015). They also include concerns expressed for fisheries using drifting FADs, such as the potential for excessive exploitation of juveniles of tuna and other species (e.g., dolphinfish) (Morgan 2011; Dagorn et al. 2013; CRFM 2015) and potential for increases in incidental by-catch (Morgan 2011; Dagorn et al. 2013; Leroy et al. 2013). These also include the potential for FADs to act as ecological traps (Hallier and Gaertner 2008; Dagorn et al. 2013) and the analytical problem of how the fish aggregating properties of FADs preclude a straightforward interpretation of catch-per-unit-effort as an index of stock abundance (Ehrhardt et al. 2017b).

These concerns contributed to prompt the establishment of the WECAFC FAD Working Group on the Development of Sustainable aFAD Fishing in the Lesser Antilles in 2001, which was later expanded to include the National Institute for Ocean Science (IFREMER), the Japan International Cooperation Agency (JICA) and Caribbean Regional Fisheries Mechanism (CRFM) as regional partners. These concerns also led to the drafting of the Sub-regional aFAD fishery management plan for the Eastern Caribbean in 2015 (CRFM 2015). In 2019, the Regional WECAFC FAD WG obtained the endorsement of the Recommendation WECAFC/17/2019/21 *"On the sustainability of fisheries using moored fish aggregating devices in the WECAFC area"*[1]. This recommendation explicitly recognized "*... the need to improve data and information to reduce uncertainties to stock assessment methodologies currently used and to monitor long-term impacts of these fisheries on the stocks...*". In line with this recognition, one of the key activities of the pursuant EU- funded project GCP/SLC/217/EC "*Support to the Secretariat of WECAFC in implementing targeted actions of the 2019-2020 Workplan on improved regional fisheries governance*" is the development of a guide for improved monitoring of aFAD catches and improved assessment of aFAD impacts on stocks.

This guide is mainly aimed at national/local fishery authorities and researchers involved in developing and implementing fishery data collection systems. It first describes recent efforts in improving fishery data collection systems involving aFADs in the WECAFC region, with focus on the Eastern Caribbean. It then builds on such efforts to propose a way forward that hinges on the potentially transformative power of Information and Communication Technology (ICT) tools to address past and current data deficiencies.

It is expected that the full uptake and implementation of many of the monitoring and data collection recommendations provided here will be incremental and will require a phased-in approach for adoption.

1. http://www.fao.org/fi/static-media/MeetingDocuments/WECAFC/WECAFC2019/17/RecWECAFC%20XVII-2019-

1.1 A brief review of recent efforts to improve fishery data collection systems in WECAFC countries with significant aFAD fisheries

In 2008, the Secretariats of CRFM, CARICOM and JICA, signed the implementation of The Study on the Formulation of a Master Plan for Sustainable Use for Fisheries Resources for the Coastal Community Development in the Caribbean (CRFM/JICA 2012). This study, which covered 13

CARICOM countries, conducted baseline surveys to facilitate characterization of the fisheries of several of the participant countries and identify key issues that needed addressing. Among the issues identified were those surrounding the collection and treatment of fisheries statistics. These included (1) insufficient data collection to inform decision making, (2) inadequate data management, (3) insufficient use of the Caribbean Fisheries Information System (CARIFIS), and (4) inadequate dissemination of information. Moreover, this baseline study recognized that substantial differences existed among countries in the development of their fisheries statistical systems. This study also emphasized the importance of establishing a regional database for the countries of the Caribbean region, but recognized that this would be a difficult undertaking given the differences in capabilities and policies among countries.

This study also led to the execution of a pilot project on the aFAD fishery in two countries, St Lucia and Dominica, with the aim of (1) improving the capacity of fisheries officers and fishers' organizations to manage pelagic resources exploited using aFADs and, (2) increasing the productivity of the aFAD fishery by developing skills and capacity to utilize pelagic resources. Based on the experience of the aFAD pilot project component of the Master Plan Study, the 5-year Caribbean Fisheries Co-Management (CARIFICO) Project followed up in 2013. It aimed to further develop a co-management approach to aFAD fisheries for each participating country. This project was expanded to include five countries with aFAD fisheries, Antigua and Barbuda, St Kitts and Nevis, Dominica, St Lucia, St Vincent and the Grenadines and Grenada. A key co-management output of this project was the development of a data collection logbook system to be completed by fishers, as part of their responsibility to help monitor the aFAD fishery.

In parallel to these efforts, Barnwell (2014) conducted a review of fishery data collection systems in selected countries of CRFM with a view to assessing the extent to which aFAD data were being integrated into these systems. Several key findings emerged from this report and through subsequent feedback from participating countries in relation to minimum data requirements (CRFM 2014). Notably, that data collected should be consistent with the requirements by ICCAT's 2011 Recommendation on a Multi-annual Conservation and Management Program for Bigeye and Yellowfin tunas and in relation to the Guidelines for Preparation of FAD management plans (Annex 2 of the same recommendation). Moreover, the report recognized efforts of several countries to integrate aFADs in their data collection systems, but further highlighted existing differences among these countries in the data collected as well as in data management tools. It thus recommended some degree of standardization among countries in data management tools, minimum data requirements, fishing effort measures and data collection methods (census vs sampling). It also recommended the regular collection of biological data (at a minimum length frequency data). Discussions on these findings also highlighted the importance of incorporating socio-economic data (fuel costs; unit price of fish; value of catch) into the data collection process (CRFM 2014).

The Barnwell report also recognized the value of sharing a common computerized data management system across countries to integrate and aid in standardized datasets and thus to facilitate addressing research questions. However, it also recognized that past efforts in this regard had failed due to a lack of consistent technical assistance. Thus, the preferred approach across the different countries at the time was to maintain their respective data management systems, while continuing to work towards standardizing minimum data requirements for both catch and effort and biological data.

1.2 The WECAFC Data Collection Reference Framework (DCRF), regional database, and regional logbook

Recognition of the urgent need for improved fishery statistics within the WECAFC region resulted in the establishment of the WECAFC-FIRMS (Fishery Resource Monitoring Program) partnership in 2014, which led to the establishment of WECAFC Fishery Data and Statistics Working Group (FDS-WG) in 2016. This partnership represented a substantial step forward towards strengthening the regional management capacity of WECAFC by, among others, helping increase and improve information content on fisheries data and statistics, helping increase accuracy of data and statistics by using agreed practices in data collection, and helping develop and implement agreed practices of data sharing. A key output of the initial stages of this partnership (WECAFC-FIRMS Phase I) was the foundation of a regional database, which was proposed and tested with pilot data in the 2015-2016 period. This output was further built upon (during the WECAFC-FIRMS Phase II) by developing agreements regarding minimum data requirements for fisheries under management plans and by working on the governance and operationalization of the WECAFC Regional Database, which included the establishment of a regional data collection reference framework (DCRF) and documentation of best practices for logbooks and data sharing policies and guidelines.

1.2.1 The WECAFC Data Collection Reference Framework (DCRF)

The WECAFC DCRF is meant to facilitate capacity building in fisheries statistics in WECAFC Members by serving as reference standard document for national fishery data collection systems. It also serves as an instrument to support the scientific mandate and priorities of WECAFC, CRFM and OSPESCA via a modular data structure broken down in tasks and sub-tasks, which jointly allow for an incremental approach to the implementation of fishery systems depending on the capacity of the Member.

The WECAFC DCRF document was first endorsed by WECAFC as an interim version in July 2019, during the 17th Meeting of the Commission, and finally endorsed as a living document during the 18th Meeting of the Commission in July 2022. The DCRF document outlines the main principles by describing the main themes for standardized data collections across the region (WECAFC 2022). Table 1 describes the broad data requirement components (tasks and sub-tasks) of the DCRF. The document contains working definitions, further describes the structure of the data collection, and provides appendices with WECAFC standard classifications (e.g. gear type, vessel type; nominal effort by vessel type; etc) and lists of all priority species and other reference species. It is thus expected that WECAFC Members will align with such data structure principles to provide the regional database with the minimum information needed for stock assessment and monitoring.

Table 1 – Data requirements of the WECAFC Data Collection Reference Framework (DCRF) broken down by components (tasks).

ID	Task	Sub-task	Data	Description
I	Regional statistics	Fishing capacity	Number of active fishing vessels; total capacity; engine power; total nominal catch. Data by year, flag state; fleet segment, and subarea.	Provide a general summary overview of the fishery sector of each country in the wider Caribbean region, with an indication of total fleet capacity and total nominal catches, reported for subareas relevant to WECAFC.
		Landings	Nominal catch. Data by year, flag state, subarea, and species.	The regional overview of nominal catches by country, species and subareas for all aquatic species
II	Catch and effort	Catch	Retained catch; discarded catch; nominal catch. Data by year, flag state, fleet segment, fishing mode, subarea and species.	Catches, provided on a yearly basis by fishing unit, are for most fisheries defined in weight units as the total weight of catches (in live weight equivalent), and in number of individuals regarding discards, or for certain tuna fisheries.
		Effort by fleet segment	Days fishing; nominal effort; fishing vessel count. Data by year, flag state, fleet segment, fishing mode and subarea.	The fishing effort deployed by national flagged vessels, reported on a yearly basis by fleet segment, fishing mode, and subarea, with catches (and landings) for the corresponding fishing units
III	Fleet	Fleet engaged by fishery (primary gear, target species)	Number of active vessels. Data by subarea, fleet segment and species.	Nominal effort by fishery is expressed in terms of capacity (number of vessels, total capacity, engine power) by subarea, fleet segment, and target species.
		Vessel registry	Vessel descriptors.	Regional vessel registry fed by the national vessel records or registries.
IV	Biological information	Size data	Total retained catch (weight); total discarded catch; total weight of samples; length class /sex/maturity; number of individuals at length; total weight of individuals.	Size frequencies of the samples (retained and discarded) measured for each species classified by major fleet, gear sample units, time strata and area strata and sex for select species.
		Catch at size data	Length class; sex; stage of maturity; total weight of individuals; total catch.	Reported catch at size classified by primary fleet, gear, species time unit and area and by sex (for select species).
V	Endangered, Threatened, Protected (ETP) species catches	By-Catch ETP	Landings (in numbers or weight as appropriate); number of discards including fate upon release (in numbers or weight as appropriate); number of discards dead (in numbers or weight as appropriate).	The discards resulting from endangered, threatened, or protected species catches are reported, whether landed, discarded dead or discarded alive.
VI	Socio-economics	Employment	Number of fishers. Data by country, sub-area, time-use, gender and age group.	Employment in the fishery sector is a useful indicator of the importance of the fishery sector in the region. This indicator aims to present number of fishers by category (fully employed or part time ones), by gender (male / female) by the major fleet, and area for the reference year.
		Participation in fishing activities	Count of fishers; count of fishers x days fishing.	Number of fisherfolks actively taking part to fishing activities, and the intensity of such involvement.
			Total nominal catch; unit price by species; total value. Data by year and country.	The value of capture fisheries production at first sale after landing of the catch and average value of species' prices per kg (in USD).

1.2.2 The WECAFC regional database

The next logical step has been the establishment of a WECAFC Regional Database (WECAFIS) to which the member states contribute with their data via data sharing agreements. The database is currently operational and data calls are defined yearly by the Commission. The regional data manager creates a template in the regional database that is shared with the national data managers at the country level. The national data managers have the responsibility of harmonizing national data with the standard requirements of the regional database, after which they submit the data to the Commission. The regional data manager subsequently validates these data for inclusion to the regional database. Once the data are validated, they are published in the WECAFC Regional Database according to the Regional Data Access and Sharing Policy. The WECAFC-FIRMS system[2] is the place for managing and disseminating information on status and trends of WECAFC marine resources and fisheries, following the FIRMS Information Management Policy.

1.2.3 The WECAFC regional logbook

To align with the DCRF, the WECAFC has proposed logbook guidelines that provide a methodological framework to collect necessary fishery-related data for national fisheries management and policy making, stock assessments and reporting to WECAFC (WECAFC 2018). These were endorsed by the first meeting of the FDS-WG in May 2019, with a request for them to be tested through pilot use cases so to develop implementation guidelines. Moreover. the WECAFC logbook will need to be reviewed by FDS-WG for any possible adjustment under the global standard of logbook data structure of the Coordinating Working Party on Fishery Statistics (FAO 2022).

These logbook guidelines propose a modular approach for developing regional logbooks. The use of different modules is here critical because it allows the data collection process to take place at incremental levels of detail so that it can adapt to the needs and data collection capacity of each participating country. In that regard, the logbook can cover a broad range of data types, which may be reported on a simple logsheet for daily activity records of a small-scale fisher to a detailed logbook recording information per fishing event during a fishing trip.

