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Review of the state and challenges of the Moored Fish Aggregating Device (MFAD) Fishery in the WECAFC region

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Working document

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Contents

Abbreviations and acronyms

CARIFICO	Caribbean Fisheries Co-management Project
CFMC	Caribbean Fisheries Management Council
CLME	Caribbean Large Marine Ecosystem project
CRFM	Caribbean Regional Fisheries Mechanism
DFAD	Drifting Fish Aggregating Device
ERA	Ecological Risk Analysis
FAO	Food and Agriculture Organization
ICCAT	The International Commission for the Conservation of Atlantic Tunas
IFREMER	French Research Institute for Exploration of the Sea
JICA	Japan International Cooperation Agency
MAGDELESA	Moored fish Aggregating Devices in the Lesser Antilles project
MFAD	Moored Fish Aggregating Device
NAFCOOP	National Association of Fisherfolk Cooperatives
OSPESCA	Central America Fisheries and Aquaculture Organization
SAP	Strategic Action Plan
WECAFC	Western Central Atlantic Fishery Commission

1. Preface

This document presents a review of the current state and challenges of the MFAD fishery across the WECAFC region to support the development of the Caribbean Regional Management Plan for the Moored Fish Aggregating Device (MFAD) Fishery, following the Recommendation of the 3rd meeting of the WECAFC ad hoc Joint Working Group on Development of Sustainable Moored Fish Aggregating Device (MFAD) Fishing in the Lesser Antilles held on April 30th- May 2nd 2019 - Recommendation WECAFC/17/2019/21 (Amendment to Recommendation WECAFC/15/2014/2) - which was endorsed during Seventeenth Session of the Commission held on July 15-18 2019 in Miami, US, and was the basis for the 2019-2020 Programme of Work adopted by the Commission. This Programme sought to increase the knowledge of, and experience with, moored-FADs related fisheries, with the ultimate goal of strengthening regional fisheries management and good-practice approaches for fisheries and aquaculture development. The development of this document was funded by the European Union through the Food and Agriculture Organization of the United Nations (FAO) and its Western Central Atlantic Fishery Commission (WECAFC).

This review builds on that of the CRFM sub-regional management plan (CRFM 2015a) by seeking to expand the geographic scope to include the wider Caribbean region and update on the current state of the MFAD fishery across the region. It is the result of a desk review, interviews with several key informants, and a regional online survey on MFAD use across the region that took place between August and October 2021. Respondents from twenty countries/overseas territories with significant MFAD fisheries took part in the survey. These countries/overseas territories were St. Eustatius, Dominica, Bonaire, Haiti, Antigua and Barbuda, Guadeloupe, Martinique, St Lucia, Puerto Rico, Bermuda, Montserrat, St. Vincent and the Grenadines, Florida (USA), Saba, Anguilla, Tobago (Trinidad and Tobago), the Dominican Republic, Curaçao, Cayman Islands, and Grenada. Seventy percent of the respondents were affiliated with national/local fishery and/or coastal management authorities. Respondents were also asked to rank a series of challenges and issues of the MFAD fishery - most of which had been previously identified by the CRFM sub-regional management plan - based on urgency in addressing to help identify regional priorities. Details and in-depth findings of the regional survey are given in Appendix II. A summary of the biology, distribution, and exploitation status of fish stocks of species typically caught on MFADs is given in Appendix III.

2. State of the MFAD fishery

2.1. Fish Aggregating Devices (FAD)

Observations that some fish tend to associate with natural or man-made floating objects and that such behavior can be used by fishers to facilitate fish detection and capture go back thousands of years ago (Castro et al. 2002; Taquet 2013). This associative behavior is observed in many taxonomically diverse fish species (Castro et al. 2002), although the physical distance at which such association takes place will differ markedly (from several cm to several km) among species and even among different life stages of the same species (e.g. small juveniles versus large adults) (Castro et al. 2002). A number of non-mutually exclusive biological hypotheses have been put forward to explain why fish associate with floating objects (Freon and Dagorn 2000; Castro et al. 2002). These include floating objects protecting against predators (the *shelter* hypothesis), acting as indicators of high food availability (the *indicator-log* hypothesis) and increasing encounter rates with other similar fishes (the *meeting point* hypothesis), with the general recognition that the support for any given hypothesis will depend largely on the life stage and/or species of interest (Freon and Dagorn 2000; Castro et al. 2002; Ehrhardt et al. 2017b). Whatever the biological explanation, fishers in the warm seas have historically capitalized on this fish behavior by building floating objects and placing them in the sea to fish under (or near) them (Castro et al. 2002; Taquet 2013)

2.2. Defining a Moored Fish Aggregating Device (MFAD)

A moored Fish Aggregating Device (MFAD) is hereby defined as any man-assembled structure composed of surface (or subsurface) buoyant components attached to an anchoring system resting on the sea bottom, which is primarily designed and deployed to attract fish to facilitate their capture. This definition excludes oil rig platforms (Franks 2000) as well as other anchored man-made objects deployed in the sea for other purposes (e.g. oceanographic data buoys (Silva et al. 2021)) even though such structures also both attract fish and can sustain important fisheries.

This definition excludes the practice of shadow fishing using boats (Arocha 2019) and fisheries making use of drifting Fish Aggregating Devices (DFAD), including the flying fish fishery in the eastern Caribbean (Gomes et al. 1998) for which there is already a management plan (CRFM 2014c) and the industrial purse-seine fishery that accounts for most tuna catches worldwide (Taquet 2013); the latter in particular operates in a very different socioeconomic, technological, governance and management context from most MFAD fisheries globally (Taquet 2013).

2.3. Historical overview of the MFAD fishery in the Wider Caribbean

The most comprehensive accounts of the development of the MFAD fishery in the Caribbean are given by (Reynal et al. 1999; Reynal et al. 2002) and are briefly summarized in CRFM (2015a). One of the earliest official records of the use of MFADs in the insular Caribbean region dates from the 1968-1971 period and took place in the context of exploratory fishing activities under the Caribbean Fishery Development Project funded by the UNDP/FAO (Wolf 1974; Wolf and Rathjen 1974). This experience yielded unimpressive results due to the very short lifespan of the rudimentary MFAD designs used and small aggregations within that time frame. Around the same time exploratory work linking MFAD design to aggregating properties was being conducted in the Pacific coast of Costa Rica (Hunter and Mitchell 1968), in the Gulf of Mexico (Panama City, USA) (Klima and Wickham 1971), and further north in South Carolina (Hammond et al. 1977, cited in de Sylva 1982) . In a review of MFAD use, de Sylva (1982) was among the first to specifically highlight the potential of MFADs for the Caribbean in a public fisheries forum (34th Gulf and Caribbean Fisheries Institute conference) in 1980. Subsequently, in 1983, fishery officers of the Eastern Caribbean identified FAD use and training as one of top priorities for their region (McIntosh 1984). The use MFADs was at that time viewed as a means of reducing fish imports in the Eastern Caribbean to satisfy the increasing local demand for fish products, given that coastal resources were already heavily exploited in many small island states, whereas pelagic resources were underexploited (Reynal et al. 2002). In the 1980s the use MFADs continued to be explored across the insular Caribbean, including in Martinique, St Kitts, Guadeloupe, Dominica, Grenada, Haiti, US Virgin Islands, Puerto Rico, and Cuba (McIntosh 1984; Reynal et al. 1999 and references therein), as well as in the eastern USA (Rountree 1989; Stephan and Lindquist 1989). Much of the research focus at the time was on the aggregating properties of different MFAD designs generally deployed at relatively shallow depths and short distances from the coast (Reynal et al. 2002).

In the late 1980s and throughout the 1990s, the introduction of drifting droplines with live bait (in addition, to surface trolling) around MFADs and the deployment of MFADs in deeper waters (and further away from the coastline) in the French Antilles allowed specifically targeting large oceanic pelagics such as large yellowfin tuna and billfishes and resulted in tangible increases in fishing yields (Reynal et al. 2002). This change in fishing strategy around MFADs helped initiate a steady increase in the number of locations across the region adopting the use of MFADs to present times (See Fig 1 in Wilson et al. 2020).

2.4. Current MFAD use across the region

The 2021 MFAD regional survey (hereafter referred to as the MFAD Survey; Appendix II), combined with interviews with key informants, and a review of the literature jointly yield a snapshot of the current state of the MFAD fishery across the WECAFC region. Twenty-six locations across the region have a significant MFAD fishery. Nearly all these locations (92%) are Caribbean islands, in line with the historical development of the MFAD fishery in the region. The only two continental locations with a significant MFAD fishery are northeast Brazil and northwest Florida. However, in Brazil, the use of MFADs to target tuna is being gradually replaced by the practice of shadow fishing since the 2010's, and so MFADs appear to be rapidly disappearing (Marco Bailon, pers. com.) whereas, in Florida, the number of MFADs is very small (Table 1). Overall, these results highlight that the MFAD fishery remains mainly confined to the insular Caribbean, as previously documented (CRFM 2015a).

There is currently an estimated total number of 3,600+ MFADs deployed across the region (Table 1), in line with previous estimates (Wilson et al. 2020). In that regard, two locations, the Dominican Republic and Guadeloupe, jointly account for 86% of all MFADs in the region. There is also an estimated total number of 7,200+ fishers and 3,200+ vessels engaged in MFAD fishing either full- or part-time across the region (Table 1). Excluding Florida, the only location where MFADs mainly support recreational fishing (Appendix II), yields a revised estimate of 6,200+ fishers and 2,700+ vessels engaged in MFAD fishing across the region mainly for commercial and/or subsistence purposes. The MFAD survey indicates that in nearly all locations trends in MFAD vessel numbers have remained stable or increased over the last five years (Appendix II). These estimates and trends support an important role of MFAD fishing in sustaining fishers' livelihoods and food security in the insular Caribbean region.

2.5. Objectives of the MFAD fishery

The MFAD Survey indicated that current objectives to support MFADs remain consistent with historical objectives in the region (See Table 5 in CRFM 2015a), namely improving fisher livelihoods (via increased revenue and fishing efficiency and reduced fuel consumption), supporting food security, and decreasing fishing pressure in coastal systems (Table 2). Interesting, objectives about improving co-management and social cohesion among fishers have gained prominence over the last few years relative to the objectives outlined by the desk review in CRFM (2015a), likely as a result of recent efforts to improve co-management approaches in the region (Tamura et al. 2018) (Table 2).

Table 1 – List of WECAFC countries (and/or their overseas territories) and whether they currently have a significant MFAD fishery; for those that do (grey shading), estimates of numbers of public and private MFADs as well as MFAD fishers and vessels (full- and part-time) are provided. NA- No data available

Country / Territory	MFAD fishery	Public MFADs	Private MFADs	MFAD boats	MFAD fishers	Comments / Sources
Anguilla (British OT)	Yes	0	25	15	15	More MFADs to be deployed after the hurricane season
Antigua and Barbuda	Yes	8	20	15	35	Six public MFADs to be deployed in 2022; about 40-80 illegal private MFADs set by foreign vessels
Aruba (Dutch Caribbean)	No	-	-	-	-	
Bahamas	No	-	-	-	-	There is one MFAD, but it is used exclusively for research
Barbados	Yes	1	0	NA	NA	A total of 17 public MFADs to be soon deployed
Belize	No	-	-	-	-	
Bermuda (British OT)	Yes	1	0	5-25	5-75	One additional public MFAD to be re-deployed after being lost
Bonaire (Dutch Caribbean)	Yes	6	1	20	20	
Brazil	Yes	0	NA	NA	NA	The use of MFADs has declined considerably in the last decade; very few boats now use MFADs.
British Virgin Islands (British OS)	NA	NA	NA	NA	NA	
Cayman Islands (British OT)	Yes	0	2	-	-	
Colombia	No	-	-	-	-	
Costa Rica	No	-	-	-	-	
Cuba	No	-	-	-	-	
Curacao (Dutch Caribbean)	Yes	0	20	10-15	10-15	
Dominica	Yes	2	20	300	600	
Dominican Republic (south coast)	Yes	0	2500	1250	2500	
Grenada	Yes	0	3	70	140	Four to five MFADs present at any given time
Guadeloupe (French OT)	Yes	<30	600	218	387	Estimates from 2008 (public) and 2012 (private) - current numbers are probably higher
Guatemala	No	-	-	-	-	
Guyana	No	-	-	-	-	
Haïti (southeast department)	Yes	6	3	250	1500	This is an estimate for about 150 km of coastline; there are more MFADs along the rest of 1,700 km of Haitian coastline.
Honduras	No	-	-	-	-	
Jamaica	No	-	-	-	-	
Martinique (French OT)	Yes	4	20-25	220	377	
Mexico	No	-	-	-	-	
Montserrat (British OT)	Yes	4	0	8	25	Six MFADs were recently lost
Nicaragua	No	-	-	-	-	
Panama	No	-	-	-	-	
Puerto Rico (USA OT)	Yes	11	10	-	-	
Saba (Dutch Caribbean)	Yes	0	15-20	12	22	
Saint Kitts and Nevis	Yes	0	100	75	100	50% of MFADs in Nevis and 50% in St Kitts
Saint Lucia	Yes	8-10	0	200-250	450-500	
Saint Vincent and the Grenadines	Yes	6	0	50	100	
Sint Eustatius (Dutch Caribbean)	Yes	1	5	6	6	Two MFADs were recently lost
Sint Marteen (Dutch Caribbean)	Yes	0	2	20	NA	Source: Wilson et al. (2020)
St Barthelemy (French OT)	Yes	0	100	22	NA	Source: Wilson et al. (2020)
St Martin (French OT)	NA	NA	NA	NA	NA	
State of Florida (USA)	Yes	8	0	500+	1000+	MFADs located off Destin - Fort Walton Beach
Suriname	No	-	-	-	-	
Trinidad and Tobago	Yes	0	100	-	60-80	Only Tobago has MFADs
Turks and Caicos (British OT)	No	-	-	-	-	
US Virgin Islands (USA OT)	Yes	4	0	20	NA	Source: https://coastalanglermag.com/usvi-fish-aggregating-device-fad-program/
Venezuela	No	-	-	-	-	

Table 2. Frequency of citation of high-level objectives to support a MFAD fishery by respondents from 20 territories/countries with MFAD fisheries. The list of objectives was based on CRFM (2015).

High level objective	Citation frequency
To increase fisher revenue	18
To increase fishing efficiency for fishers	17
To decrease coastal or nearshore fishing pressure	16
To increase local availability of fish products	15
To reduce fuel consumption	14
To support food security	14
To reduce fish imports	10
To promote social cohesion and collaboration among fishers	9
To promote co-management	8
To reduce competition among fishers in resources/fishing grounds	7
To generate new added value products	5
To increase employment	5
To encourage fishers to remain within territorial waters	4
To increase safety at sea	4
To support or develop a charter/sports fishing market	4
To conduct research on pelagic species biology and/or fishing techniques	4
To increase fish exports	3
To reduce conflicts between fishers and other users of the sea (e.g. shipping, tourism)	3
To decrease physical demands of fishing	2
To control or reduce use of private MFADs	1

2.6. Fishing vessels and safety at sea

Most vessels making use of MFADs in the region are small-sized (<9 m long) multipurpose vessels (made of wood, fiberglass, or fiberglass and wood) equipped with outboard engines engaged in one-day fishing trips (CRFM 2015a). Moreover, the MFAD Survey indicated that (1) in half of these locations MFAD vessels were generally decked, (2) in most of these locations MFAD vessels were typically equipped with ice boxes, whereas (3) only in a few of these locations MFAD vessels were equipped with winches (Appendix II). Typical outboard engine power can differ by up to one order of magnitude among locations (e.g. 15-18 hp in Haiti (Vallès 2016) vs 176 hp (on average) in Guadeloupe (Guyader et al. 2018)), although the prevailing engine horse power across most locations is 100 hp and above (Appendix II). Most crew sizes engaged in MFAD fishing involve 2-3 fishers (Appendix II)(CRFM 2015a).

The MFAD Survey indicated that in the majority (≥50%) of locations most fishers (1) had safety signaling equipment, (2) had emergency flotation devices, and (3) had navigation equipment; however, (4) they were not trained in safety at sea, (5) did not have alternative means of propulsion in their vessels, and (6) did not wear personal protective gear to handle large fish (Fig 1).

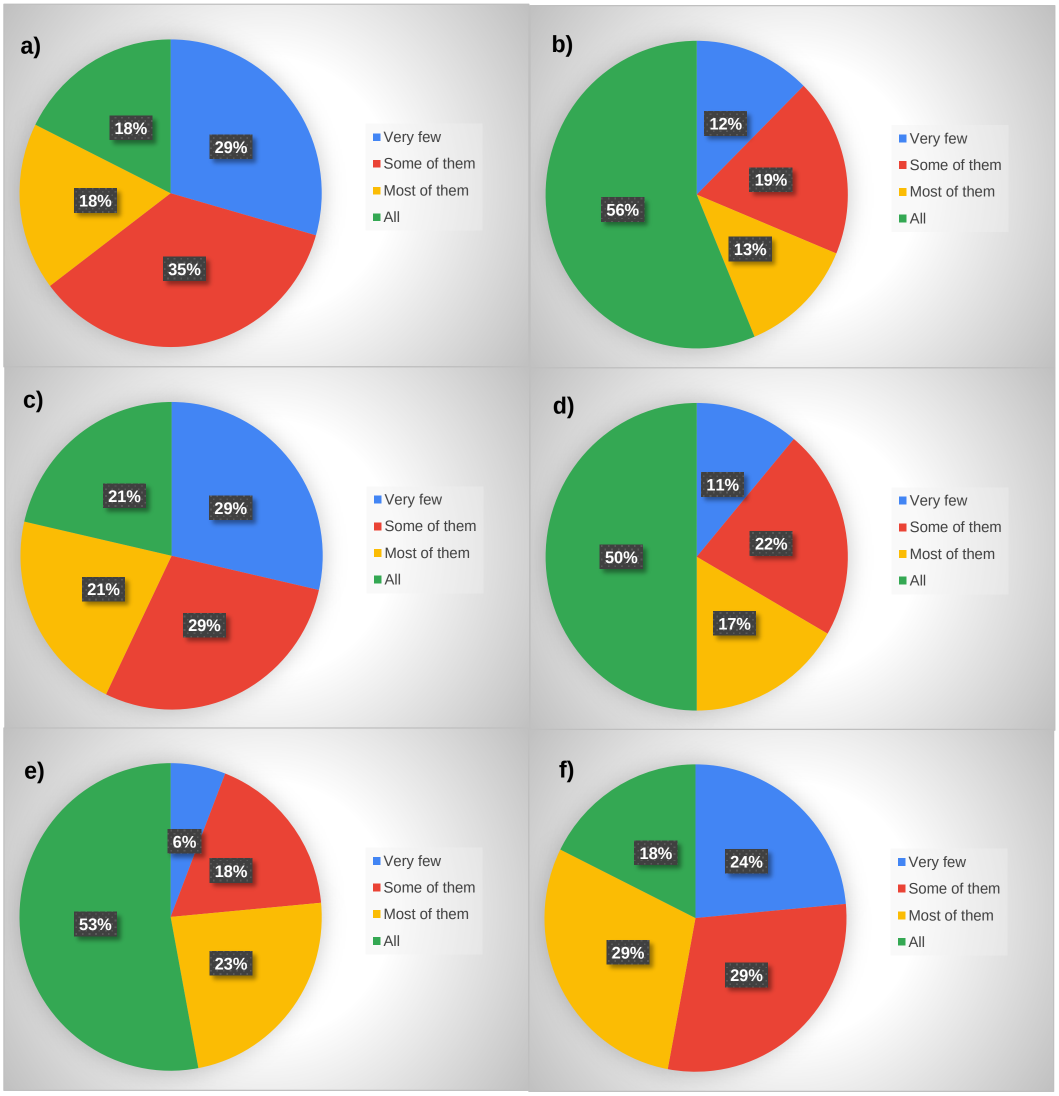

Figure 1 – Safety at sea conditions for MFAD fishers as percentage of responses across 20 territories indicating the number of fishers in their respective locations that a) are trained in safety at sea, b) have safety signaling equipment (e.g. VHF / radio-telephone, torch, flares, mirror, air horn, etc), c) have alternative means of propulsion (e.g. oars, sail rigs, auxiliary engine), d) have emergency flotation devices (e.g. floats, life-jackets, large plastic containers), e) have navigation equipment (e.g. compass, GPS), and f) have personal protective gear to handle large fish (e.g. noose, boots, gloves).

2.7. Fish handling on board and post-harvest facilities

The MFAD Survey indicated that the extent to which large fish typically caught on MFADs are processed onboard (spiked; bled out; gutted; preserved on ice) differs markedly across the region (Fig 2a-d). This variability in fish handling and conservation practices likely reflects a combination of factors including the degree to which domestic markets impose (or not) quality standards (Gentner et al. 2018), duration of fishing trips, local availability of ice, and whether fishers are trained in fish handling.

As indicated in CRFM (2015a), the landing sites for MFAD catches are typically part of the larger pool of landing sites for pelagic species. Following FAO (2004) these can be assigned to three categories: (1) a beach with no or minimum makeshift facilities, (2) a developed small landing site with some government-provided facilities such as covered working areas, water supply, lighting, gear sheds, and (3) a developed complex including a building, office space, freezers and jetty. In that regard, the MFAD Survey supports that in many locations across the region adequate facilities to handle large fish are still lacking (Fig 2e). This is consistent with a recent study by Montes et al. (2017), which found that most fishers (including MFAD fishers) in each of five insular Caribbean countries were not openly satisfied with the services and facilities of the landing sites they had access to, with the degree of overall dissatisfaction varying markedly among countries.