The guidelines identify data (Modules 0-3) that should be collected in any type of fishery to provide the minimum data required for fisheries management and stock assessments. These data constitute the mandatory data requirements for any logbook (core data) and are shown in Fig 1, which include (1) basic information on the vessel and crew (e.g. registration number, owner/captain name, number of crew, port), (2) a description of the fishing trip (departure and arrival time and date; time spent fishing, target species), (3) a description of fishing gear (e.g. length of the line) and effort by gear (e.g. number of hooks; number of hours gear fished), including basic FAD data (e.g. location) if FAD are being used, (4) a summary of landings by species (distinguishing between retained and discarded catch) and (5) a report of Nil fishing activity.

The guidelines also identify additional detailed information (Modules 4-6) to be collected depending on a fishery's or country's requirements and the final goal of the logbook. These additional data requirements (in Appendix I) include (1) a summary of catch and effort data per day (all gears combined), (2) a detailed description catch and effort data per day per gear, including bait types and more detailed characteristics

2. https://firms.fao.org/firms/en

of the gear used (e.g. hook type), (3) catch data broken down by gear, (4) detailed information about FAD use (if fishing involves FADs), (e.g. FAD dimension and materials) and (5) environmental data parameters (e.g. sea surface temperature). Moreover, these additional data also include (6) biological data (e.g. length frequency distributions) for a given species and gear, (7) by-catch data by species (e.g. quantity and state when discarded) and (8) trip cost data (e.g. fuel cost; ice cost; trip revenue).
Finally, these guidelines also provide a summary of regional best practices in logbook implementation. The modules in these guidelines may be implemented as paper-based or electronic logbooks as may be required by each country.

Thus, overall, the WECAFC logbook provides a template to help standardize data reporting for the different types of fisheries across the region, including aFAD fisheries.

FIGURE 1.
Data requirements for the mandatory section (core data) of the WECAFC logbook. Taken from WECAFC (2018).

Administrative information

Officer Name: ....

Affiliation: ....

Date of data submission: DD / MM / YYYY

MODULE 1 - VESSEL INFORMATION

SECTION 1.1 - VESSEL DESCRIPTION

Trip number: .... [this should be assigned automatically by a system or in the printout book (book number / book page number)]

SECTION 1.1 – VESSEL DESCRIPTION

Vessel Name:

Registration Number:
Flag:

Vessel home site/port:

Captain Name:

Owner Name:

Identification Number / permit number (fishing license):

Number of Crew:

SECTION 1.2.a – additional VESSEL INFORMATION [Optional] (small-scale fisheries / for vessel registry update)

Owner address (address/city/region or island/country):

Owner phone number:

SECTION 1.2.c – Additional VESSEL INFORMATION [Required if the vessel is not included in a centralized registry]

IMO: | Year of construction:
IRCS: | Construction Location:
LOA: [unit] | Hull type: checkbox with list of hull type
Draught: [unit] | Vessel Type: checkbox with list of vessel type
Beam: [unit]
GT: [unit]
[unit]
Main engine power: [unit]

MODULE 2 - FISHING TRIP DESCRIPTION

SECTION 2.1 – Fishing Trip DESCRIPTION

Departure date: DD / MM / YYYY time : Port* departed:

Return date: DD / MM / YYYY time : Port* returned:

Fishing Zone**: -

Time spent in the fishing zone(s): ☐ h / ☐ days
(h if less than one day at sea . / days if more than one day at sea)

Time spent fishing in the fishing zones): ☐ h / ☐ days
(h if less than one day at sea . / days if more than one day at sea)

Target Species***: - -
- -

Type of fishing ☐ small-scale ☐ commercial fishing ☐ sport fishing

*"port" includes all points of departure/return, including port, village, beach, settlement
** drop down; if multiple zones/gears are used during the trip, please enter each separately
Please refer to the user manual for the fishing zones list
*** Please refer to the user manual for the target species list

SECTION 2.2- Gear and effort DESCRIPTION

SECTION 1.3a – Gear DESCRIPTION

Primary gear (select one)

☐ gillnet
mesh size:..............[unit]
length of net:........[unit]
nets operated
#of hours gear fished
:..........

☐ Seine
mesh size :..............[unit]
length of net:........ [unit]
#of hours gear fished
:..........

☐ Cast net
mesh size:..............[unit]
length of net:........[unit]
#of hours gear fished
:..........

☐ Long lines
Length of main line:......[unit]
# of hooks:..........
lines operated
of hours gear fished:..........

☐ Hook & lines
Length of main line:......[unit]
# of hooks:..........
#of hours gear fished:..........

☐ Traps
mesh size/trap:...[unit]
L W or V (*)
# of traps:..........
#of hours gear fished:..........

☐ Free diving
hours spent diving:..........

☐ Scuba diving
Number of tanks:..........
hours spent diving:..........

☐ Compressor diving
hours spent diving:..........

Indicate if **a secondary gear** was used and which one
☐ Gillnet (add similar as above) ☐ Seine ☐ Cast net
☐ Long lines ☐ Hook & lines ☐ Traps

Use of FAD ☐ Yes ☐
If yes: FAD ID, location(s) and hours spent around the FAD and the time:
FAD ID / Location / hours(h) FAD ID / Location / hours(h)

(*) L = Length / W = width / V = Volume

MODULE 3 – Landings Summary

SECTION 3.1 – Retained and discards declaration (all weight are in live weight equivalent)

Landings	**Quantity / Number**			
Species	Nominal catch weight* [unit]	Nominal catch number* [optional]	Discarded weight* [unit]	Discarded number* [optional]
Lobster (*Panulirus argus*)				
Conch (*Strombus gigas*)				
Nassau Grouper (*Epinephelus striatus*)				
Barracuda (*Sphyraena spp.*)				
Wahoo (*Acanthocybium solandri*)				
Dolphinfish (*Coryphaena hippurus*)				
...				
...				

*live weight equivalent

SECTION 3.2 – Landings / nominal catches declaration

Landings	**Quantity [Unit]**		
Product type	Landed product weight	Conversion Factor [optional]	Nominal catch weight *
Frozen Lobster (*Panulirus argus*)			
Conch body (*Strombus gigas*)			
Fresh Nassau Grouper (*Epinephelus striatus*)			
Fresh Barracuda (*Sphyraena spp.*)			
Wahoo (*Acanthocybium solandri*)			
...			
...			

*live weight equivalent

SECTION 2.3- Crew list for this fishing trip

SECTION 1.3 – Crew list

Crew first name	Crew family name	Position

Reporting Nil fishing activity

Section 1.3 - Nil fishing activity report

Date from: DD / MM / YYYY
Date to: DD / MM / YYYY
Reason for nil fishing: ☐ maintenance ☐ at dock ☐ unloading ☐ other: ....

☐ Nil fishing during the month of: MM/YYYY ..../.......

1.3 A description of fishery data being currently collected across the region by countries/territories with aFAD fisheries

The existence of considerable differences among countries in the implementation of fishery statistical systems is confirmed by the results of a recent survey of key informants across 20 territories/countries with significant aFAD fisheries (Vallès, in prep). First, one quarter (25 percent) of the territories/ countries were not engaged in any type of systematic fishery data collection involving aFADs. The remainder of territories/countries (75 percent) did have an active fishery data collection system facilitated by a standardized data collection form (Table 2) and; nearly all these countries/territories explicitly distinguished landings from aFAD fishing from non-aFAD fishing.

A closer look into the critical data component needs of the territories/countries with active data collection systems identified some pieces of information that were collected across most (>75 percent) countries/territories. These included (1) time spent fishing, (2) number of fishers on boat, (3) fishing techniques used, (4) total weight landed and (5) total weight landed by species (Table 2). In contrast, only 50 percent of these countries/territories quantified the number of fishing lines actively fishing, a more refined measure of fishing effort. Even fewer territories/countries recorded the location/ identity of aFAD used and fuel consumption expenses (Table 2). These results support the need to implement a minimum set of standardized data requirements towards achieving improvements in basic fishery statistics for aFAD fisheries used in stock assessment and monitoring.

TABLE 2 – Percentage of territories/countries (out of 15) with significant aFAD fisheries that collect data on twelve variables from fishing trips to aFADs based on a recent survey of twenty territories/countries. Note that five out of the twenty territories/countries surveyed are not engaged in any systematic fishery data collection involving aFADs. Yes - data are always collected; sometimes - data are only collected sometimes; No – data are not collected. Red and green colors indicate high and low consistency across territories/countries, respectively.

Variable	Yes	Some times	No
Fishing techniques used	93%	7%	0%
Total weight landed	93%	7%	0%
Time spent fishing	87%	13%	0%
Number of fishers on boat	87%	7%	7%
Weight landed by species	86%	14%	0%
Estimate of revenue from sale	64%	7%	29%
Number of fishing lines in the water	50%	17%	33%
Number of fish landed	47%	27%	27%
Number of fish landed by species	47%	33%	20%
Time spent travelling	43%	14%	43%
aFAD ID or location	38%	23%	38%
Fuel consumption and other expenses	36%	29%	36%

2. Minimum data requirements for aFAD fisheries: the CRFM logbook

Between 2014 and 2015, the CRFM supported the CARIFICO project by helping further develop a logbook for the aFAD fishery with input from the five countries that were at the time part of the project (Mohammed and Masters 2014; Masters and Mohammed 2015; Mohammed 2015; Mohammed and Masters 2015). The process leading to a final logbook is described in detail in Mohammed (2015). This logbook effort, which followed up previous work (CRFM/JICA 2012; Barnwell 2014; CRFM 2014) and involved an additional review of fishery statistical systems implemented during the CARIFICO project, was expected to considerably strengthen existing fishery data systems by:

1. Supporting the standardization of aFAD data requirements and collection across countries to help consolidate these data for regional-level fisheries analysis.
2. Allowing the development of adequate performance indicators to assess the status of the fishery in relation to specific management socio-economic objectives commonly associated with aFAD fishing.
3. Aligning data requirements with those of ICCAT recommendations for large tunas.
4. Allowing the quantification of the effects of aFAD fishing on key biological components of the ecosystem, namely the capture of juveniles of target species, target species undergoing overfishing and non-target species.
5. Allowing assessing the effect of gear type, bait and fishing depth on fishing yields and species composition.
6. Allowing assessing the effect of selected environmental factors on fishing yields and species composition.

The CRFM logbook contains four different sections, including (1) a general section that identifies the boat, boat owner and landing site; (2) a section with the logsheets to enter the relevant information for each fishing trip; (3) a section with a map of fishing zones, aFAD locations and landing and departure sites; (4) a section with guidelines for completing the logsheets, including example drawings of key species to facilitate field identification and (5) an example of fully filled logsheet. An example of logsheet is presented in Figure 2.

Of particular relevance, the minimum data types contained in this final version reflect the outcome of an iterative participatory process with fishery officers of the five countries and a necessary compromise between keeping data requirements to a minimum to facilitate participation of fishers while maximizing information output to meaningfully guide aFAD fishery management. These data requirements thus represent a validated minimum standard for the aFAD fishery in the region. Table 3 shows the data requirements of the logsheets of the logbook.

Fig 3 illustrates the links between the different variables in the CRFM logbook with an example of data for a hypothetical fishing trip. A boat with two fishers leaves port at 5 a.m. hours and returns at 11 a.m. During that time, it visited two different FADs. At the first aFAD, both droplines and surface trolling gear were used and blue marlin, yellow fin tuna and dolphinfish were captured. At the second aFAD, only trolling operations occurred and dolphinfish were captured. The logbook form explicitly requires linking a specific gear to the species caught, along with the provision of data on effort (number of hooks and fishing hours), fishing depth, time of day, and type of bait associated with the gear. These minimum data types are critical because the abundance and composition of the catch are known to be strongly influenced by changes in any of these variables and by the location of the aFAD (e.g. distance from shore, mooring depth, level of exposure) (reviewed in CRFM 2015). These data types (variables) may also be used to provide reasonably accurate estimates of CPUE and fishing efficiency. Moreover, the logbook form requires informing about the presence of other boats fishing on the same aFAD, which is likely to affect yields by individual fishing boats (Sidman et al. 2014). It also seeks to quantify potential differences across locations in weight reporting due to the level of processing that fish might undergo while on-board, which should facilitate the process of data standardization and consolidation across locations. Although individual fish sizes (or weights) are not requested, the form does require reporting the number of fish caught of each species with each specific gear. This piece of information can be combined with the total weight caught to derive the average individual fish weight for each species captured, a crude size-based metric that could nevertheless meaningfully inform management about spatiotemporal trends in sizes for individual species (Shin et al. 2005).

The form also requests the identification of non-target groups (e.g. turtles, sharks, mammals, sea birds) caught while fishing and their fate (kept, discarded alive or dead). Although on the logbook form the capture of such groups is not directly linked to a specific gear or a specific aFAD, which is useful information, the comment section in the form could be used to do so. The form also seeks to capture the potential effect of sea conditions on fishing yields by requesting simple information on sea state, water colour, and whether Sargassum rafts were present that day. Importantly, the form also requests the input of financial data for the fishing trip. It captures the expenses endured during the fishing trip, namely on fuel, oil, food, ice, and lost gear as well as the revenue generated by the sale of the catch, acknowledging that not all fish caught might be sold.