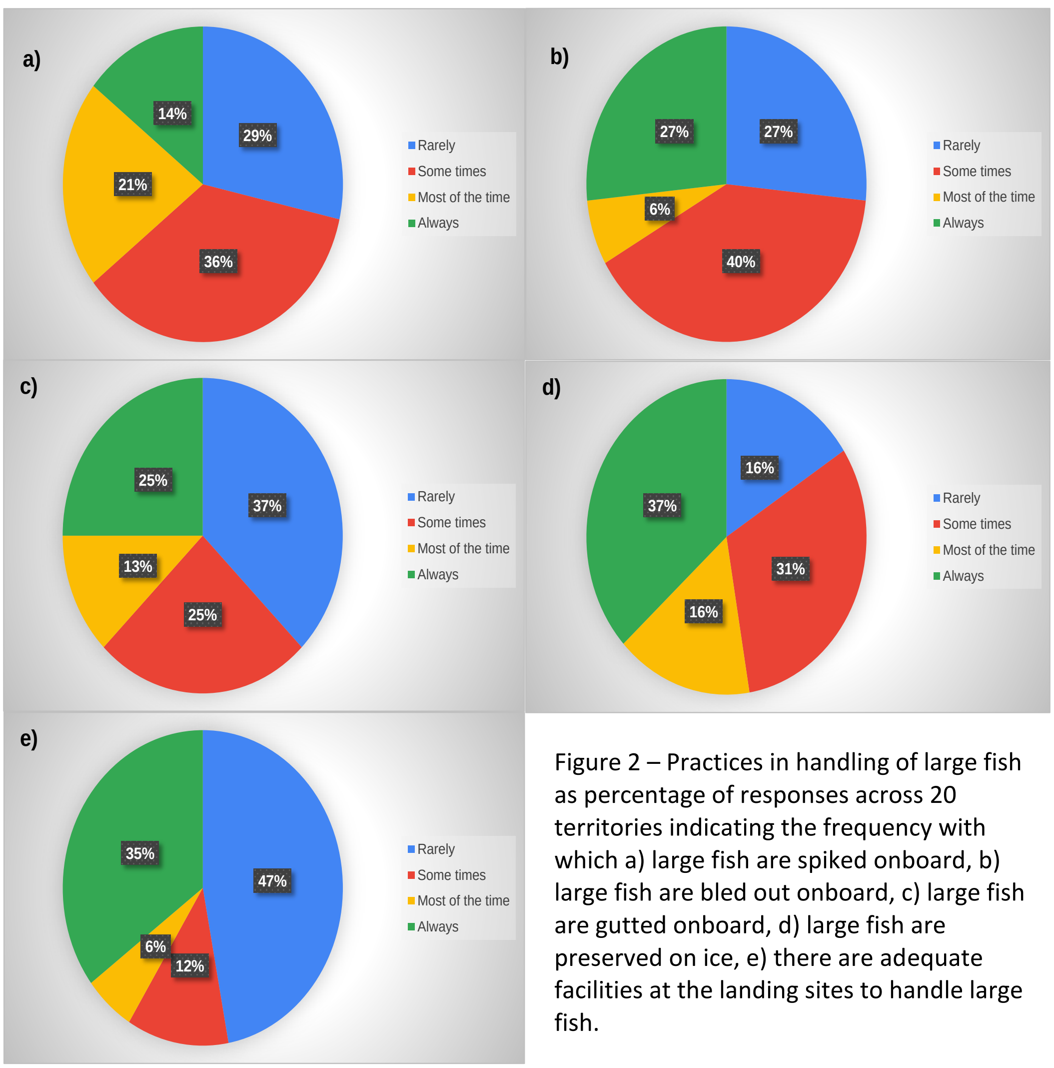

Figure 2 – Practices in handling of large fish as percentage of responses across 20 territories indicating the frequency with which a) large fish are spiked onboard, b) large fish are bled out onboard, c) large fish are gutted onboard, d) large fish are preserved on ice, e) there are adequate facilities at the landing sites to handle large fish.

2.8. MFAD design, cost, and lifespan

A MFAD is typically made up of six distinct components: (1) the surface float component (typically made up of string of buoys or floats or a single spar buoy), (2) an aggregator component aimed at attracting fish (e.g. tarpaulins, plastic strips, coconut leaves), (3) a mooring line (which can be made of a diverse range of materials including polypropylene, polyester, nylon, cable rope, banana string, telephone wire), (4) a mooring component (typically made up of concrete blocks or barrels, sand bags, old engines), (5) a surface marker to minimize collision with boats (typically including a flag, a radar reflector, a light, mast), and (6) the joining elements (shackles, thimbles, knots, swivels) (Fig 3 and 4).

Depending on their dimensions, design complexity, and materials, MFADs can be classified as heavy, semi-heavy or light, although in reality designs will vary along a continuum (Dempster and Taquet 2004). All three types of MFAD designs can be found in the region (CRFM 2015a). Heavy MFADs generally have a single large buoy made of steel, PVC, or composite material as surface component (Dempster and Taquet 2004; Gervain et al. 2015). This component is generally designed to remain on the surface even in the face of strong currents (Fig 3d; except in the case of subsurface MFADs – Fig 3c). The mooring line is typically made of different sections of high-diameter and high-quality materials that fulfill different functions with the ultimate goal of minimizing the risk io rupture of the mooring line (Gervain et al. 2015). The line segment just below the surface component is typically made of sinking material (e.g. chain, cable, polyester, polyamide) to ensure that it never reaches the surface in periods of low currents. The first section of this line (e.g. first 50m-200 m) will also be physically reinforced to resist fish bites and cuts by fishing lines. The line segment coming from the anchoring component is typically made of floating material (e.g. polypropylene, polyethylene) to ensure that the line does not drag on the sea floor during periods of low currents (Gervain et al. 2015). Due their size and high buoyancy, heavy MFADs often require large anchoring components (e.g. one or several large concrete blocks) and thus their safe transport and deployment typically requires larger vessels than those typically used by MFAD fishers.

Semi-heavy MFADs are smaller and have a surface component made out of a string of resistant buoys that sink with the currents and return to the surface after immersion (Fig 3a,b) (Dempster and Taquet 2004); the more expensive models might also have a mooring line with sections also made of markedly different materials to minimize the risk of rupture. If the mooring line is entirely made of floating line (e.g. polysteel), ballasts can be attached to the line to prevent it from reaching the surface under low currents (Fig 3b).

At the other end of the continuum are the light MFADs, which generally have a relatively small surface component made of a string of cheap locally available floats (e.g. plastic drums, cans, recycled floats/buoys) that will tend to sink under strong currents and are likely to implode during prolonged immersion (Fig 4); the surface component will be generally attached to the anchoring component often via a single low-diameter cheap line made of whatever material is locally available (e.g. banana string, polyethylene). Light MFADs often lack surface markers specifically designed to avoid collisions with boats (e.g. flags; radar reflectors). The anchoring components of semi-heavy and light MFADs are relatively small and light (e.g. concrete blocks, old engines, sand bags), which allows fishers to transport and deploy MFADs themselves using their small vessels (Fig 3a, b and Fig 4). CRFM (2015a) and references therein provide a review of the evolution of MFAD designs in the Caribbean region. MFAD designs from the French Antilles first, and subsequently from the FAD Pilot project of Dominica (CRFM/JICA 2012) have been particularly influential in driving MFAD design in other locations in the region (FAO 2007; CRFM 2015a; Defoe 2020).

A major ecological concern surrounding the use of MFAD is the loss of the units, which are often made nearly entirely of non-biodegradable materials, thus contributing to marine litter. Such losses can also threaten the economic viability of the fishery. MFADs can be lost in various ways including when (1) the upper part goes adrift because of rupture of the mooring line, (2) the whole MFAD sinks after implosion or destruction of surface buoys or floats, and (3) the whole MFAD goes adrift due to insufficient anchor weight or because the sea bottom is too steep (Gervain et al. 2015). The surface component remains the most vulnerable part of the MFAD. Potential causes of loss are diverse and include excessive strain by swells and waves, damage by collision with boats, buoy/float implosion due to submersion under strong currents, mooring line cut by fishing lines or fish bites, tangling with drifting objects, inadequate mooring line design, incorrect assembly of components, incorrect MFAD deployment, vandalism, and lack of maintenance (Gervain et al. 2015).

Best practices in MFAD design and materials to minimize MFAD losses have been documented (Gervain et al. 2015) and include, among others, sufficient anchoring weight in relation to the mooring lines and the system of buoys; correct night and day markings to prevent boat collisions; sufficient buoyancy of the floating component to prevent buoy submersion and implosion under strong currents; extra protection against cuts by fishing lines and fish bites of the mooring line below the surface; presence of a sinking mooring line below the floating component and a floating mooring line above the anchoring component to prevent the line from floating to the surface or dragging on the sea bottom, respectively, when there is no current (CRFM 2013a; Gervain et al. 2015). Most of these features are found on heavy MFAD models and are lost progressively as models transition through semi-heavy designs to the light ones.

Greater investments in materials and design should lead to a greater life span of the MFAD unit (Gervain et al. 2015). The MFAD Survey highlighted that, relative to private MFADs, public MFADs are more likely to be equipped with surface markers, a sinking line below the floating component, a floating line above the mooring component, and a large concrete block as mooring component (Appendix II). Thus, public MFADs across the region are more likely to align with best practices in MFAD design. As expected, the MFAD Survey also confirmed that public MFADs are also more likely to last several years after deployment than private MFADs, with the latter most frequently having about one year of lifespan (Appendix II). The MFAD Survey also indicated that public MFADs more frequently fell into the cost bracket exceeding USD 8,000 per unit across the region, whereas private MFADs more frequently fall into the USD 1,000-2,000 bracket (e.g. USD 1,000-1,800 in Dominica; Defoe 2020). However, depending on location, materials and depth of deployment, some private MFADs can largely exceed that bracket (up to USD 5,000 in Guadeloupe; Guyader et al. 2018) but also so go well below (USD 100-150 in the Dominican Republic; Gentner et al. 2018) (Fig 4). On the other hand, the MFAD Survey also indicated that private MFADs are more likely to be replaced within just a few months when lost than public MFADs, with the latter more likely to be replaced within a year (Appendix II). In contrast, public MFADs are much more likely to be recovered when lost than private MFADs (Appendix II). The MFAD Survey also found that two thirds of locations with public MFADs reported that the MFAD units had clear markings allowing owner identification; when it came to locations with private MFADs, only half of these locations reported that the MFAD units had clear markings allowing owner identification (Appendix II).

The MFAD Survey indicated that tarpaulins and plastic strips are the most frequently used types of aggregator materials for both private and public MFADs, although in a few locations potentially animal entangling materials such as old nets are still being used (Appendix II). Storm events were most frequently cited as causes of MFAD losses for both MFAD types, followed closely by mooring lines being cut by boats (Appendix II). The MFAD Survey also supported differences between private and public MFADs in depth of deployment, with public MFADs more frequently deployed between 501-1000 m and private ones between 1001-2000 m (Appendix II). The latter likely reflects efforts by fishers to deploy private MFADs further away from the coastline to maximize catches of large oceanic pelagics while minimizing the chances of other fishers fishing on their MFADs (Guyader et al. 2013; Guyader et al. 2018), although it cannot be discarded that these differences might be confounded by the varying bathymetry across locations.

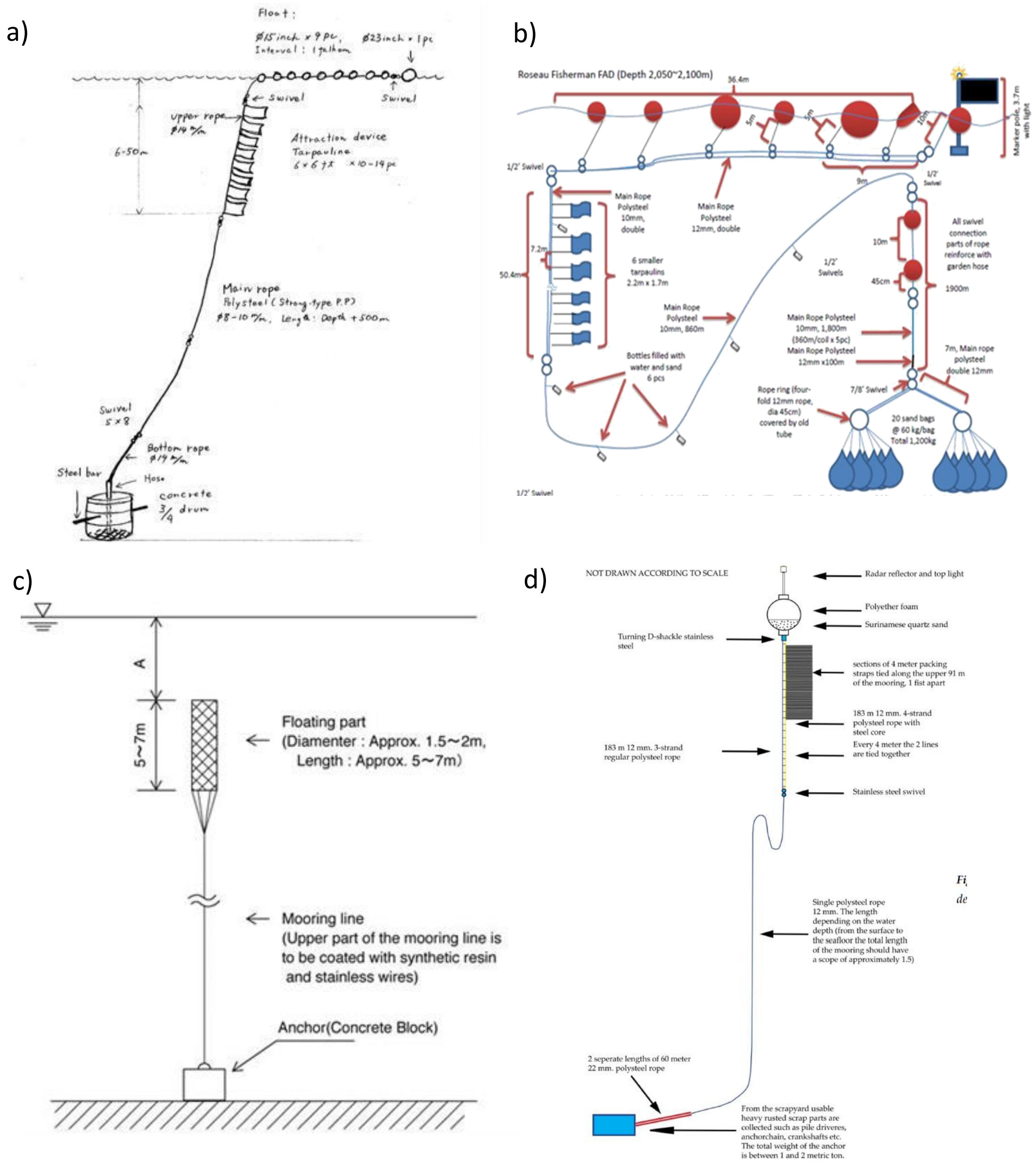

Figure 3 – Diversity of MFAD designs including (a) a semi-heavy traditional MFAD from Dominica, (b) an improved semi-heavy MFAD from Dominica, (c) a heavy “mega” MFAD from Dominica, and (d) a heavy MFAD from Curacao. Sources are Defoe (2020) for Dominica and Dilrosun Faisal (unpublished) for Curacao

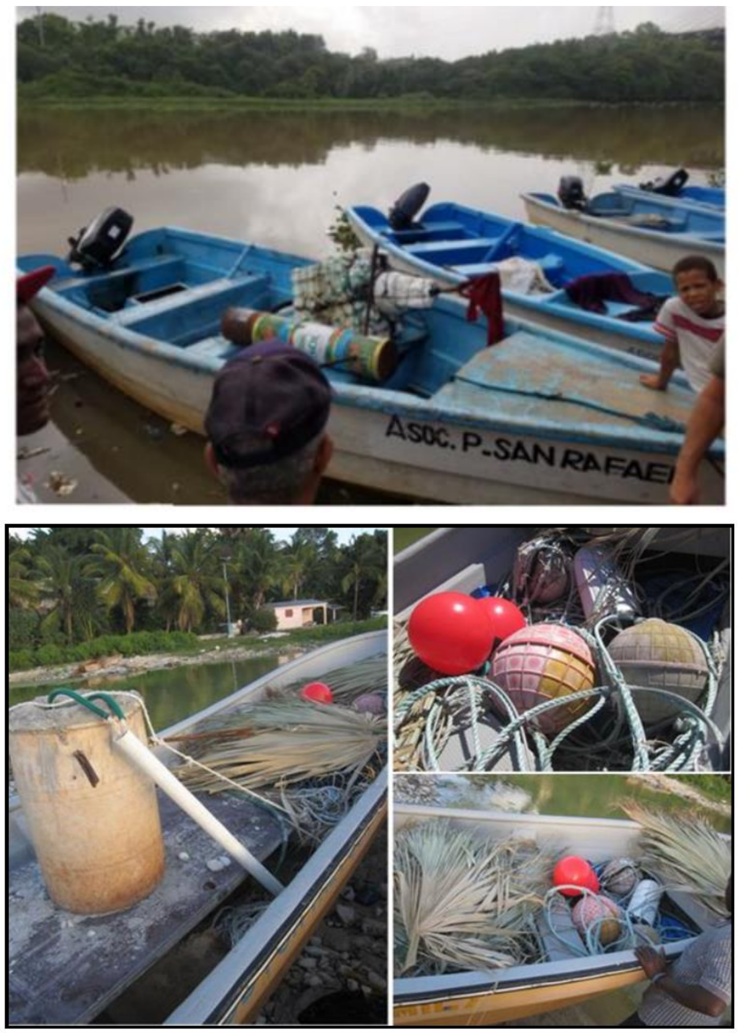

Figure 4. Anchor and floating components for light MFADs ready for deployment in (a) the Dominican Republic and (b) Haiti. Taken from Gertner et al. (2018) and Vallès (2015)

2.9. Fishing techniques, target species and sizes, and variability in catch composition

The MFAD Survey found that fishing near MFADs across the region takes place mainly within 100 m from the MFAD during daylight hours; fishing techniques are largely dominated by the surface (<2 m deep) and sub-surface (2-10 m deep) trolling and drifting droplines using live small pelagic species (e.g. flyingfish) and small-bodied tuna species (e.g. skipjack) as bait as well as artificial lures, as previously reported (CRFM 2015a). When specifically targeting large individuals of large oceanic pelagics such as yellowfin tuna and marlin, fishers will generally troll near the MFAD using artificial lures to capture small-bodied tuna species (e.g. bonito) or juveniles of large-bodied tunas (e.g. yellowfin tuna), which tend to aggregate near the surface (Doray et al. 2007) (Fig 5), and will subsequently use these as live bait in drifting droplines operating a greater depths (Guillou and Lagin 1997; Sidman et al. 2015; Gentner et al. 2018; Defoe 2020). Wahoo and dolphinfish are often targeted using surface and sub-surface trolling with baited hooks or artificial lures (Guillou and Lagin 1997) as well as with handlines with baited hooks (Defoe 2020).

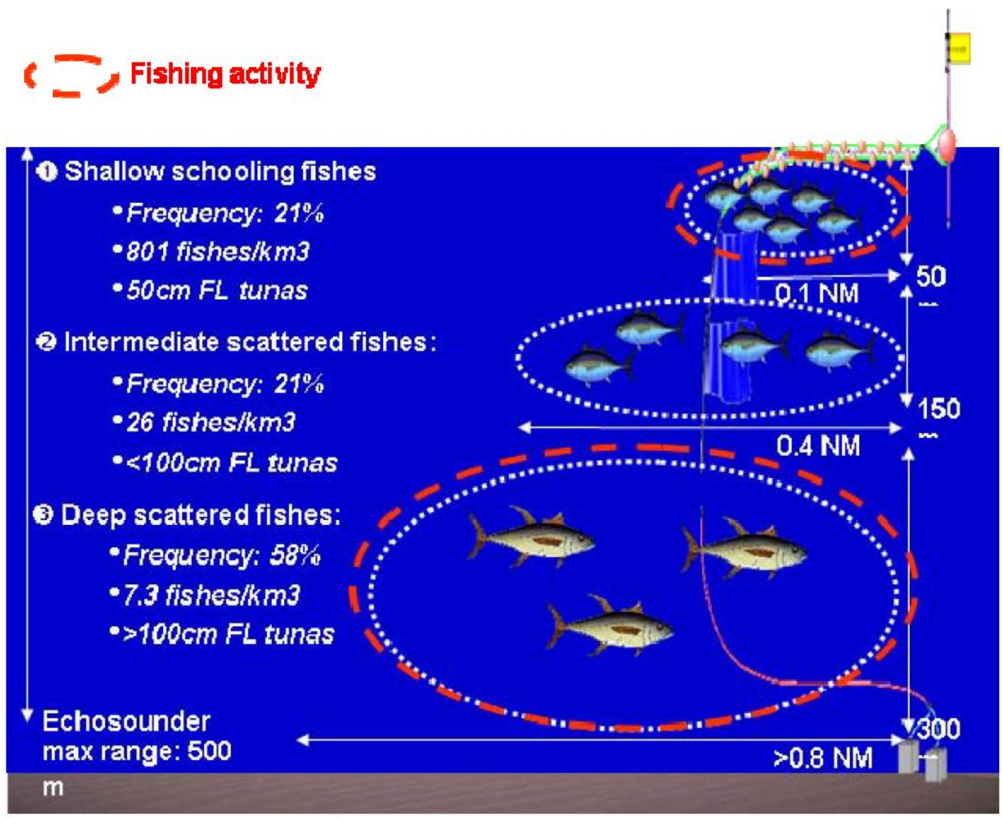

Figure 5. Changes in the species and size of tuna associated with a MFAD along the depth gradient. Taken from Doray (2007)

A great diversity of oceanic and coastal pelagic species associates with MFADs and thus MFAD fishery landings often include multiple species. The MFAD Survey found that eight species accounted for ¾ of frequency of reporting. These include, by decreasing order of importance, yellowfin tuna, wahoo, blackfin tuna, blue marlin, skipjack, bigeye tuna, dolphinfish, and little tunny (Fig 6). These species overlap largely with the most abundant species reported in long-term (≥1 year) fishery landing data from MFADs across the region, including the Lesser Antilles (Fig 7 and Table 3) or Greater Antilles (Fig 8a; Table 4).

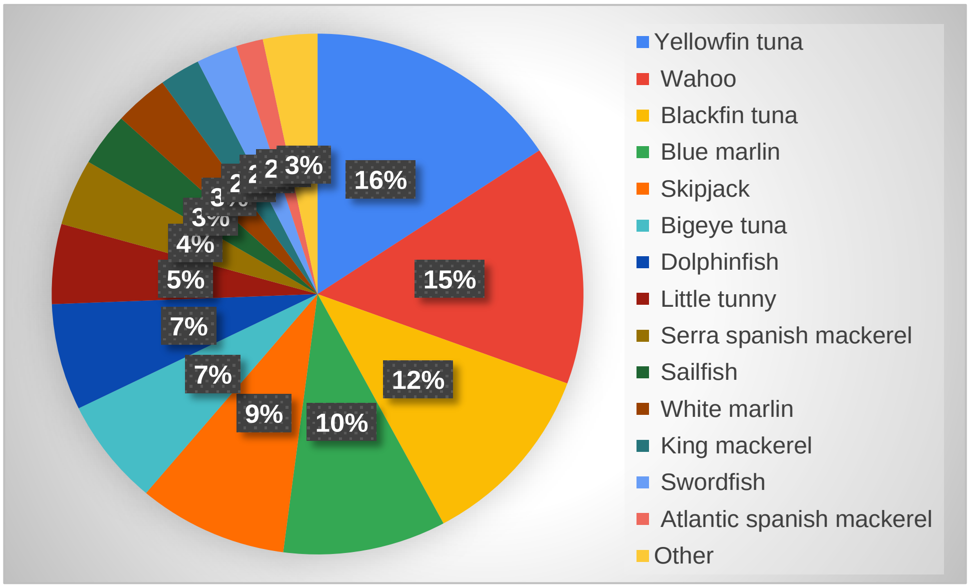

Figure 6. The most frequently reported target species on MFADs across 20 territories.

Table 3 - Top five fish groups caught on MFADs over ≥ 1 year in five islands in the Eastern Caribbean. Taken from CRFM (2015a).