The minimum data requirements proposed by the CRFM logbook can be used to develop performance indicators that can be contrasted with a range of broad management objectives typically associated in aFAD fishery in the region (Table 4).

FIGURE 2.
Logsheet of the CRFM aFAD logbook showing the data requirements for a fishing trip

Boat Name:	Boat registration number:	
Departure site (see map to identify site):	Departure date (day/month/year):	Departure time:
Landing site (see map to identify site):	Landing date (day/month/year):	Landing time:

FISHING EFFORT	Number of Fishers:		
Gear Types: TR: trolling; HL: Handline DL: Dropline; LL: Longline RR: Rod & Reel	*See map to identify FAD # or fishing area*		
	FAD # or fishing area:	FAD # or fishing area:	FAD # or fishing area:
Gear used (select from above) :			
Number of lines			
Number of hooks			
Number of hours fished:			
Day (D) or night (N) fishing:	D □ N □	D □ N □	D □ N □
Total number of boats fishing:			
Depth fished: □ feet □ metres (tick one)			

CATCH

Levels of processing – Gutted (GU); Gilled (GI); Headed (H); Finned (F); Whole (W)
Bait Type: Artificial Lure OR Natural Species – list species (list below)
Weights in □ lbs □ kg (tick one) - **Weights are** □ estimated □ measured on a scale (tick one)

FAD#/ fishing area	Species	Level of Processing (encircle which applies)	Gear Type (encircle which applies)	Bait Type	Weight Caught	No. Caught	Weight Sold	Unit Price
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					
		GU GI H F W	TR HL DL LL RR					

BY-CATCH	Turtles	Seabirds	Sharks	Whales	Dolphins	Porpoise	Manatee	Other
Number Kept								
Number discarded dead								
Number discarded alive								

FISHING COSTS	Indicate money spent in XCD for the following that are <u>used</u> for the fishing trip						
	Fuel:	Oil:	Ice:	Food:	Bait:	Gear:	Other (specify):
	Amount of oil <u>used</u> for the trip: Gallons □ Litres □ (tick one)				Amount of fuel <u>used</u> for the trip: Gallons □ Litres □ (tick one)		

SEA STATE (encircle one): see the Sea State Code Chart in the guidelines	Calm (glassy)	Calm (rippled)	Smooth (wavelets)	Slight	Moderate	Rough	Very rough	High	Very high

WATER COLOUR (encircle one): see the Water Colour Description Chart in the guidelines	Blue	Milky turquoise-purple	Blue-green	Green	Dark green	Light brown	Red/Reddish Red strikes	Pink	Purple	Seaweed present

COMMENTS & OBSERVATIONS: ....
....

SUBMISSION OF LOGSHEET: Name of fisher (in BLOCK letters)...

Signature of person filling in the log sheet: .... Date of completion of log sheet (day/month/year): ....

FOR OFFICIAL USE

Received by:-	Signature:-	Date (day/month/year):
Verified by:-	Signature:-	Date (day/month/year):
Computerized by:-	Signature:-	Date (day/month/year):

TABLE 3 – Data requirements of the CRFM logbook for aFAD fisheries (Figure 2) and its links with ICCAT data requirements for catch recording (Annexes 2 and 6) and WECAFC logbook data requirements. Xc – WECAFC logbook mandatory data; Xa- WECAFC logbook additional data.

CRFM logbook Information category	Entry requirement	ICCAT	WECAFC logbook
Basic fishing trip information	Boat name	X	Xc
	Boat registration number	X	Xc
	Departure site	X	Xc
	Landing site	X	Xc
	Departure date	X	Xc
	Landing date	X	Xc
	Departure time		Xc
	Landing time		Xc
Fishing gear and effort	FAD identifier or fishing zone	X	Xc
	Number of fishers on boat		Xc
	Gear type used	X	Xc
	Number of lines	X	Xc
	Number of hooks	X	Xc
	Number of hours fishing		Xc
	Total number of boats fishing on aFAD		
	Fishing depth		Xa
	Bait type: artificial lure vs natural species		Xa
	Time of day: night vs day		
Catch	Species ID	X	Xc
	Weight caught (kg or lbs)	X	Xc
	Means of weight estimation	X	
	Level of weight processing (gutted, gilled, headed, finned, whole)	X	Xc
	Number of fish	X	Xc
Fishing trip revenue	Weight sold (kg or lbs)		Xc
	Unit price		
By-catch	Selected groups (turtles, seabirds, sharks, dolphins, porpoises, manatee, other)	X	Xa
	Numbers kept, discarded alive, and discarded dead	X	Xa
Fishing trip costs	Fuel volume and cost		Xa
	Oil volume and cost		Xa
	Ice, food and bait cost		Xa
	Loss gear cost		Xa
Sea conditions	Sea state (calm to very high)		
	Water colour (blue to purple)		
	Seaweed presence/absence		
Basic recorder information	Name of fisher	X	Xc
	Name of data collector	X	Xc
	Date		Xc

FIGURE 3.
Links between variables prescribed in the logsheets of the CRFM logbook for a fictitious fishing trip at two aFADs using different gear, spending different amounts of time and capturing different species.

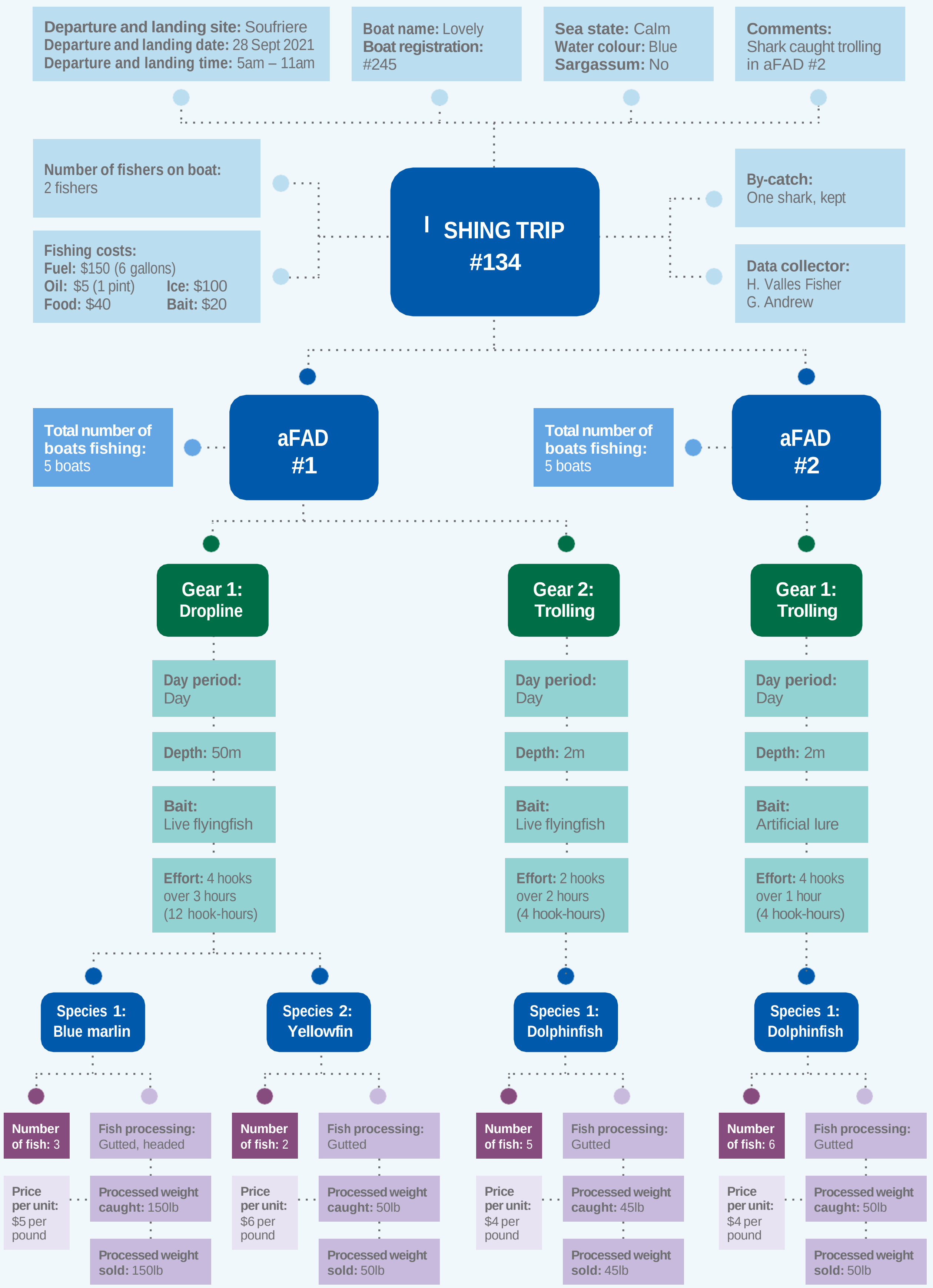


TABLE 4 – Relationship between broad management objectives typically associated with aFAD fisheries in the Caribbean and performance indicators that can be derived from the minimum data requirements in the logsheets of the final version of the CRFM logbook for aFAD fisheries. * - It is critical to clearly distinguish between aFAD fishing and non-aFAD fishing in the logsheet.

Commonly cited management objectives – Socio-economic domain	Performance indicator(s)*	Relevance
To increase fisher revenue	Total revenue per fishing trip; net added value per fishing trip (revenue minus expenses); net added value per fisher per hour per fishing trip	High
To reduce fuel consumption	Fuel consumption and cost per fishing trip	High
To increase fishing efficiency for fishers	Catch per unit effort (CPUE); Value of catch per unit effort (VPUE)	High
To support food security	Total weight landed	High
To increase local availability of fish products	Total weight landed	High
To reduce competition among fishers in resources/ fishing grounds	Number of boats fishing in an aFAD at the same time	Medium
To decrease physical demands of fishing	Total number of fishing trips; average time at sea per fishing trip; average travel distance per fishing trip	Medium
To encourage fishers to remain within territorial waters	Average travel distance per fishing trip; total number of fishing trips	Medium
To increase safety at sea	Average travel distance per fishing trip; total number of fishing trips	Medium
To increase employment	Number of fishers per fishing trip; total number of fishing trips	Medium
To support or develop a charter/sports fishing market	Number of fishers per fishing trip; total number of fishing trips	Medium
To reduce fish imports	Total weight landed	Low
To increase fish exports	Total weight landed	Low
To generate new added value products	Total weight landed	Low
To reduce conflicts between fishers and other users of the sea (e.g. shipping, tourism)	-	None
To promote co-management	-	None
To promote social cohesion and collaboration among fishers	-	None
Recommended management objectives – Biological and ecosystem domain	**Performance indicator(s)**	**Relevance**
To reduce catches of juvenile fish	Average individual fish weight caught per species per fishing trip	High
To reduce catches of overexploited species	Total weight caught per species per fishing trip; total number of individuals caught per species per fishing trip; CPUE per species	High
To reduce by-catch of key groups	Number of individuals caught per group per fishing trip	High
To decrease coastal or nearshore fishing pressure	Number of fishers per fishing trip; Total number of fishing trips compared to baselines	Low
To minimize ecological trap effects	-	None

2.1 Alignment of the CRFM logbook with ICCAT data reporting

In line with previous efforts, the data requirements of the logsheets of the CRFM logbook were developed to align as much as possible with ICCAT data reporting requirements at the time, particularly those dictated by Annex 1 and Annex 2 of the ICCAT Rec 14-01 – Recommendation by ICCAT on a Multi-annual Conservation and Management Program for Tropical Tunas (Mohammed 2015). This recommendation has received several amendments since 2015 (ICCAT Rec 16-01; ICCAT Rec 19-02; ICCAT Rec 20-01). It is important to note that in all amendments the data requirements only apply to fishing vessels from ICCAT's Contracting and Cooperating Non-Contracting Parties and Entities (CPCs) that are at least 20 m in length, typically purse seine and bait boat vessels. These requirements are thus not directly relevant to the smaller-sized vessels (<9 m long) engaged in the aFAD fishery across the WECAFC region, irrespective of the CPC status of their country of origin, except for those engaged in pole and line fishing in southern Brazil, which is one of ICCAT's CPC. However, as Mohammed (2015) points out, it is highly recommended that WECAFC countries engaged in aFAD fishing in the region integrate such data requirements in their fishery data collection systems, to the extent that it is possible, to support conservation and management efforts for tuna, given the importance of these stocks for food security and livelihoods in the region.