Top groups	Grenada	St Vincent and The Grenadines	Martinique	Dominica	Guadeloupe
1	Blackfin tuna	Blue marlin	Blue marlin	Yellowfin tuna	Yellowfin tuna
2	Yellowfin tuna	Yellowfin tuna	Yellowfin tuna	Dolphinfish	Dolphinfish
3	Cavalli	Blackfin tuna	Little tunny	Skipjack	Little tunny
4	Dolphinfish	Dolphinfish	Blackfin tuna	Blackfin tuna	Blue marlin
5	Rainbow runner	Skipjack	Dolphinfish	Sharks	Rainbow runner

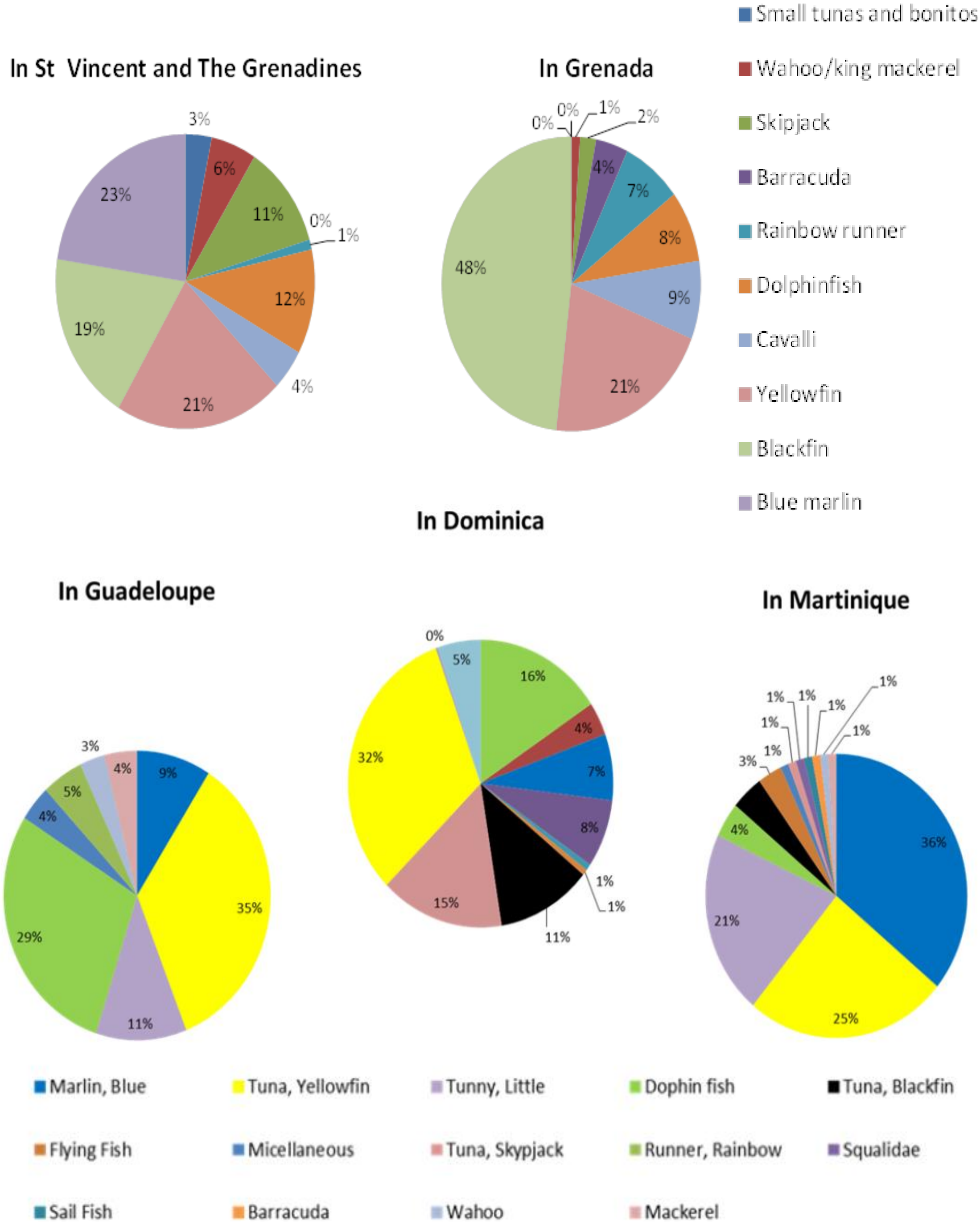

Figure 7. Catch composition over ≥ 1 year from MFADs in five different islands of the eastern Caribbean. Adapted from (CRFM 2015a) based on CRFM (2013b) and Mathieu et al. (2014)

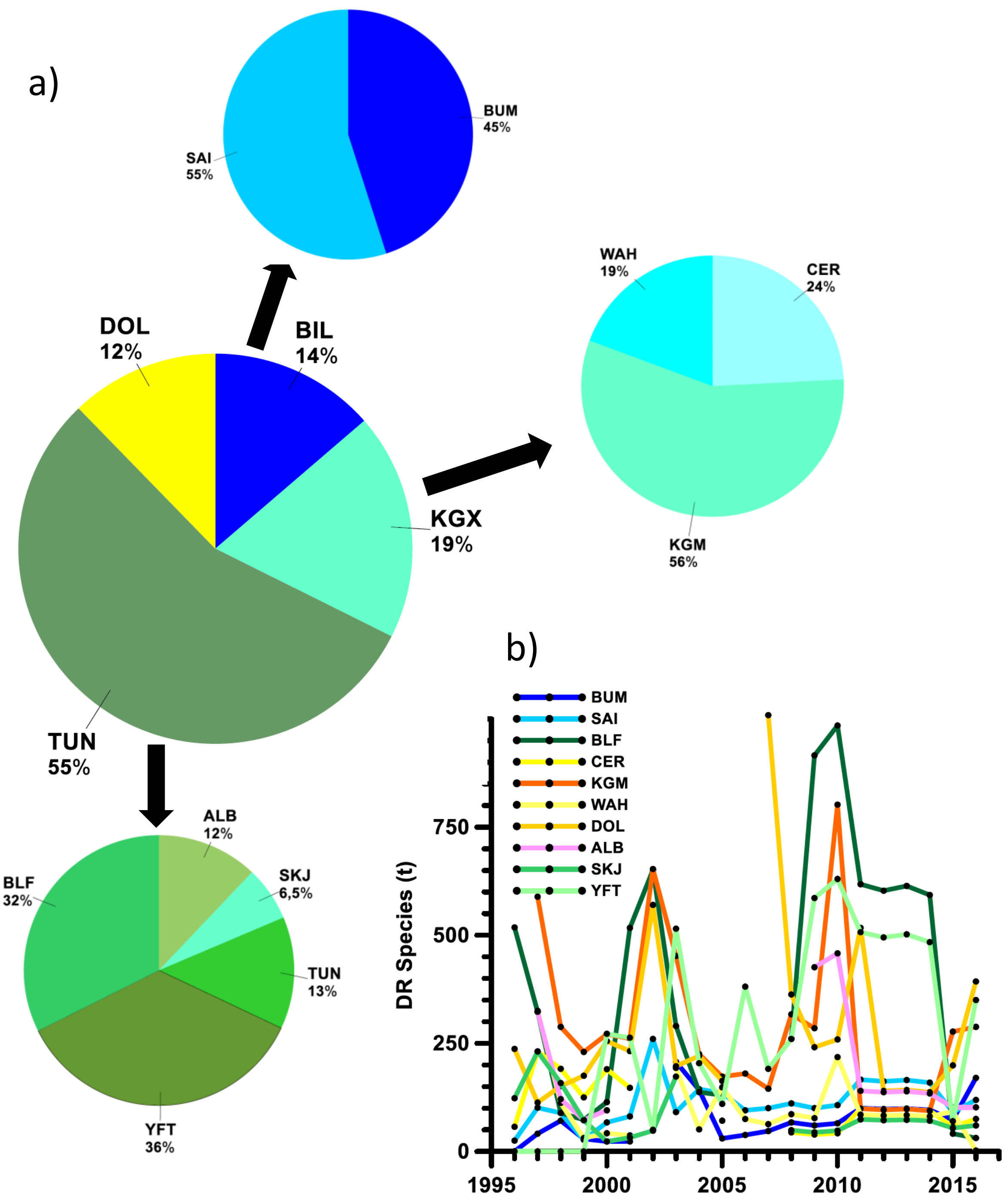

Figure 8. Landing composition of large pelagics in the Dominican Republic (a) broken down by relative abundance for the 2014-2016 period, and (b) by yearly landings between 1996 and 2016. These landing data come mainly from the use of MFADs in the south of the island. ALB- Albacore tuna; BIL – Billfish; BLF- Blackfin tuna; BUM- Blue marlin; CER - Cero mackerel; DOL – Dolphinfish; KGM- King Mackerel; KGX – Kingfishes; SAI- Sailfish; SKJ – Skipjack; TUN - other tunas; WAH -Wahoo; YFT - Yellowfin tuna. Taken and adapted from Arocha (2019).

Table 4. Average landing composition of large pelagics in the Dominican Republic for which data are available over the 2015-2019 period and corresponding percentage of total reported landings (all fishing types combined) in the region that they represent. These landing data come mainly from the use of MFADs in the south of the island. Taken from Arocha (2021)

Species	Metric tons per year	% of total reported landings for the region
Yellowfin tuna	220.4	0.7
Skipjack	40.4	0.8
Albacore	267.2	6.4
Blackfin tuna	23.0	1.9
Blue marlin	155.4	19.5
Sailfish	117.4	7.4
Dolphinfish	391.8	10.3
Wahoo	19.2	2.5
King mackerel	286.8	3.0
Cero	48.2	24.3
Total	**1569.8**	**2.8**

It is important to highlight that tuna aggregations around MFADs will tend to have greater proportions of juveniles relative to adults than free-swimming schools of tuna (Fonteneau et al. 2000; Dagorn et al. 2013). Moreover, MFADs allow targeting all year-round species that were traditionally fished only during certain periods of the year coinciding with the passage of their adult migrations such as dolphinfish (Guillou and Lagin 1997). These two factors ultimately result in catches around MFADs of specific fish groups that are often dominated by pre-mature individuals (Doray and Reynal 2002). These fish groups include notably yellowfin tuna, blackfin tuna and dolphinfish (but not blue marlin; Fig 9). The targeting of pre-mature individuals for commercial purposes around MFADs raises legitimate concerns about their potential to lead to growth overfishing and recruitment overfishing (Fonteneau et al. 2000; Dagorn et al. 2013; MRAG 2017), particularly given the lack of data on juvenile mortality and growth rates for some of these groups in the region. Although the MFAD Survey indicated that in two thirds of the locations small fish (<2kg) generally made less than 25% of the catch (Appendix II), even at such low levels juveniles are still likely to numerically dominate the catch (Reynal et al. 2002). Moreover, the use of juvenile tuna as bait is rarely quantified as part of the catch, highlighting an area for improved monitoring.

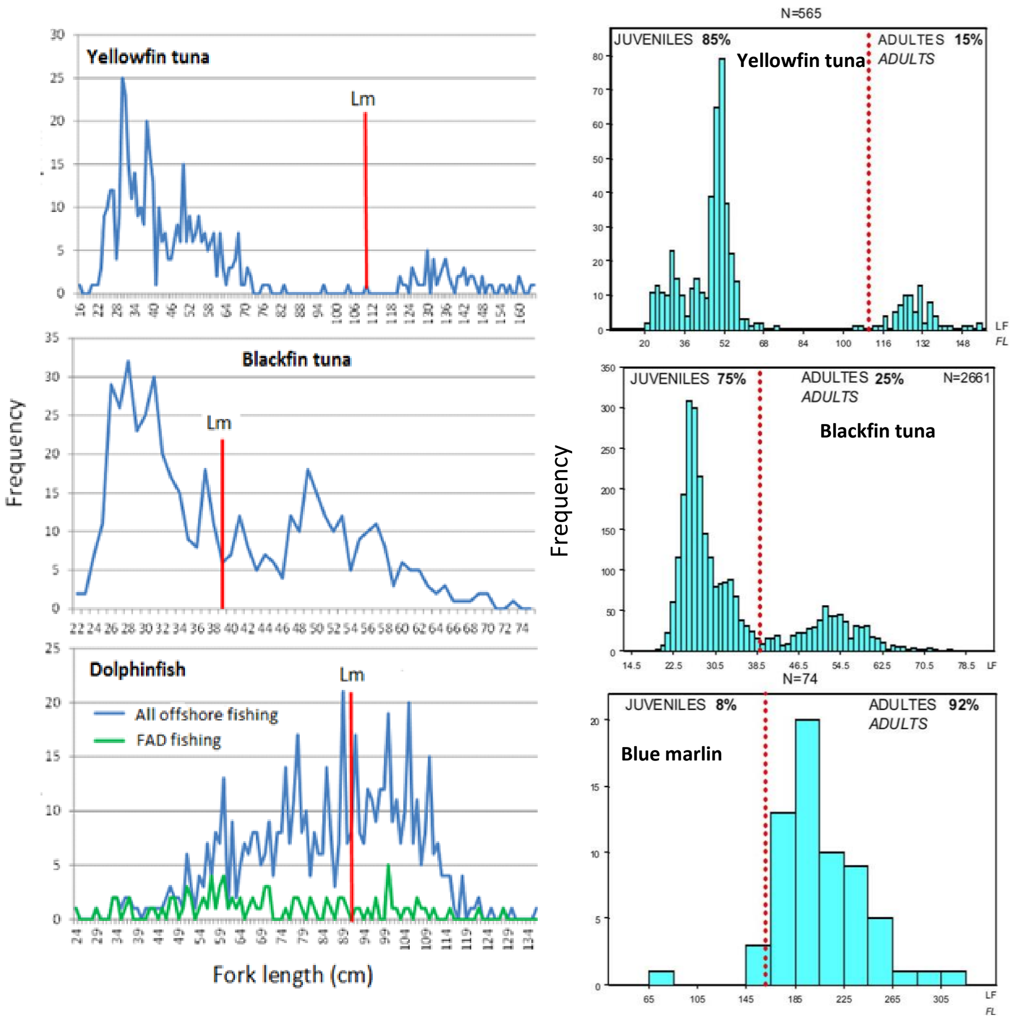

Figure 9 - Size-frequency distributions of fish caught around MFADs in Martinique (left panels) between 2008 and 2013 and (right panels) between 1998 and 2001. Vertical red lines indicate length at maturity (Lm). Taken and adapted from CRFM (2015a) and Doray et al. (2002).

Beyond the fishing techniques employed for MFAD fishing, which species dominate MFAD catches will differ in space and time over a range of scales. A review of variability in catch composition on MFADs in the region and underlying factors is given in CRFM (2015a); there are differences in catch composition within islands (Atlantic vs Caribbean side) and among islands (with no clear latitudinal pattern) as well as between night and day, among months (seasonal), and among consecutive years in the same location. Such differences are driven by a combination of (1) factors influencing the likelihood of target species encountering MFADs such as proximity to migration routes (e.g. distance from shore) and the seasonality of such migrations, (2) factors influencing the aggregation dynamics of such species once they encounter the MFADs (e.g. residence time, depth re-distribution over the dial cycle), and (3) factors potentially affecting fish catchability on MFADs (e.g. bait availability; sea conditions) (CRFM 2015a and references therein).

The MFAD Survey also supported differences across locations in seasonality of MFAD use. Fifteen locations reported seasonality in MFAD fishing, whereas five reported a lack thereof. There is direct evidence supporting both scenarios. Pooling data across the fifteen locations suggested a broad regional seasonal pattern for MFAD fishing between May and November (Appendix II), which broadly aligns with that documented in some locations for some years such as Martinique (2009,2010) and Guadeloupe (2008, 2010) (Mathieu et al. 2014). Other locations certainly seem to fish on MFADs all year round as it was the case of Dominica in 2008-2010 period (Mathieu et al. 2014). Such differences across the region in seasonality of MFAD use likely reflect the interplay of very different factors. For example, the MFAD Survey indicated that the four most frequently cited reasons for seasonality in MFAD use were, by decreasing order of importance, abundance of target species, market demand for fish, low revenue from other fishing activities, and good sea conditions for offshore fishing. These results suggest that the economic incentives for MFAD fishing and environmental and ecological conditions within which MFAD fishers operate differ markedly across the region.

In terms of incidental by-catch, the MFAD Survey suggested that the capture of marine mammals, sea turtles, and sea birds on MFADs was infrequent across the region, possibly because the use of entangling materials such as old nets as aggregators appeared to only take place in a few locations (Appendix II). In contrast, incidental by-catch of sharks on MFADs was reported to occur more frequently across the region, with sharks being one of the most frequently reported non-target fish species caught on MFADs (Appendix II).

2.10. MFAD total landings, number of fishing trips and yields per fishing trip

Long-term monitoring of fishing trip landings exists in many locations across the region. However, published reports of MFAD landings are rare because unambiguously separating MFAD catch data from other types of fishing has only started to be implemented more recently (CRFM 2015a). Table 5 shows the most recent yearly estimates of MFAD landings from the studies compiled by CRFM (2015a) along with a recent study from Dominica. Data from the Dominican Republic are given in Fig 8b and Table 4. These data show that MFAD landings vary by one to two orders of magnitude across the region, with Guadeloupe and the Dominican Republic largely dominating yearly reported landings with estimates exceeding 1,000 tons per year.

Table 5. Yearly estimates of fish landings from MFAD across the region

Location	Yearly estimate (metric tons)	Temporal coverage	Number of MFADs	Source
Grenada	22	Aug 2012- Jul 2013	1	CRFM (2013b)
St Vincent	5	Aug 2012 - Nov 2013	2	CRFM (2013b)
Haiti (southeast)	43	Jun 2013- Aug 2014	6-7	Vallès (2015)
Guadeloupe	1090	2008	400	Guyader et al. (2011)
Martinique	311	2009; 2010	12	Reynal et al. (2011)
Dominica	91	1994-2014	Multiple	Defoe (2020)[1]

[1-]Note that estimates for Dominica might include some offshore fishing of large pelagics without using MFADs

It is important to provide a regional perspective of the contribution of MFAD landings to total reported landings (all fishery types combined). In that regard, it is informative to use data from the Dominican Republic as reference, since this is likely the largest single contributor to MFAD landings in the region (Table 4 and 5) and the data available are likely to mainly reflect MFAD fishing (Arocha 2019). Data over the 2015-2019 period indicate a relatively small contribution to total reported landings with an estimate of 2.8% when all species are combined (Table 4). However, there is considerable variability in such contributions when data are broken down by target species, with landings of several important tuna species (yellowfin, skipjack, blackfin) accounting for very small fractions of total landings (<2%; Table 4) whereas other species such as blue marlin and cero accounted for large contributions (≥19.5%; Table 4), highlighting the importance of species-specific monitoring and perspective.

There is also a pervasive lack of data across the region on fishing effort on MFADs (e.g. fishing trips) as well as landings per fishing trip. In Guadeloupe, Guyader et al. (2013) most recently estimated 12,000 fishing trips to MFADs in 2008 for yields of approximately 100 kg per fishing trip. In Martinique, Reynal et al. (2015) more recently estimated a yearly number of fishing trips of 6,500 between 2009 and 2012 with a drop to about 4,350 trips in 2013, with yields varying between 55 kg and 85 kg per fishing trip. In Dominica, Sidman et al. (2014) found that yields per fishing trip varied between 56 kg and 118 kg during a short-term study in 2012. More recently in Dominica, Defoe (2020) used historical landing records between 1994 and 2014 to estimate between 2,000 and 5,000 yearly trips to MFADs and between 7 kg and 39 kg (average: 23 kg) of fish landed per fishing trip, although such estimates might include some non-MFAD fishing of large pelagics. In south Haiti, a short-term (two-week) study in 2015 estimated landings per fishing of 18 kg (Vallès 2015), whereas a longer-term (2007-2014) study found a median estimate of 29 kg per fishing trip (Vallès 2018). Data on total number of fishing trips to MFADs in Haiti were not available (Vallès 2018).

The above studies highlight that yields per fishing trip to MFADs can differ considerably across the region. Interestingly, the MFAD Survey found that most locations reported yields per fishing trip exceeding 76 kg, but a few locations did report values less than 50 kg (Appendix II), capturing the full range of values provided by the above studies. However, the limited geographic range and number of studies with published MFAD landing data still precludes a rigorous regional analysis of fishing efficiency on MFADs. Such analysis will also require more precise information on MFAD numbers and location as well as on total fishing effort on individual MFADs. For example, Sidman et al. (2014) found that yields per fishing trip halved with the doubling of the number of boats using the same MFAD (from 2 to 4 boats). Similarly, Reynal et al. (2015) found that catches per fishing trip on MFADs deployed away from the coast (>24 nautical miles) were three times higher than on MFADs close to the coast (<12 nautical miles), partly because fewer fishers exploited the distant MFADs (3-8 vessels per MFAD close to the coast vs 2-6 further away). Thus, estimates of MFAD density and of the degree of MFAD fisher concentration on MFADs are needed to adequately assess drivers of fishing efficiency on MFADs. In that regard, the MFAD Survey indicated that in one third of locations MFADs were often being simultaneously used by more than five fishing vessels (Appendix II), suggesting a potential dilution of individual fishing yields per boat.

2.11. Socio-economic aspects of the MFAD fishery

In terms of age demographics, in the context of a JICA/CARIFICO project, Montes et al. (2019) interviewed 316 fishers across five countries (St Kitts and Nevis, Grenada, St Lucia, Dominica, St Vincent and the Grenadines) with significant MFAD fisheries and found that their ages spanned a wide range (from late teens to early 70s), with an overall average of 41 years. In terms of basic education, the vast majority of fishers had either primary or secondary education, although the extent to which fishers had completed secondary education differing across countries (Montes et al. 2017). Interestingly, Montes et al. (2019) also found that recent MFAD fishers tended to be younger and more educated (i.e. a higher proportion with secondary education) than long-time MFAD fishers and non-MFAD users, suggesting that the MFAD fishery is attracting new younger and more educated fishers rather than converting other fishers to MFAD fishing (Montes et al. 2019). Similarly, Guyader et al. (2013) and Mathieu et al. (2014) found that fishers investing in MFAD fishing in Guadeloupe tended to be younger. The MFAD Survey aligned with these findings, with most frequently cited age groups for MFAD fishers across the region ranging between 30 and 50 years old and evidence that in one quarter of locations MFAD fishers appeared to be younger (Appendix II). This is relevant because the younger and more educated fishers are more likely to integrate Information and Communication Technology (ICT) systems into their business and marketing activities and early warning programs for hazards (Khan et al. 2019), which is desirable in all fronts.

Data on the socio-economic dimension of the MFAD fishery and on its performance relative to other types of fishing are lacking (CRFM 2015a). In the context of the aforementioned JICA/CARIFICO project, Montes et al. (2019) compared the perceived and self-reported livelihood assets (natural, physical, financial, social and human) among fishers who did not use MFADs and those who were long-time (<6 years) and recent (1-5 years) MFAD users. Overall, fishers who used MFADs reported higher levels for all livelihood assets than those who did not (Fig 10), supporting that MFAD fishing improves fisher livelihoods.

In Guadeloupe, Guyader et al. (2013) provided the most detailed comparative economic analysis to date of MFAD fishing and other types of fishing; they found that MFAD yielded higher economic performance than coastal fishing, provided that trip duration (much longer for MFAD fishing) was not seen as an opportunity cost (Figure 11 a, b). They pointed out to the role of increases in state aid available to MFAD fishers (via vessel subsidies), which might have contributed to promote the growth of the MFAD fishery (Guyader et al. 2013). They also argued that current MFAD fishing strategies (visitation of multiple distant MFADs in a trip) and high, unregulated, private MFAD numbers likely lower the economic performance of the fishery in Guadeloupe (Guyader et al. 2013).

In southeast Haiti, where there are very few opportunity costs for fishers, daily fishing trips on MFADs yield higher median profits than most types of coastal fishing (Fig 11 c), and this was particularly the case when MFADs were close to the landing sites (Vallès 2018). However, this remains a system where capital costs (vessels, MFAD units, gear, engines) have been heavily subsided by aid projects (Macías 2014) and remain to be integrated into the economic analysis. There is thus urgent need for cost-benefit studies of the MFAD fishery that comprehensively take into account local socio-economic contexts.