Table 3 highlights the alignment in data requirements between the CRFM logbook sheets and ICCAT's Annex 6 requirements and shows that it reasonably satisfies most of ICCAT's demands. Moreover, ICCAT requires that (1) the logbook is numbered by sheets, (2) the logbook is filled every day and before port arrival, (3) one copy of the sheets must remain attached to the logbook and (4) logbooks must be kept on board to cover a period of one-trip operation. In that regard, the CRFM logbook is itself numbered and contains numbered logsheets; it was meant to be filled after each fishing trip, which in the context of aFAD fishing in the region would take place within the same day; it was also meant to be printed in a carbon-less copy paper so that fishers could retain one copy of the logsheets (Mohammed 2015). However, it remained to be seen whether the logbook could stay inside the vessel throughout the entire fishing trip, given the space constraints of small fishing boats and thus the increased likelihood of damage or loss (Mohammed 2015).

2.2 Alignment of the CRFM logbook with the WECAFC logbook

There is also a good alignment in data requirements between the CRFM logbook and the WECAFC logbook (Table 3). This is not surprising because both the DCRF and WECAFC logbook were originally designed to align with ICCAT requirements. Importantly, nearly all the core data needs of the WECAFC logbook (Modules 0-3; Fig 1) are covered by the CRFM logbook, although some differences do exist for these mandatory data. First, the WECAFC logbook requires reporting both nominal catch weight and discarded weight (Module 3; Fig 1). The CRFM logbook does not explicitly require reporting discarded weight (Fig 2). However, it requires the reporting of landed weight after onboard processing (e.g., gilled, gutted or whole), which is more practical in the context of artisanal aFAD fishing (Fig 2). That said, knowledge of the level of onboard processing can be used to estimate the discarded weight, helping bridge this misalignment between logbooks. Second, the WECAFC logbook explicitly requires the reporting of no fishing activity (Nil fishing; Fig 1) but this is not the case in the CRFM logbook (Fig 2). Third, in the context of aFAD fishing, the WECAFC logbook also requires stating the amount of time spent around the aFAD and the time (Module 2 section 2.2; Fig 1), which is not the case in the CRFM logbook (Fig 2).

In terms of the non-mandatory additional data requirements of the WECAFC logbook (Modules 4-6; see Appendix I), the CRFM logbook either fully or partially aligns with these, depending on the fishery aspect they cover. In this regard, the CRFM logbook fully aligns with the summary of catch and effort data per day (Module 4 section 4.1; Appendix I) and per gear type (Module 4 section 4.2.2; Appendix I) required by the WECAFC logbook. It also fully aligns with the requirements for economic data (Module 6; Appendix I).

On the other hand, the CRFM logbook only partially aligns with the level of detail required by the WECAFC logbook for more refined measures of fishing effort involving hook and line (Module 4 section 4.2.1; Appendix I). For example, both the CRFM and WECAFC logbooks require data on bait types and number of hooks, but only the WECAFC also requires data on the start and end time of line sets or line and on hook characteristics (Fig 2; Appendix I). Similarly, the CRFM logbook only partially addresses non-core data needs in the WECAFC logbook specific to aFAD fishing (Module 4 section 4.2.3; Fig 2; Appendix I). For example, both logbooks require information on the location (or ID) of aFAD used, but only the WECAFC logbook also requires information about aFAD characteristics (e.g. dimensions, materials, natural vs artificial; Fig 2; Appendix I). Moreover, whereas both logbooks make provisions of the recording of environmental data, they differ in the variables measured. The WECAFC logbook focuses on sea surface temperature (Module 4 section 4.2.3; Appendix I), whereas the CRFM one focuses on perceived water quality (e.g. color) and sea state properties (e.g. calm) at the time of fishing (Fig 2). Both logbooks request data on number of by-catch and condition when discarded (e.g. dead or alive), but CRFM logbook does not require identifying discards at the level of species (Fig 2), whereas the WECAFC logbook does (Module 5 section 5.2; Appendix I). Finally, the WECAFC logbook includes a section for the collection of biological data (individual length frequencies for target species; Module 5 section 5.1; Appendix I), which is absent in the CRFM logbook (Fig 2).

In summary, there is very good alignment between the CRFM and WECAFC logbooks in terms of the minimum requirements for data collection considered as mandatory (core data) by the WECAFC logbook. This assertion also applies to some data items that are considered as non-mandatory by the WECAFC logbook, such as the more detailed description of catch and effort by gear and the economic data. The remainder data requirements from the CRFM logbook, will help fill some, but not all, the additional non-mandatory sections of the of the WECAFC logbook.

2.3 Moving forward: Building on the CRFM logbook for minimum data requirements

The data requirements contained in the CRFM logbook logsheets represent a significant step forward towards achieving data collection standardization to inform local management objectives, while meeting ICCAT's minimum data requirements to support conservation and management of regionally shared stocks (CRFM 2015) and nearly all the mandatory (core) data requirements of the WECAFC logbooks. Moreover, identification of gear types, main target species, and fishing maps (and zones) can be easily customized to reflect local context across the region. Importantly, the logsheets can also be used to monitor the pelagic fishery that does not make use of aFADs (for example, by identifying location of fishing zone), helping integrate aFAD and non-aFAD fishing datasets. Thus, it is recommended that the data requirements and form layout of the logsheets of the logbook be considered as the basic data template to support data collection across multiple aFAD fisheries.

2.3.1 Recommended amendments to the data requirements of the CRFM logbook data sheets

Small data requirement changes to the current CRFM logbook logsheets would help maximize its alignment with the mandatory data requirements of the WECAFC logbook and ICCAT's 19-02 Recommendations, while not representing any substantial additional burden on the data collection process. These recommended changes include adding (1) the reporting on non-fishing activity, in line with the WECAFC logbook, (2) the reporting of time spent on around an aFAD and (3) the reporting of catches that were discarded whole (and thus not landed in any form).

Moreover, a fourth valuable addition to the logsheets of the CRFM logbook would be a data requirement item clarifying when fishing takes place under fish aggregating objects other than aFADs, which could distinguish between artificial logs resulting from human activities involving fishing (wrecks, old nets) or not (abandoned tanks) as well as between natural logs of plant (Sargassum rafts) or animal origin (whale sharks). Distinguishing among different types of fish aggregating objects is particularly important given the now well-established seasonal presence of Sargassum rafts across the region (Franks et al. 2012).
In contrast, it is recommended that the requirement to provide environmental data by the CRFM logsheets, namely information on sea conditions and water color, is eliminated due to the inherent subjectivity associated with the measurements required. Instead, the possibility of fitting selected aFADs with low-cost electronic instruments that provide accurate measurements of environmental variables using aFADs as marine observatories likely represents a better alternative to the collection of environmental data by fishers (see Section on aFADs as fishery-independent research tools).

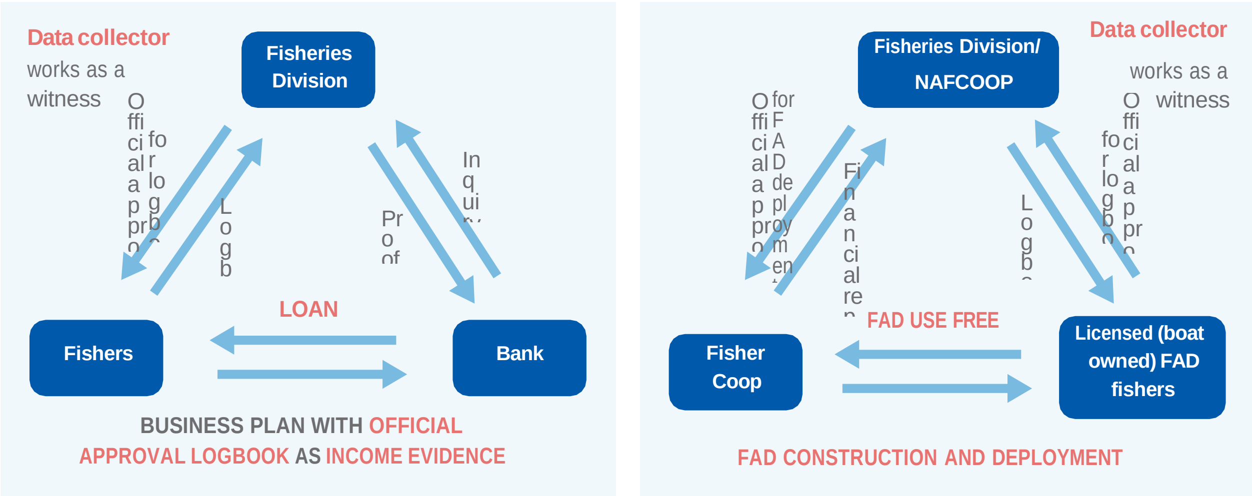
2.3.2 The challenge: Implementation of the data collection

The CRFM logbook was originally conceptualized to be carried during each fishing trip and to be filled by the fishers themselves under an arrangement of willingness to participate and acknowledgement of shared responsibility in data collection. Recognizing the important challenge that the latter represents, Mohammed (2015) outlined a number of recommendations to facilitate the adequate and regular use of the logbook by fishers. These included (1) the need to raise awareness among the resource users themselves (fishers) of the importance of the data collected to measure progress towards management objectives affecting them personally, such as increasing their revenue, and to continually maintain their engagement by providing them with regular feedback on the results derived from these data; (2) the need to raise awareness among decision-makers of the importance of the data to objectively highlight the socio-economic importance of the fishery towards the need of securing adequate financial and human resources to support the data collection system and (3) the need to train fishers in identification of fish species, the latter training integral to ensuring credible data, to respond to the minimum data requirements in the logbook.

In reality, a practical/simple and efficient approach towards the effective completion of the logbook by the fishers themselves in a sustainable way remains unresolved. During the CARIFICO project in Dominica, which promoted a co-management approach, it was proposed that fishers licensed to fish on aFADs would be required to keep records of their fishing trips in a logbook. Moreover, to further incentivize fishers, it was proposed that such logbooks, when certified by the Fisheries Division, could be used as income evidence to apply for bank loans (Fig 4 left panel) (CRFM/JICA 2011). It was also proposed that permission of the deployment of new aFADs by a fisher cooperative (coop) would be subject to the contribution of such fisher coop in logbook record and fees collected for FAD use (Fig 4 right panel) (CRFM/JICA 2011). However, the system did not ultimately work (J. Defoe, pers com). Thus, Mohammed (2015) recommended that provision of data by fishers should be mandatory or legislated, rather than voluntary, and subject to appropriate monitoring, control and enforcement, including meaningful penalties for breaching these obligations. However, as Tilley (2020) points out "*the promise of co-management or the potential of data systems to improve the sustainability of shared resources is unlikely to be a sufficient incentive on its own for fishers to engage and participate in data collection... [] ... because people whose livelihoods are labor intensive and often subsistent, prioritize other activities over completing lengthy data forms*". Thus, it is unlikely that a system relying exclusively on logbooks being filled by fishers will be successful in the long-term, even if so legislated, unless it is integrated into a larger framework that, in addition to offer both incentives (improved personal finances) or penalties (non-renewal of licenses) to fishers, helps drastically minimize both the time and individual effort that is required by such data form filling.

FIGURE 4.

Schematic representation of relationships between logbook submission by fishers and proposed incentives such as logbooks acting as proofs of financial standing for bank loans (left panel) and conditioning the granting of aFAD fishing licenses to regular logbook submission (right panel). Excerpt from CRFM/JICA (2011)



2.3.3 A practical solution: Information and communication technology (ICT) to improve data collection and aFAD monitoring

As previously stated, it is highly recommended that the data requirements and layout of the logsheets in the CRFM logbook become the basic template for data collection. Alternatively, the WECAFC logbook could be used as the reference template given the good alignment between both logbooks. However, the lack of success in the implementation of a fisher logbook system even in the context of a co-management approach, coupled with the difficulties of safely maintaining a logbook in the small fishing vessels that characterize the aFAD fishery in the region, highlights the need to identify alternative practical/ simple and cost-efficient approaches for data collection. In that regard, Mohammed (2015) raised the potential of Information and Communications Technology (ICT) as an alternative worth exploring. ICT tools are increasingly being used in fisheries and can contribute significantly to data collection and Monitoring, Control and Surveillance (MCS) strategies, which are essential components of sustainable fisheries management (FAO 2007). As such, it is now widely recommended that governments and other agencies (1) integrate ICT into fisheries projects using people-centred and pro-poor approaches based on affordable technologies that can be supported locally and which are fit for purpose and (2) promote the adoption of modern fisheries-specific technologies in the context of co-management (FAO 2007).

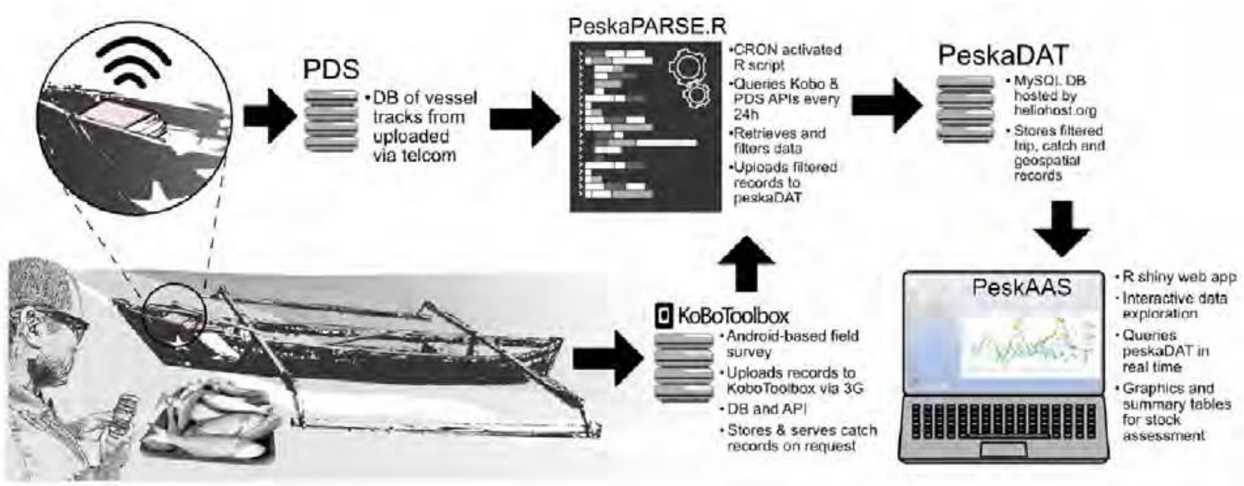
Two promising technologies that are currently being implemented under contexts of limited resources and data-poor information systems in small-scale fisheries are the use of (1) Vessel Tracking Systems (VTS), i.e. systems using satellite and cell network technology to monitor the location and movement of vessels of any size, and (2) electronic applications on smartphones or tablets allowing the capture of fisheries data and automatic transfer of such data to a centralized database. Moreover, the combination of both techniques provides a very powerful and efficient way to both characterize fishing effort locations and levels and characterize fishing yields, while facilitating standardization of data entry and minimizing data entry errors and transcription and with a potential for near-real-time analysis. Importantly, with carefully designed forms and adequate training, capturing fisheries data electronically has the potential to drastically reduce the time and individual effort (by data collectors or the fishers themselves) involved in recording data from individual fishing trips, and thus increase the chances of voluntary participation from fishers and overall lead to more cost-effective data collection.

A recent example of the value of the combined use of these two ICT tools in a data-poor small scale fishery context is given by Tilley et al. (2020). Tilley and colleagues introduce a near-real-time, open-source monitoring and analytics system called "PeskAAS" for small-scale fisheries. In particular, this application goes beyond simply facilitating data collection and allows for the integration of data collection with the data analysis and visualization of data summaries for managers and fishers. The system is an interactive web-hosted R Shiny application that can access a database in real-time using several R packages. It allows bringing catch data recorded at landing sites into a web-based user-friendly interactive R session, where users can create informative summary plots of the data. The application is hosted remotely, but there are also ways to implement it locally if needed. Importantly, the application is scalable for different levels of usage with modest subscriptions fees. In their case study, fishery catch data are obtained by data collectors at the landing sites using 3G-enabled tablets hosting a digital survey form developed in KoBo toolbox, which is a free suite of tools for field data (https://www.kobotoolbox.org/). The authors also developed the cloud-based MySQL database and R script to access the data, which are all open-source. Additional details about the application and its components are given in Tilley et al. (2020).

Moreover, the authors combined the use of the PeskAAS application with a VTS via the installation of tamperproof solar-powered GPS units on a sample of boats per landing site. These GPS units recorded point location data every 5 seconds and communicated those data to the cellular network. Importantly, by linking catch data with GPS tracks for individual fishing trips, the system can be used to train models to predict unknown variables such as gear and habitat type for trips with GPS data only. A diagrammatic illustration of the end-to-end integration of the data cycle is given in Fig 5.

In a related study, Tilley et al. (2019) used the PeskAAS application and framework to monitor and compare catches rates of aFAD and non-aFAD fishing trips in Timor-Leste. With these data in hand, they were able to demonstrate the aFAD fishing led to higher catch rates and that aFADs could pay for themselves after only five months of fishing (Tilley et al. 2019).

FIGURE 5.
Diagrammatic representation of the PeskAAS application. From bottom to left, catch data from a vessel are entered into a KoboCollect survey form on a smartphone. These data are uploaded into the KoboToolbox database. An R script (PeskaPARSE.R) pulls brings these data along with the vessel's movement data obtained by the GPS unit (PDS: Pelagic Data Systems Inc.) in the vessel. These data are then checked and filtered and uploaded into a database (PeskaDAT). The PeskAAS application can then be used to query the database and provide near-real-time graphics and analytics.

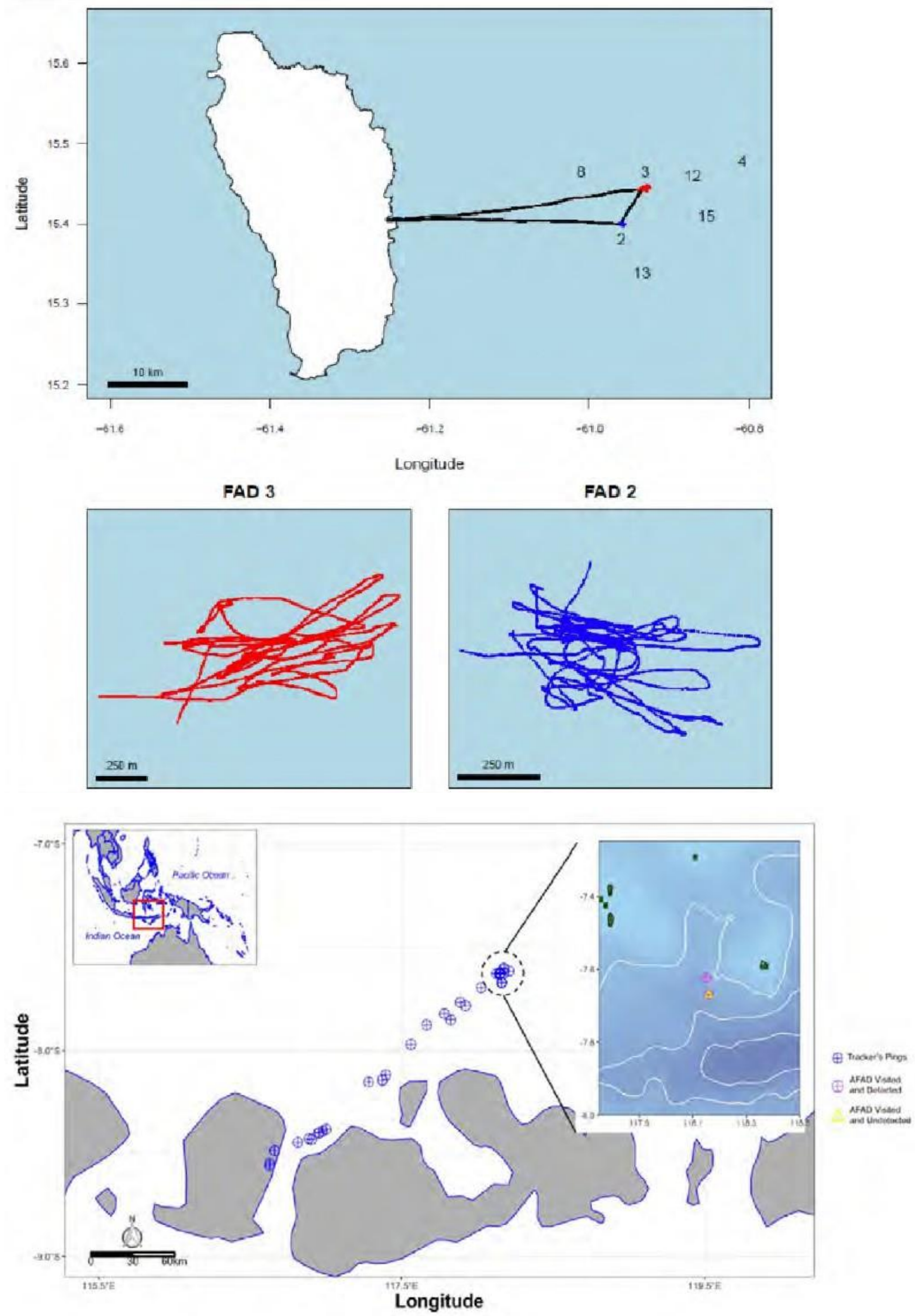


It is important to note that the fixed location of aFADs renders them particularly amenable to monitoring via VTS. Indeed, VTS use could lead to better estimates of the number and location of aFADs that are being exploited by fishers at any given time thus better informing current aFAD capacity; it could also lead to better estimates of the time that individual vessels spend fishing on these units thus better informing CPUE analyses. In Dominica, Alvard et al. (2015b) and Alvard et al. (2015a) used light and small waterproof GPS units that could be easily accommodated into aFAD fishing vessels to document their tracks at 1-s intervals. They were able to identify specific spatial patterns in the tracks and vessel speeds (e.g. area restricted search) that coincided with the location of aFADs (Fig 6 top panel); more refined analysis allowed them to even distinguish between fishing techniques (fishing for bait versus dropline fishing). Similarly, and more recently, Widyatmoko et al. (2021) also used small GPS units to track vessel movements in Indonesia and identify features of vessel movement that were associated with aFADs (Fig 6 bottom panel). In so doing, they were able to provide a minimal estimate of number and location of aFADs; they also confirmed that aFAD deployment was not in compliance with local regulations. In that regard, an interesting feature of Tilley et al. (2020)'s GPS units (manufactured by Pelagic Data System Inc.) is that they are solar-powered and cannot be turned off nor can they be tampered with, thus positional data cannot be falsified again adding additional credibility to the information collected. All the above studies make use of low-cost and/or publicly available technologies.

Finally, the use of ICT tools for fisheries monitoring seems to be organically gaining ground in the insular Caribbean. Dominica is leading the way by currently using an electronic data collection system based on the KoboToolbox with data collectors using tablets at the landing sites and the data being automatically uploaded into a database. The fishery officers of Dominica are also developing their own R scripts to generate fishery reports (J. Defoe, D. Theopille, and K. Hilton, pers. com.). On the other hand, both Montserrat and Barbados are currently experimenting with VTS technology for artisanal fisheries with positive buy-in from fishers (A. Ponteen, pers. com; S-A Cox, pers. com). It thus seems a pivotal time to support the development of electronic data collection systems and VTS to support fisheries data statistic systems across the region; if developed with a good understanding of local context and if supported by decision-makers as relates securing support for system development, they have the potential to mediate a transformational change in fisheries monitoring and management in the region over a range of scales (local, national, and regional).

FIGURE 6.

Tracks of aFAD fishing vessels in Dominica (top panel) and Indonesia (bottom panel) obtained using low-cost small-sized GPS technology. These tracks can be analyzed using publicly available applications to identity aFADs. For more details, see Alvard et al. (2015b) and Widyatmoko et al. (2021).



3. Additional measures towards improving fishery monitoring systems

3.1 Ensuring collection of biological data to supplement catch and effort data

In addition to the collection of catch and effort data on aFADs, it is recognized that detailed biological data on the main target species or on species of special interest should be collected, as proposed under the DCRF Task IV. Such data should ideally include individual fish weight, length, and maturity stage (see also Data Sharing and Integration section). Such data are crucial to inform about gear size selectivity, natural and fishing mortality rates and fish condition and reproductive status; these types of data are an integral requirement towards well informed stock assessment models. Here, the data collection process could again be facilitated using electronic forms that automatically transfer the data to a central database and data collected should align at a minimum with Module 5 of the WECAFC logbook (Appendix I). The more time-consuming nature of this sampling will mean that it will necessarily take place at a lower frequency than that of the catch and effort data and might involve selected species and also required carefully designed sampling activities to ensure a minimum level of observations. However, efforts should be made to ensure that the biological sampling scheme captures with sufficient accuracy and precision the overall population structure in the catches of the selected species and its potential variability in space and time.

3.2 Improving sampling and data collection

A recent survey of key informants across 20 territories/countries with significant aFAD fisheries in the WECAFC region indicated that three quarter of these countries/territories were engaged in systematic fishery data collection involving aFADs (Vallès in prep.). Most of these countries/territories engaged in random (or haphazard) sampling of fishing trips. Only two out of 14 countries/territories indicated that the fishers themselves participated in data collection, further highlighting (a) the challenge of sharing the responsibility of data collection with fishers and (b) the need for enhanced awareness within the fisher group as to importance of this information towards ensuring long term sustainability of the resources.

The combination of Vessel Tracking Systems and electronic data collection systems could, on the one hand, help optimize sampling schemes by helping identify appropriate sampling strata based on vessel positioning at sea. On the other hand, it could further incentivize fishers to partake in the filling of electronic logbooks if the time required to do so is now drastically reduced and their data kept confidential but processed and returned to them frequently (or even in near-real time). A better delineation of sampling strata based on vessel activities at sea along with increased sampling of these strata via increased data collection by fishers will yield more precise and accurate catch and effort metrics and a more efficient use of limited human resources.