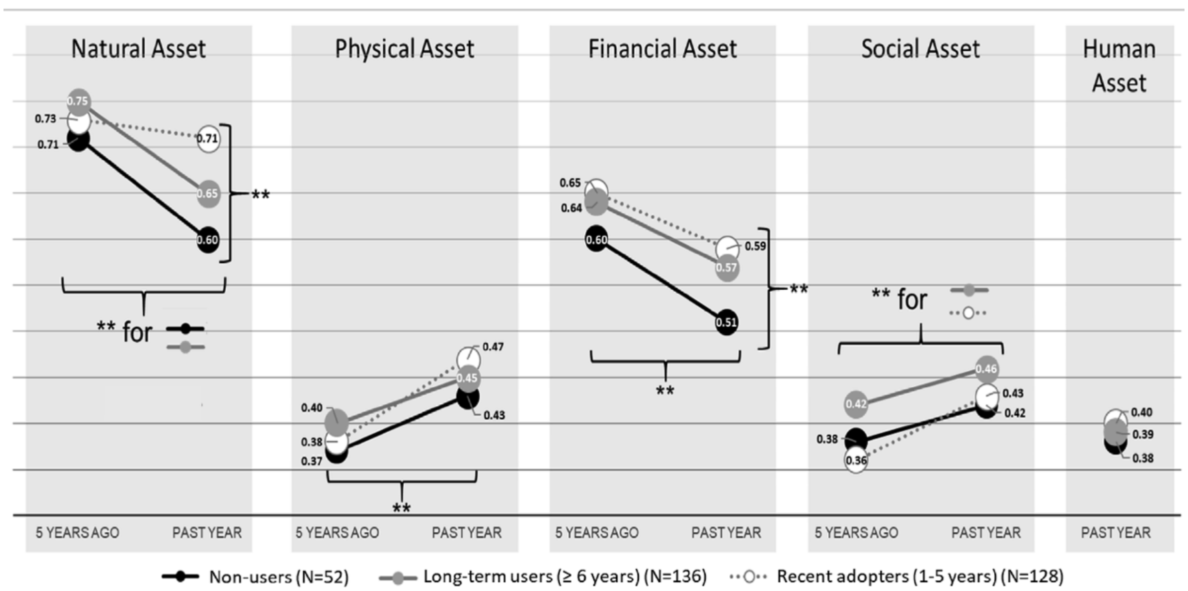

Figure 10 - Livelihood asset mean scores (natural, physical, financial, social, human) of non-MFAD users, long-term MFAD users, and recent MFAD users and across five English-speaking countries in the Caribbean over two time periods (5-years ago vs past year). Taken from Montes et al. (2019).

The MFAD Survey supported that socio-economic context differed markedly across locations in the region in ways that could affect the economic performance of the MFAD fishery, including the proportion of MFAD fishers that (1) are full-time fishers, (2) have jobs outside fishing, (3) practice other types of fishing, (4) own their own boats, (5) have access to credit lines, (6) are subsidized by government, (7) are trained in small business management, and (8) have access to training on MFAD use (Figure 12). With regard to the latter, in the context of the five-country JICA/CARIFICO project, Montes et al. (2017) highlighted that less than half of the fishers interviewed had participated in any type of training, although there were marked differences again among countries (Figure 13).

Overall, these findings combined point to considerable differences across the region in socioeconomic contexts within which the MFAD fisheries operate. This likely helps explain differences across locations in the extent to which the MFAD fishery has developed over time (Mathieu et al. 2014).

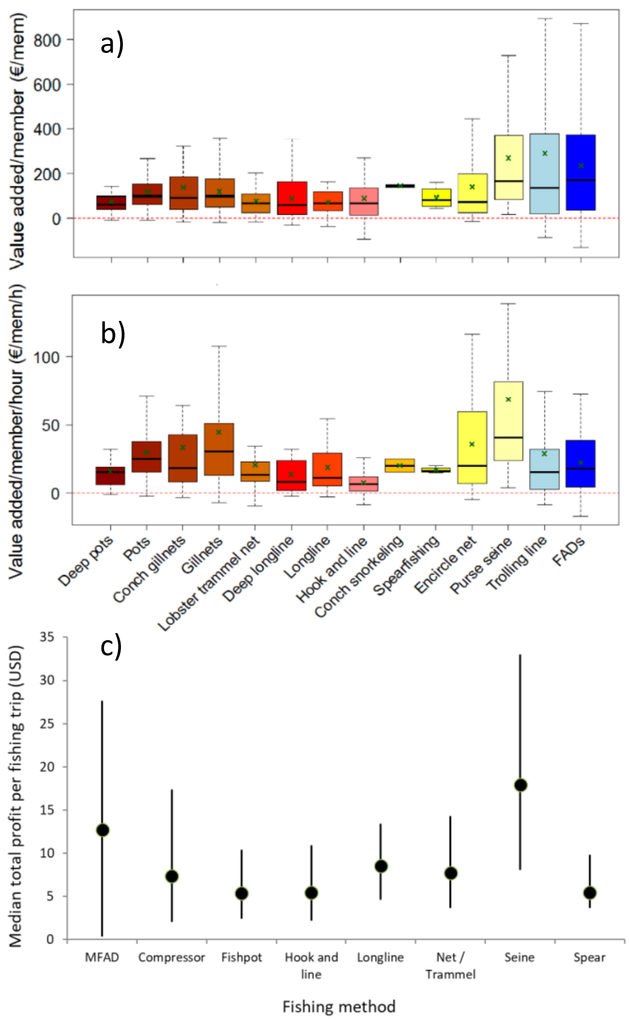

Figure 11. Comparison of fishing trip economic performance between MFAD fishing and other types of fishing in (a and c) Guadeloupe (in Euros) for each crew member (a) before and (b) after accounting for time spent at sea and in (c) southeast Haiti (USD) for a fishing trip (but not accounting for crew size or time spent at sea). Data for Guadeloupe

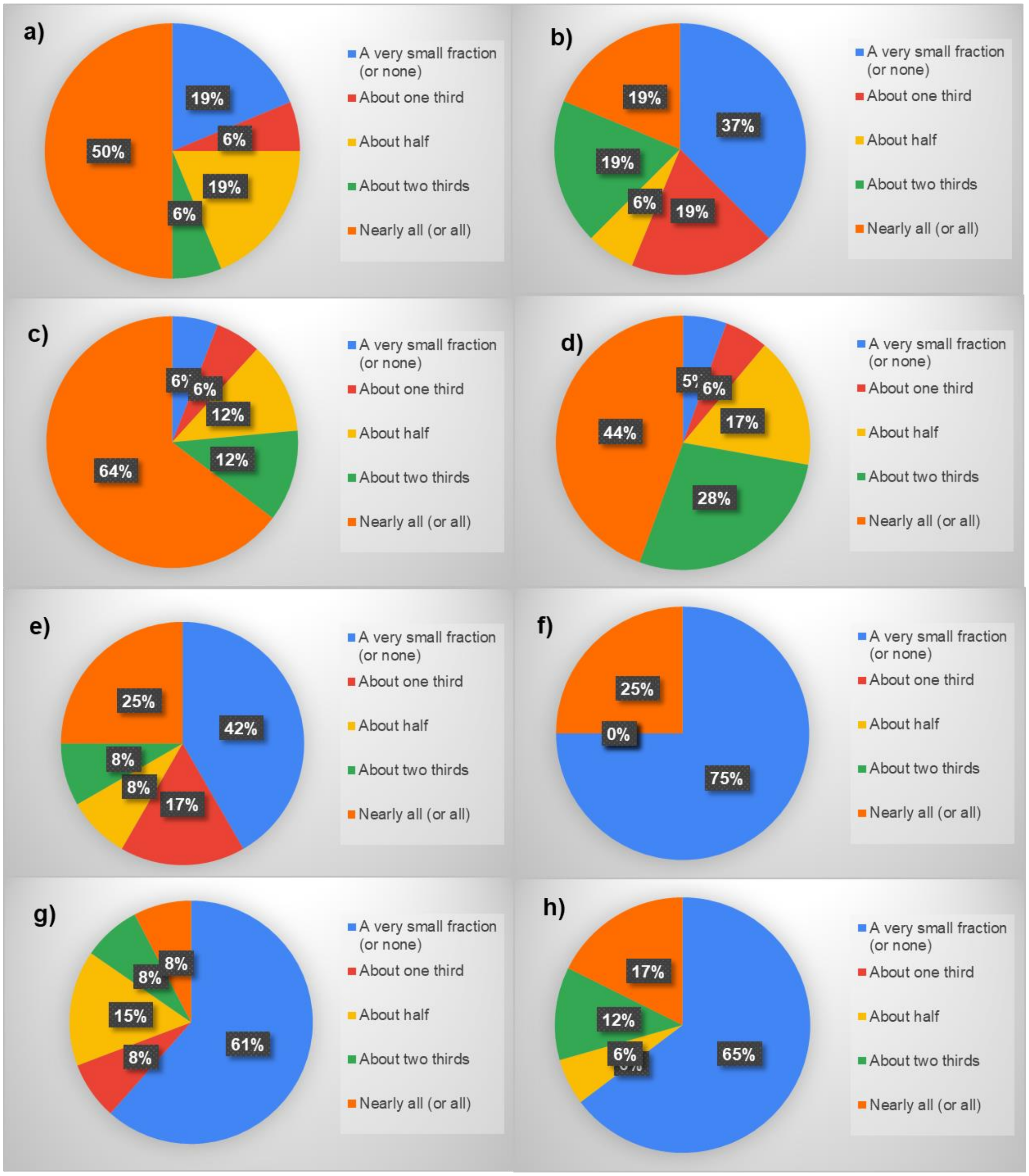

Figure 12 – Frequency of responses across 20 territories/countries quantifying the proportion of MFAD fishers that a) are full time fishers, b) also have jobs outside fishing, c) also practice other types of fishing, d) own their own boats, e) have easy access to credit lines, f) are subsidized in any way by government or non-government entities, g) are trained in small business management, and h) have access to training on MFAD use.