3.3 Ensuring data validation

The catch and effort and biological data collected will be used to inform management decisions, it is thus critical that these data are reliable and accurate and collected using robust statistical procedures. Confirming and ensuring data accuracy will require developing practical/feasible and cost effective mechanisms for independent data validation and a plan for their implementation.

The use of mobile apps for data collection could considerably help reduce incorrect data records via the use of dropdown lists for species, gears, fishing locations and other relevant variables. However, it would still be necessary to conduct regular data range checks to ensure that the values provided fall within the expected range of values and identify outliers and abnormal observations. Historical data and published reports could be used to inform the expected range of values for several variables (e.g. species-specific fish weights or lengths). It will also be very important to ensure adequate training and support of data collectors and fishers in the use of the data entry forms.

Moreover, to the extent that it is possible, it would be highly advisable to develop independent monitoring systems that capture supplemental data to be cross-checked with the catch and/or effort data for consistency. This could include periodically obtaining information on fish volume sales from those who regularly purchase fish at the landing sites. It could also include conducting surveys in local fish markets to enquire about variability in the supply of selected species as well as telephone surveys of registered/licensed fishers selected randomly from different fisher groups (sampling strata) to enquire about their recent fishing activity. These additional data sources could thus be used to identify potential sampling biases and/or gaps in the primary catch and effort data collection process so that they can be rectified or accounted for. If Vessel Tracking Systems are being used by fishers, these could be used to validate the reporting of fishing activity and fishing locations and individual aFADs. If fishers are completing and providing logbooks, it will be necessary to periodically deploy observers at landing sites who could randomly sample fishing trips of self-reporting fishers to contrast the data provided in their logbooks with the actual landings. The exact mechanisms that can be put in place for data validation will obviously depend on the local context and available resources and should be formalized and integrated into a fisheries data validation plan. Such plan should be an integral part of the fishery data collection system.

3.4 Implementing an aFAD registration and monitoring system

In line with Mohammed (2015)'s recommendations, it is critical that countries implement an official aFAD registration system that collects information on aFAD ownership, deployment depth and location, design and materials, and unit cost, and assigns a unique registration number to each new aFAD deployed. This number could then act as aFAD identifier in the field. To the extent that it is practically possible, national/local aFAD identifier systems should align with Voluntary Guidelines on the Marking of Fishing Gear (FAO 2019) and be harmonized across the region. This registration system should also be regularly updated with information about aFAD losses so that estimates of aFAD numbers at any given time are accurate. The requirement to register new aFADs and report aFAD losses should be supported with legislation. The implementation of such a registration system would further align with ICCATs 19-02 Rec. concerning the requirement to report aFAD deployment as well as aFAD losses. If adequately legislated, this system could be used to control the total number of aFADs deployed at any given time and their location. It could also help monitor and enforce potential regulations on the types of materials used for aFAD construction such as prohibiting the use of entangling materials (see Annex 5 of ICCAT 19-02 Rec). Accurate estimates of aFAD numbers in territorial waters is likely to be key to help manage the aFAD fishery at local and regional scales (see section on Improving assessment of fishing impacts of aFAD on the ecosystem and stocks). Moreover, given the decreasing cost of electronic instruments that can provide valuable data on environmental conditions (e.g. thermometers) and location (GPS units) (see Section on aFADs as fishery-independent research tools), under some circumstances it might be possible to make it mandatory for such instruments to be fitted into newly deployed aFADs as part of the registration and licensing process.

Again, low-cost ICT tools could be used to dramatically speed up the aFAD reporting and approval process via reporting/application forms supported by mobile devices. Moreover, other ICT tools such as freely available Geographic Information Systems (e.g. QGIS; http://www.qgiscloud.com) could be integrated with this registration system to identify most suitable areas for aFAD deployment and facilitate marine spatial planning. Such a system would also allow for data-driven assessments of aFAD lifespan and the factors that might influence it. Importantly, data from the registration system could be easily contrasted with fishery vessel tracks obtained via VTS and/or with aerial surveys of aFADs (Guyader et al. 2017) to identify illegal aFADs and so facilitate enforcement in near-real-time.

3.5 Implementing a licensing system

It will also be critical that countries implement an aFAD licensing system that integrates and distinguishes among all types of fishing on aFADs (subsistence, commercial, recreational, charter). This license system should also be legislated. The granting of aFAD fishing licenses should be made conditional on the users' history of compliance with rules and regulations governing aFAD use. As Mohammed (2015) rightly points out, such system could be used to not only to control access to the aFAD fishery, but also provide valuable socio-economic and demographic data on the aFAD users themselves, thus facilitating further assessment of the socio-economic impact of the fishery and potentially helping project trends. Low-cost ICT tools could again be used to acquire, store, and manage the data for this licensing system, with the added value that this should facilitate integration of different electronic databases such as the aFAD registration and aFAD licensing databases if needed, given that many aFAD owners are also likely to be aFAD fishers. The latter should provide a more nuanced description of the socio-economic dimension of the aFAD fishery.

3.6 Measuring data sharing and integration across the region

The use of the same standardized catch and effort data form, minimally adjusted to reflect the fishery context of each location (e.g. main target species, fishing gears, fishing locations), should allow for an effective and efficient integration of data across countries/territories, which is an important step towards improving the management of shared exploited stocks (CRFM 2015). A lack of consistent technical support for specialized fisheries statistics software has been in the past a major hurdle to data integration within the region (Barnwell 2014; CRFM 2014). This hurdle can now be overcome given the present information technology tools readily available for free or at affordable prices, including user-friendly field data collection and database systems such the KoBo toolbox (https://www.kobotoolbox.org/), open-source data analytical tools such as the R environment, and the widespread use of mobile smart technology across the region. With adequate initial training, the unlimited access to these tools and technology should facilitate building up the necessary local technical capacity to maintain these data systems across countries/territories with minimum external expert input.

It is important to recognize that in spite of the potential of ICT to facilitate the development and implementation of fishery data collection systems, countries will still differ in their capacities to do so. This was explicitly recognized by the original CRFM/JICA (2012) study, which had at the time proposed a Plan for data integration with short (1-3 years), medium (3-5 years) and long (5-10 years) term goals for the different groups of countries, with all countries improving their respective capabilities over time (Table 5). Expected short-term outcomes in Group C countries included the timely provision, storage, processing and reporting of data suitable to describe landings. Medium-term outcomes for these countries included, in addition to the short-term ones, the provision of biological data capable of informing management and the development and use of a fishery database. Long-term outcomes for these countries included, in addition to the medium-term ones, the provision of data suitable for stock assessments and the provision of socio-economic data for the fishery along with the integration of the fishery database with other statistical sources. Countries in the B and A groups were expected to reach these outcomes over shorter time frames and subsequently continue to improve in data capabilities in the long-term as well as to contribute with data to regional assessments and management. This staggered approach provides a useful framework to facilitate the integration of such countries and should also be adopted here. Further, it is recommended that performance be evaluated at some reasonable frequency towards determining success in making these improvements in data collection and in identifying where further training or interventions are needed in particular areas.

TABLE 5 – Excerpt from CRFM/JICA (2012) showing the proposed integration of fishery statistic systems over time across countries with markedly different monitoring capacities.

Data item	Term	Short Term			Medium Term			Long Term		
	Group	A	B	C	A	B	C	A	B	C
FISHING VESSEL AND LICENSE INFORMATION										
Vessel count				•	•					
Vessel registration		•	•		•	•	•	•	•	•
Vessel inspection status		•	✧		•	•	•	•	•	•
Issues on vessel registration		•	•		•	•	•	•	•	•
Fishing License data		•	✧		•	•	•	•	•	•
Issues on fishing license registration		•	✧		•	•	•	•	•	•
FISH CATCH AND LANDING DATA										
Estimated landing data		•	•	•	•	•	•	•	•	•
CPUE per gear and vessel type (0-9%)*1				•						
CPUE per gear and vessel type (10-30%)*1			•				•			•
CPUE per gear and vessel type (50%-)*1		•			•	•		•	•	
BIOLOGICAL FISHERY DATA										
Detailed biological data for target species *2		•	•	✧	•	•	•	•	•	•
Simplified biological data for target species *3		•	•	•	•	•	•	•	•	•
Analyzed data for fishery resource management *4		•	•		•	•	•	•	•	•
Analyzed data for stock assessment and fishery development *5		•			•	•		•	•	•
FISHERY STATISTIC REPORT										
Updated stratification of landing sites		•	•	•	•	•	•	•	•	•
Fishery statistical data sampling program *6		•	•	•	•	•	•	•	•	•
Fishery statistic annual report		•	•	•	•	•	•	•	•	•
Regional fishery data report					•	✧		•	•	✧

*1 Rate of sample size is "number of samples"/ "number of maximum possible samples" per gear and vessel type.

*2 The detailed biological collected data include fish weight, length, gonad weight, maturity, and so on. This data will be collected for the target species for at least a year, in order to optimize and simplify the biological fishery data collection.

*3 The simplified biological collected data include, for each target species, only landed total weight, number of fish, maximum fish size, and minimum fish size.

*4 Data analysis for the fishery resource management results in determination of restricted period for the target species, restricted fishing gear mesh size, and so on.

*5 Data analysis for the stock assessment and fishery development results in determination of trends and projection of the available fishery resources, development plan for fishery and aquaculture in fishery and aquaculture in fishery communities, and so on.

*6 The sampling program includes data sampling method, data sampling coverage, case of sampling schedule, implementation structure from the sampling, fishery data management method, estimation method for landings (CPUE raising factor and estimation formula) and effect on fishery statistical data, fisheries resource management, and fishery and aquaculture development.

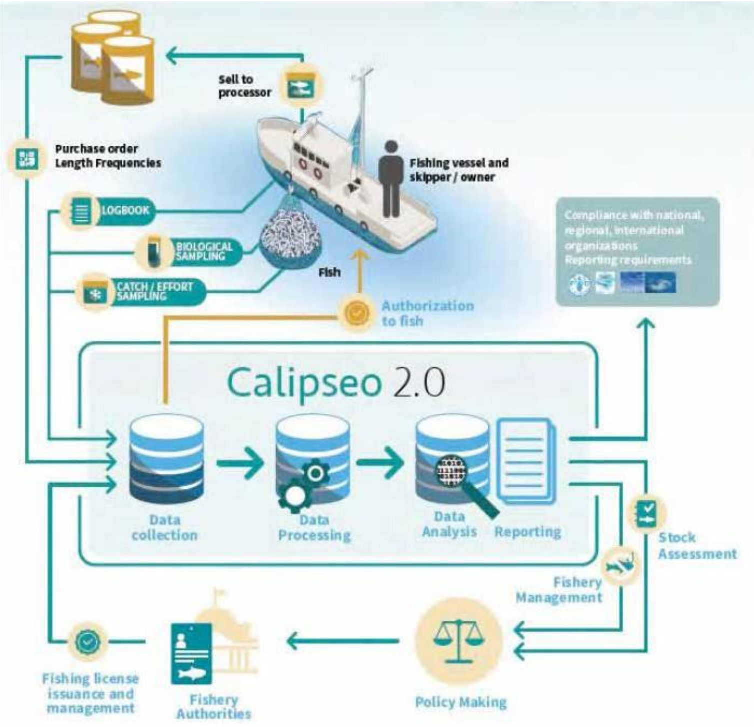
3.7 Integrating the Calipseo Information System to improve fishery data collection and reporting along the data supply chain

The Calipseo Information System[3] recently implemented by FAO-NFSI currently provides a comprehensive ICT framework to integrate and streamline national fisheries data along the entire data supply chain, including data collection, reporting in support of national fishery policies, stock assessments and reporting obligations to regional fishery bodies and FAO (Fig 7). It is a modular web-based application with open-source frameworks aimed at facilitating data management and at ensuring information flow at the national level. It also implements standard data exchange mechanisms and can be connected to mobile applications for data collection.

Its scalable form recognizes that countries will differ in their needs and capacities and so its modules can thus be deployed independently to accommodate a given country's needs. These modules include reference data aligned with international standards, data collection capabilities (e.g. catch and effort and biological sampling), management of administrative data (e.g. registries, licenses), secured data storage, data processing, data exchange and reporting (at national, regional and international levels) and a mobile data collection capabilities. This system thus provides a timely opportunity to facilitate the recommended integration of ICT previously outlined in this document across the different dimensions of the aFAD fishery.

Efforts to integrate Calipseo into national fishery statistic systems are already underway in the Caribbean. For example, Dominica is currently in the process of deploying the Calipseo platform with integration of their Kobo toolbox data system and Calipseo is also being increasingly deployed in Trinidad and Tobago, Suriname, Grenada, Guyana and St Lucia.

FIGURE 7.
Schematic representation of the Calipseo Information System and its fishery data management capabilities



3. https://www.fao.org/fishery/en/statistics/software/calipseo

4. Improving assessment of fishing impact of aFADs on the ecosystem and stocks

4.1 Anchored FADs as fishery-independent research tools

Moreno et al. (2016b) make a case for the need of fishery-independent methods to help assess the status of target stocks, given the variable quality of official catch and effort data and the frequent lack of standardization of collection and reporting of such fishery-dependent data. This is also particularly relevant for tropical tunas given the increases in fishing efficiency driven by technological advances in the purse seine fisheries that bring into question the value of CPUE as an index of relative abundance of their stocks (Fonteneau et al. 1999; Fonteneau et al. 2013). From an ecosystem-based fishery management perspective (Pikitch et al. 2004), fishery-independent methods are also necessary to assess the status of by-catch species, for which fewer fishery-dependent data exist and which are rarely the focus of stock assessments.

Currently, most industrial purse-seine fishing operations using drifting FADs to capture tropical tuna currently make use of echosounder buoys on the FADs that provide crude estimates of FAD-associated tuna biomass and transmit those estimates via satellite communications to the fishers (Lopez et al. 2014; Lopez et al. 2016). These echo-sounder buoys can establish remote continuous communications with fishing fleets and receive communications from fleets to change their settings (Ehrhardt et al. 2017a). Moreover, they can incorporate multi-frequency transducers that allow for increasingly better capacity to discriminate among tuna species and sizes (Moreno et al. 2016a; Moreno et al. 2019). These technological advancements, which have led to increases in fishing efficiency and changes in fishing strategies in the purse-seine fishery making use of drifting FADs (Lopez et al. 2014), could also be used to generate fishery-independent indices of aggregated abundance on FADs to supplement fishery-dependent ones.

In that regard, Moreno et al. (2016b) and Ehrhardt et al. (2017a) highlight the great potential of FADs as windows of scientific observation into the animal communities (fish and sea birds, mammals, and turtles) that associate with them, as sampling tools of species composition and abundance, as passage points that inform on animal distribution and movement and as sensors of the physical environment in which these animals are found. Indeed, in addition to low-cost satellite-linked echosounders, individual FADs can be equipped with various low-cost electronic tools such as under-water cameras, acoustic receivers and hydrophones that provide diverse and increasingly detailed information about animal communities and physical environment surrounding them (Table 6). Acoustic receivers on FADs can be used to detect the presence of individual fish tagged with electronic transmitters as well as download any data collected by the transmitters themselves before the tagged fish encountered the FAD (archival tags; CHAT tags), thus providing valuable information about the movement, behavior and environmental preferences of selected species (Table 6; Fig 8) (Voegeli et al. 2001; Moreno et al. 2016b; Ehrhardt et al. 2017a). Under-water cameras can provide valuable information about the diversity and aggregated abundance of the species that are not typically detected by echo-sounders, some of which might constitute important by-catch (e.g. sharks) (Table 6; Fig 8) (Moreno et al. 2016b).

Equipping aFADs with electronic instruments to conduct fisheries and biological research is increasing in the Caribbean (Merten et al. 2018; Schneider et al. 2021), whereas oceanographic data buoys are currently being used as aFADs by some fishers (Silva et al. 2018), highlighting the dual role that aFADs can play. With current estimates of 3 500+ aFADs in the WECAFC region (Wilson et al. 2020), there is great potential to expand the spatiotemporal coverage of fishery-independent data collection by equipping strategically located aFADs with such instruments and in combination with fish tagging programs. This could increase the ability to identify the drivers of the abundance of target and non-target species over a range of relevant spatiotemporal scales to supplement fishery-dependent data (e.g. Orúe et al. 2020). This knowledge expansion could be facilitated by collaborations between aFAD fishers, fisheries departments and researchers, with the fishers themselves benefitting from the same data to identify when and where to fish and so maximize fishing efficiency and minimize fuel costs. In the case of private aFADs, this would likely require data sharing agreements that protect the fishing strategies of the fishers (Dagorn et al. 2013). In addition to aFADs, which have a very clustered distribution in the region (Wilson et al. 2020), equipping selected oceanographic data buoys and oil rig platforms, which also aggregate fish (Franks 2000; Silva et al. 2018), would help expand the spatial coverage of the monitoring network beyond the insular Caribbean (Fig 9).

TABLE 6 – Types of electronic instruments that can be integrated into MFADs along with the types of data that can provide, whether they are operational or developed but need testing, and the target users (fishers; scientists). Adapted from Moreno et al. (2016b)

Data	Type of instruments	Operational	Developed but need testing for this specific application	Fishers	Scientists
Species	Underwater cameras		X	X	X
Identification	Multi-frequency echo-sounders for tunas	X		X	X
Species	Underwater cameras for sharks		X	X	X
Abundance	Echo-sounders	X		X	X
Species association time and movements	Acoustic receivers	X			X
Biology & behaviour	Coded acoustic tags	X			X
	CHAT tags		X		
Biological environment	Echo-sounders	X			X

FIGURE 8.
Schematic representation of an aFAD buoy equipped with hydrophones, echosounders and underwater cameras recording information on (tagged and non-tagged) fish aggregated under the aFAD and transmitting that information via satellite. Adapted from Moreno et al. (2016b)

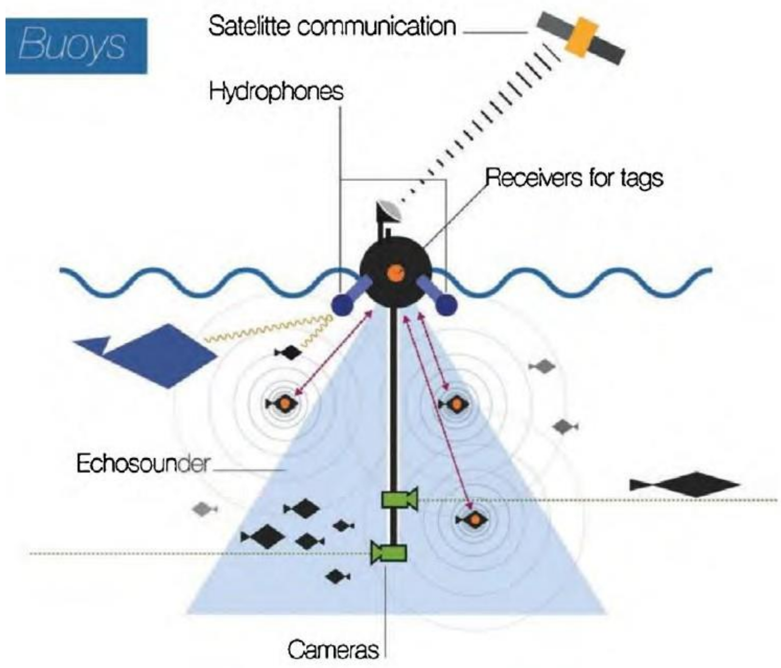
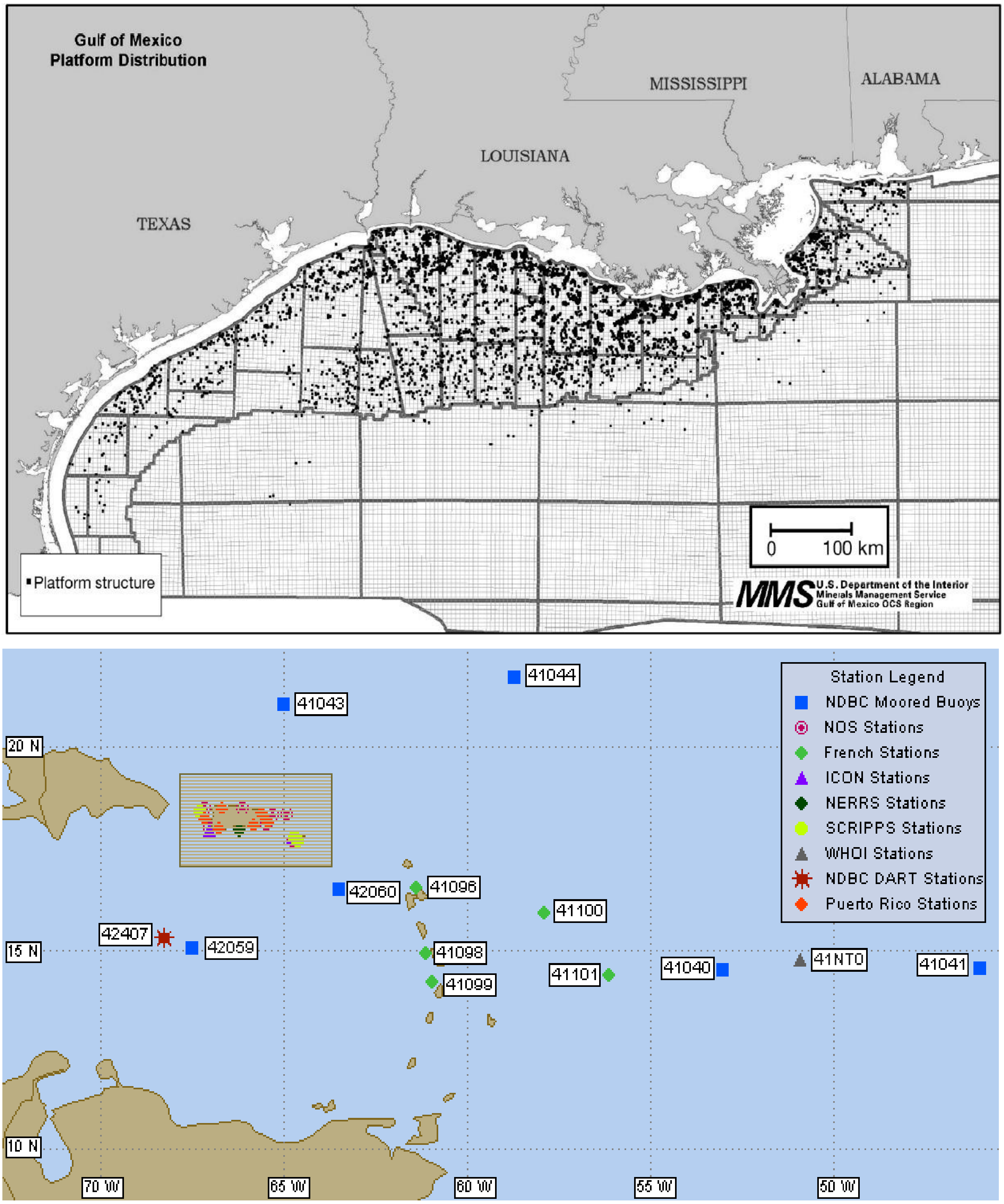


Figure 8. Schematic representation of an aFAD buoy equipped with hydrophones, echosounders and underwater camera

FIGURE 9.
Location of oil rigs in the Gulf of Mexico in 2004 (top panel) and location of oceanographic data buoys in a section of the Caribbean. Selected oil rigs and data buoys could also be equipped with technology helping identify and quantify fish aggregating under them for research. Data are from Sammarco et al. (2004) (top panel) and the National Data Buoy Center (https://www.ndbc.noaa.gov/) (bottom panel).



4.2 Addressing hyperstability on aFADs using fishery-independent data

A well-recognized challenge when assessing status of exploited stocks that associate with FADs is that catch-per-unit-effort (CPUE) might not be a reliable index of total population abundance because FADs might still attract and thus continue to facilitate the catch of, stable numbers of individuals even though total population abundance might be quickly declining under over-exploitation (Ehrhardt et al. 2017a). This decoupling between CPUE and total population abundance is known as hyperstability and manifests itself in those species that are exploited while they aggregate (e.g. spawning aggregations; Erisman et al. 2011). Ehrhardt et al. (2017a) indicated that, in the context of FAD fisheries, the problem of hyperstability remained unresolved and so highlighted the need to the develop fishery-independent estimates of abundance to inform fishery-dependent ones, yet such fishery-independent estimates are particularly difficult to obtain for tropical tunas (Moreno et al. 2016b).

In this regard, Capello et al. (2016) recently offered an innovative and promising solution that would require measuring the residence and absence time around aFADs of a subset of individuals of the population, which can be done using electronic tagging telemetry. These estimates are used to derive an association index representing the proportion of the local population (i.e. the subpopulation in proximity to the array of aFADs) that is found on aFADs. If actual abundance is also estimated at one of the aFADs, which could be done using echosounder technology (Lopez et al. 2016; Santiago et al. 2017; Santiago et al. 2020), the association index can be readily converted into an index of abundance. They empirically validated several assumptions underlying their approach with yellowfin tagging data from an array of aFADs in Hawaii (Capello et al. 2016). The authors highlighted that, by expanding tagging studies on selected species and the spatiotemporal network of observational aFADs, their approach had the potential to scale up over wider regions and so yield fishery-independent estimates of abundance for potentially both target and non-target species that would complement fishery-dependent ones at meaningful scales for regional management. Here, as Moreno et al. (2016b) point out, maximizing aFAD observational coverage through technology and estimating aFAD densities with precision (rather than controlling aFAD numbers) is key because the abundance index will depend on the number aFADs in the study system; this will undoubtedly necessitate ambitious regional research programs built upon the cooperation among fishers, researchers and relevant fisheries authorities at local, national, sub-regional and regional scales.

5. Summary

Anchored FAD fisheries across the insular Caribbean region are steadily growing, providing new economic opportunities to small-scale fishers. However, they are growing in a relatively unregulated and data-deficient environment, raising concerns about the long-term sustainability of these fisheries. Several fish stocks of large pelagic species that are currently targeted by these fisheries are considered overexploited, warranting the urgent need to improve the management of these fisheries at local, national and regional scales.

Improved management cannot be achieved without improving the national fishery data systems across the region to adequately inform stock assessments at appropriate scales. The capacity of countries with aFAD fisheries in the region to implement fishery data systems has tangibly improved over the last two decades, but there remain important deficiencies that limit critical data collection and preclude effective data sharing in all aspects of these fisheries and which have historically been difficult to overcome.

That said, the recent development of low-cost ICT tools and frameworks to support fishery data systems now provides an unprecedented opportunity to overcome historical hurdles and bring transformative change to the fishery data supply chain at local, national and regional scales. As such, several measures are here recommended to guide the process of ICT integration within local and national fishery data systems. These are summarized in Fig 10 and include:

1. Minimally amending the CRFM logbook data requirements to maximize consistency with those data requirements that are mandatory in WECAFC logbook. This will ensure standardization of these data and compliance with the WECAFC DCRF guidelines, which will maximize the potential for regional integration with the WECAFC regional database (WECAFCIS), while still addressing local data needs. This process should be overseen by the FDS-WG.

2. Aligning, to the extent that it is possible, national minimum catch and effort data requirements with those of the amended CRFM logbook, or alternatively, with those of the modular WECAFC logbook, to facilitate integration through the regional database.

3. Aligning additional national fishery data requirements with those proposed under the different tasks of the WECAFC DCRF to facilitate integration through the regional database (WECAFIS), including the collection of biological data.

4. Assessing the extent to which fishing trip data (catch and effort data, biological data, revenue and cost data) can be collected using a fisher logbook system versus a data collection system based on dedicated independent data collectors, which will undoubtedly depend on local context; the use of logbooks is likely not to be feasible in many locations at this time and even in those locations where it is implemented, it will require independent validation, highlighting that dedicated independent data collectors will remain a key component of any monitoring system.

5 Adopting the use of low-cost mobile apps connected to national databases to facilitate data collection, processing, and reporting across the different dimensions of the fishery, including administrative data (aFAD registry, aFAD fisher licensing), catch and effort and biological data and socio-economic data. Such adoption could strongly incentivize stakeholder (e.g. fisher) participation into the data supply chain by shortening the length of the data collection process itself while potentially providing valuable personalized data summary reports in useful time frames. In this regard, the experience of Dominica should be shared across the region.

6 Adopting a comprehensive ITC framework that can automatically integrate the different data types (and corresponding central databases) to provide a comprehensive view of the fishery, facilitate data cross-validation and efficiently generate data reports at all levels, including personalized fisher reports, reports for national policy making, reports for stock assessments and reports to meet obligations with regional fishery bodies (e.g. ICCAT) and FAO. The Calipseo Information System currently adopted by several Caribbean countries already offers such framework. The scalability and modularity of Calipseo can ensure that it addresses the specific needs and context of any given country and as such the experience of countries currently adopting this system (e.g. Dominica, St Lucia) should be shared across the region.

7 Integrating the use of low-cost Vessel Tracking Systems (VTS) for small boats to improve monitoring, control and surveillance. The experience of Barbados and Montserrat with these systems should be shared across the region.

8 Strengthening the local ITC and statistical capacity of countries, as appropriate and to the extent that it is possible, acknowledging that implementation of these ICT systems, even at the most basic level, will yield good returns on investment by making more efficient use of the available human and technical resources.

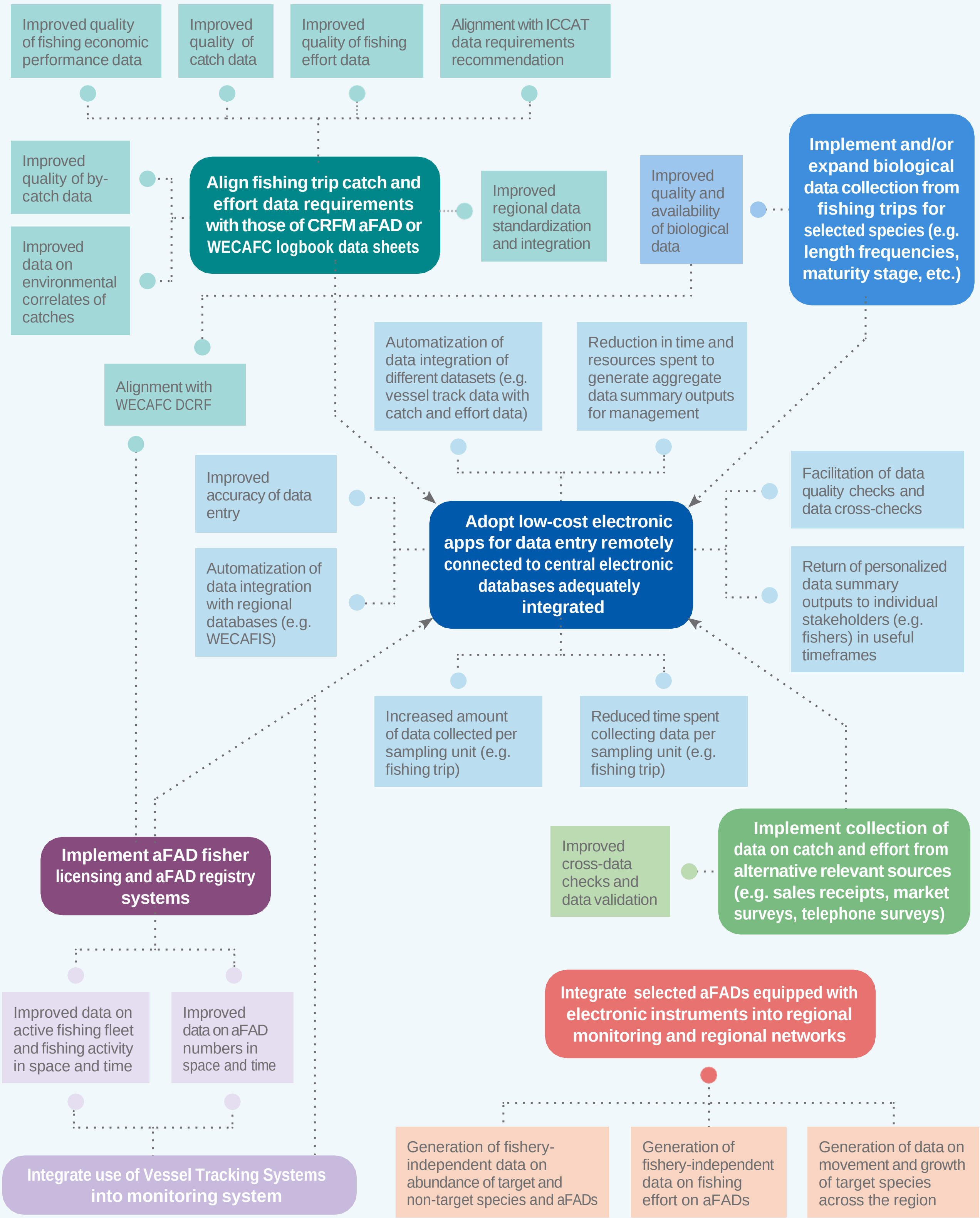
9 Developing data sharing agreements among the key stakeholders providing data at the different levels (local, national, regional) of the data supply chain.

10 Increased integration of ICT systems (measures 4-7) into the fishery data system should ultimately aim to facilitate:

- a Regular collection of biological data to supplement catch and effort data
- b Expansion of sampling coverage of both catch and effort and biological data
- c Implementation of fishing trip data validation plans
- d Implementation of aFAD registration and licensing systems
- e Data sharing at the local, national, and regional levels

11 Strengthening local research capacity to facilitate participation in regional research programs using aFADs as networks of observatories to generate critical fishery-independent data on target and non-target species.

FIGURE 10.
Links between the different actions (represented by different colors) recommended by this guide (rectangles) and associated expected outcomes (polygons). It is proposed that adequate implementation of all these actions (and any improvement of outcome) can be achieved by carefully integrating low-cost Information and Communication Technology (ICT) tools such as tailored-made mobile apps for data entry and electronic databases within and across the different components of the fishery data collection and monitoring, control, and surveillance (MCS) systems. Note that the grey component here represents a different aspect of the system aimed yielding fishery-independent data to supplement fishery-dependent data to help improve regional assessments of the state of both target and non-target species on aFADs.



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7. Appendix I – Non mandatory data requirements of the WECAFC logbook

Module 4 – Daily Fishing Activity
One page per set or haul
need to refer to the above trip description: trip #.... (from section 1)

SECTION 4.1: summary catch and effort data per day

Day: DD / MM / YYYY

Time spent fishing this day:

Gear 1 : ☐ gillnet ☐ Seine ☐ Cast net
☐ Long lines ☐ Hook & lines ☐ Traps
Soaked Time .... h

Gear 2 : ☐ gillnet ☐ Seine ☐ Cast net
☐ Long lines ☐ Hook & lines ☐ Traps
Soaked Time .... h

Target Species	Quantity *[Unit]*	Discards
Crawfish (*Panulirus argus*)		
Conch (*Strombus gigas*)		
Nassau Grouper (*Epinephelus striatus*)		
Barracuda (*Sphyraena spp.*)		
Wahoo (*Acanthocybium solandri*)		
Mahi Mahi (*Coryphaena hippurus*)		
...		

SECTION 4.2: catch and effort data per day / per fishing activity

SECTION 4.2.1: Line Set information

Line Set number:

Start line set: date: DD/MM/YYYY / time : – Coordinate at start: Longitude / Latitude

End line set: date: DD/MM/YYYY / time: : – Coordinate at end: Longitude / Latitude

Start line haul: date: DD/MM/YYYY / time : – Coordinate at start: Longitude / Latitude

End line haul: date: DD/MM/YYYY / time: : – Coordinate at end: Longitude / Latitude

Area fished: *(please refer to the area(s) defined in the manual section)*

No of hooks: .... – Hook type: .... – Hook size: .... – Hook Offset: ....

Line material: .... – Line diameter: .... *[unit]*

Fishing Depth: Start: .... *[unit]* / End: .... *[unit]*

Use of baits: ☐Yes ☐No
Type of baits used
Artificial ☐Yes ☐No
If Natural: species: .... / ... quantity .... *[unit]*
.... / ... quantity .... *[unit]*
.... / ... quantity .... *[unit]*
.... / ... quantity .... *[unit]*

SECTION 4.2.2: Catch data

☐ Unsuccessful event/set (no fish caught)

Target Species	Quantity *[Unit]*	Discards
Crawfish (*Panulirus argus*)		
Conch (*Strombus gigas*)		
Nassau Grouper (*Epinephelus striatus*)		
Barracuda (*Sphyraena spp.*)		
Wahoo (*Acanthocybium solandri*)		
Mahi Mahi (*Coryphaena hippurus*)		
...		
...		

SECTION 4.2.3: FAD use

Position (coordinates): ......lat / long...........

FAD number when available: ....

FAD type: ☐ drifting natural FAD ☐ drifting artificial FAD

FAD design characteristics:

Dimension: ....*[unit]*

material used in the floating part: ....

material used in the underwater hanging structure: ....

Type of the activity: ☐ set ☐ deployment ☐ hauling ☐ retrieving ☐ loss ☐ intervention on electronic equipment ☐ other: ....

SECTION 4.2.3: Environmental parameters

Sea Surface temperature: ......° [unit]

To be discussed: Other?

MODULE 5– Biological data

SECTION 5.1– landed species size DISTRIBUTION

Section 5.1

Total catch: ....[unit].........

Sample selection method: ....

Sample weight ...[unit]

Species*	Size Class	Number	location
Nassau Grouper	Size class 1 (a from b *[unit]*)		
	Size class 2 (b from c *[unit]*)		
	...		
	Size class n (y from z *[unit]*)		
...			

* See Manual for species list

Section 5.2: By-catch data

By-catch Species*	Quantity *[Unit]*	Discards	Condition when discarded	Location
...				
...				

* See Manual for species list

Module 6 – Trip cost

Type of fuel	☐ Diesel	☐ Gas	other:
Cost of fuel:	*[currency]*	Cost of oil:	*[currency]*
Quantity of fuel:	*[unit]*	Quantity of oil:	*[unit]*
Bait cost:	*[currency]*		
Food cost:	*[currency]*		
Ice cost:	*[currency]*		
Other expenses cost:	*[currency]*		
Total trip revenue:	*[currency]*		

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