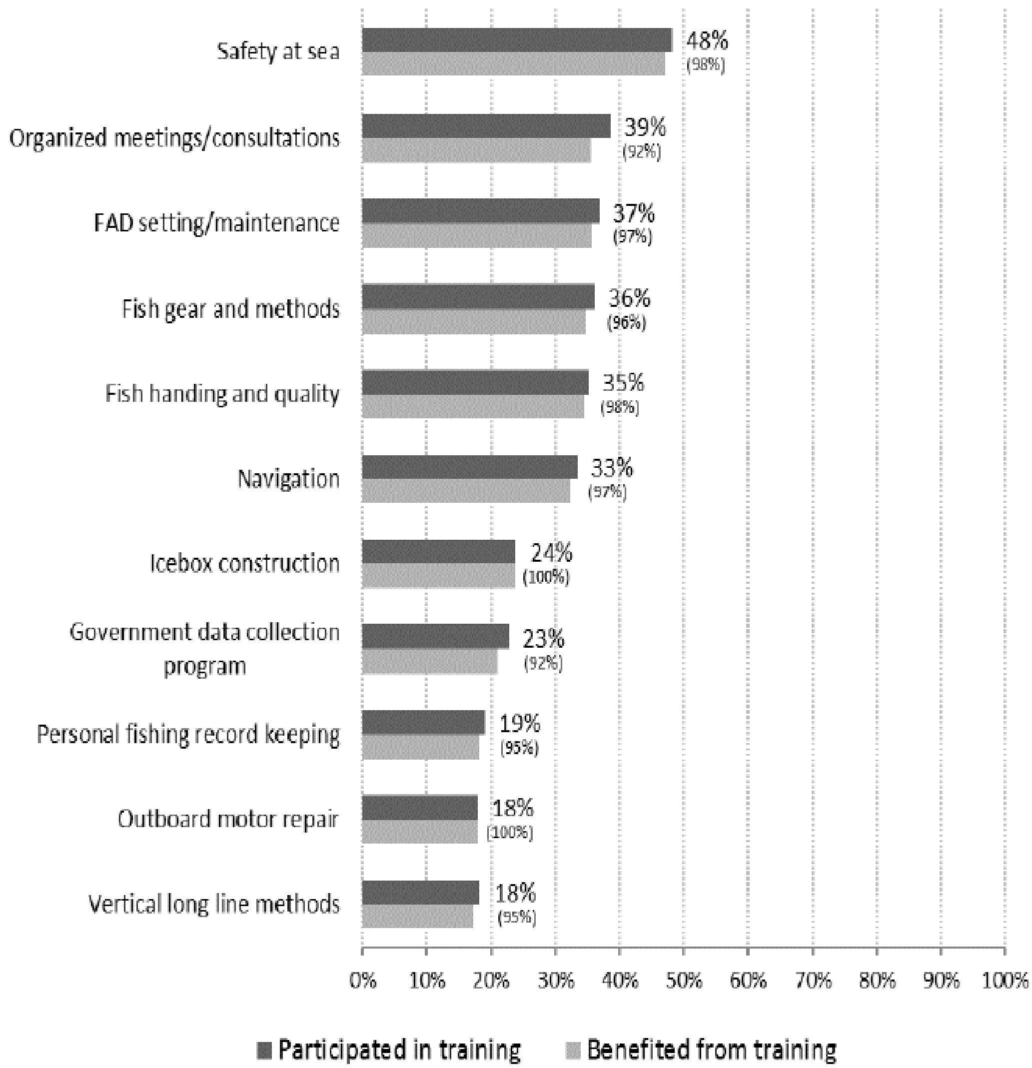

Figure 13. Percentage of fishers across five English-speaking countries that have received training in various topics concerning marine fishing and percentage of fishers how felt they benefitted from such training. Taken from Montes et al. (2017)

2.12. MFAD management systems

2.12.1. Private versus public MFADs

As pointed out in the CRFM (2015a) sub-regional plan, the introduction of MFADs at a given location usually is done via the implementation of short-term fishery development projects funded by government or non-governmental agencies (See Table 9 in CRFM 2015a) and typically involve the deployment of public MFADs that tend to align with best practices in MFAD design and are consequently relatively expensive to maintain in the long-term even with government support. The general expectation is therefore that the revenues generated by the MFAD fishery will ultimately contribute to support the maintenance and replacement of these public MFADs when the projects' funding runs out. However, it has been notoriously difficult to create a sustainable funding scheme relying on fisher contributions to maintain public MFADs across the region (e.g. Defoe 2020). Instead, once the fishery is locally adopted, fishers will prefer to invest in their own private MFADs, either individually or by forming groups to fund private collective MFADs. Private MFADs are often suboptimal from a design perspective but are also much cheaper and easier to replace and deploy than public MFADs, which gives fishers greater ability to track the abundance of pelagic resources; importantly, they are also less likely to be detected and thus used by other fishers, which leads to higher revenue for the owners, but also to more frequent conflicts with non-owner users of the MFADs. Table 6 provides a comprehensive summary of the diverse implications of having public versus private MFADs for the management of the fishery as documented in the CRFM (2015a) sub-regional plan.

As shown in Table 1, the extent to which the MFADs deployed at a given location can be considered private versus public differs markedly across the region. Across 25 locations for which information on the number of private and public MFADs was available, 28% of these locations only had public MFADs (e.g. Barbados), 40% only had private MFADs (e.g. Tobago), and the 32% remainder of locations had both MFAD types (e.g. Antigua and Barbuda) (Table 1). However, in terms of absolute MFAD numbers deployed across the region, the vast majority (97%) are private MFADs (Table 1).

The MFAD Survey also revealed that in most locations (57%) where private MFADs existed, these were owned by individual fishers, whereas only in about one third of locations (29%) private MFADs were collectively owned by groups of fishers. In the few remainder locations (14%) private MFADs could be owned by individual fishers or groups of fishers. Among those locations where MFADs could be owned by individual fishers, two locations (Guadeloupe and the Dominican Republic) reported 11-15 MFADs per fishers, followed by Anguilla with 6-10 MFADs, Saba with 2-5 MFADs, and Dominica, Antigua & Barbuda and Martinique with only 1 MFAD per fisher.

Table 6. Relative comparison between public (funded by government or non-government agencies for collective and inclusive use) and individual private (funded by an individual fisher for his/her intended exclusive use) MFADs of attributes relevant to the management and economic performance of the MFAD fishery. Attributes for private collective FADs (i.e. owned by a group of fishers) will typically lie somewhere in the middle. Taken (and minimally adapted) from CRFM (2015).

Attributes	Public FAD	Private individual FAD
Benefits and costs	**Benefits shared by all fishers; minimal costs to fishers**	**Costs and benefits borne by a single fisher**
FAD design	**Expensive, but highly visible and longer-lived FAD units:** o More regular fishing activity	**Inexpensive, inconspicuous, shorter-lived FAD units:** o More irregular fishing activity due to frequent FAD loss and/or immersion
FAD maintenance	**Highly dependent on public fund availability:** o Low fisher's engagement in FAD maintenance	**FAD maintenance and replacement mainly dependent on fisher's funds:** o High fisher's engagement in FAD maintenance

and replacement	o Slow replacement time o Lower long-term financial sustainability	o Fast replacement time o Higher long-term financial sustainability: self-financing
Ratio of number of FADs to number of fishers	**High number of fishers per FAD unit:** o Low overall FAD density in EEZ o Low overall yields per fishing trip o Fishing gear used must be compatible with presence of other users	**Multiple FAD units per fisher:** o High overall FAD density within EEZ o Possible dilution of fish aggregating effects o Visits to multiple FADs in a fishing trip o High overall yields per fishing trip o Fishing gear used can be incompatible with presence of other users
Distance to shore	**Nearshore deployment (<10 nm):** o High unauthorized recreational fishing on FADs o High safety at sea o High vessel and engine size not required o Low fuel costs o High amounts of coastal pelagics (e.g. blackfin tuna)	**Offshore deployment (>20 nm) and secrecy in deployment:** o Low unauthorized recreational fishing on FADs o Low safety at sea o High engine and vessel size required o High fuel costs o High amounts of oceanic pelagics (e.g.yellowfin tuna)
Levels of enforcement of regulations	**High levels of regulation enforcement:** o Low interference with shipping o Low levels of conflicts over FAD use: ▪ Cut-off and entanglement of fishing lines o No illegal FAD fishing in foreign waters	**Low levels of regulation enforcement:** o High interference with shipping o High levels of conflicts over FAD use: ▪ Between FAD owner vs non-owners ▪ Between FAD fishers and other fisheries (e.g. long-lines, recreational) o High illegal FAD fishing in foreign waters

2.12.2. MFAD regulation

As pointed out by the CRFM (2015a) sub-regional plan and more recently by Wilson et al. (2020), the proliferation of private MFADs has very likely been favored by a pervasive lack of comprehensive MFAD regulation across the region. Moreover, in those instances where specific pieces of MFAD formal regulation exist (see Table 10 in CRFM 2015a), they appear to be seldom enforced (e.g. Guyader et al. 2017; Montes et al. 2017). There is also evidence that that many fishers might be simply unaware of rules governing public and private MFAD use when such rules exist (Montes et al. 2017), pointing also to a problem of ineffective communication and sensitization within and among stakeholders.

The lack of a comprehensive and well-enforced regulatory framework for MFADs across the region is particularly well illustrated by the findings of the MFAD Survey. Out of 21 aspects of MFAD use that are amenable to regulation, only four aspects had specific pieces of regulation that were enforced in 50% or more of the locations surveyed (Table 7). These four aspects were (1) the requirement to provide catch and effort data, (2) penalties for breaching regulations, (3) rules about how MFADs need to be marked to avoid collisions at sea, and (4) rules about where MFADs can be deployed (Table 7). In contrast, the remainder 14 aspects of MFAD use were not the subject of any regulation or rule in most of the locations (Table 7). Many of these aspects were relevant to the fishery impacts on various components of the ecosystem (e.g. MFAD loss reporting; MFAD materials; seasonal closures; target species/sizes; fishing techniques) (Table 7). Moreover, the MFAD Survey also revealed that only 2 of 20 locations (Grenada and St Lucia) currently had a local MFAD management plan (Appendix II). These results are highly consistent with a recent study highlighting that Caribbean countries differ markedly in the legal provisions surrounding MFAD use (FAO 2016a).

Table 7 – Percentage of respondent territories/countries that fall into one of three categories of rule/regulation on 21 aspects of MFADs and MFAD fishing. The 21 aspects are ranked (from top to bottom of the table) by order of decreasing percentage in the category of regulations and rule that exit and are also enforced.

Rule / regulation	**Regulations or informal rules exist AND enforced**	**Regulations or informal rules exist BUT rarely enforced**	**Regulations or informal rules DO NOT exist**
Requiring provision of catch and effort data	58%	11%	32%
Penalties for breaching rules/regulations	53%	11%	37%
How MFADs need to be marked for boat traffic (e.g. light, radar reflector)	53%	16%	32%
Where MFADs can (or cannot) be deployed	50%	11%	39%
Requiring MFAD registration	47%	26%	26%
Who can set MFADs (and how)	47%	32%	21%
Governing who has priority to fish on MFADs (e.g. MFAD owner; commercial vs recreational fishers)	40%	10%	50%
How to apply for permission to set MFADs	40%	40%	20%
How MFADs need to be marked for ownership tracing (e.g. registration #)	33%	11%	56%
Requiring users to have a MFAD fishing licence	29%	18%	53%
Requiring MFAD loss reporting	28%	0%	72%
The distance from a MFAD subject to the regulation (e.g. 1 km radius)	28%	17%	56%
What fishing techniques are (or are not) allowed (e.g. prohibition of certain gears)	25%	15%	60%
How to fish when multiple boats use same MFAD (e.g. clockwise boat movement)	25%	30%	45%
Prohibition of certain MFAD materials	22%	11%	67%
Which fish species/sizes can (or cannot) be targeted	20%	10%	70%
Informing the general public about MFAD location (e.g. press release)	17%	22%	61%
When is fishing allowed (e.g. night vs day fishing; seasonal closures)	5%	0%	95%
Standards for MFAD buoy volume and mooring weight	5%	5%	89%
Minimum distance between MFADs	5%	5%	89%
Maximum MFAD densities allowed	5%	5%	89%

2.12.3. Conflicts on MFADs

A lack of adequately enforced regulatory framework should increase the likelihood of conflicts among MFAD users, which has been an aspect of the MFAD fishery that has attracted particular attention (Gentner et al. 2018; Guyader et al. 2018; Sadusky et al. 2018; Defoe 2020; Wilson et al. 2020). Interestingly, the MFAD Survey suggested that conflicts among MFAD users and acts of vandalism involving MFADs were infrequent across most locations in the region (from once a year or less to a few times a year). Nonetheless, a few locations such as Guadeloupe and Dominica, did report considerably higher frequencies, with conflicts occurring on a weekly basis (Appendix II). In the absence of actual data, these results should be interpreted with caution as conflict frequency estimates will depend on several factors that are likely to vary across the region, including the number MFAD fishers and the likelihood of conflict reporting. That said, the survey did reveal that, when conflicts took place, they were mainly driven by local fishers using MFADs that they did not own or by interference between commercial and recreational fishers on MFADs, which are two well-established reasons (Angelelli and Reynal 2007; Ramdine 2007; Gentner et al. 2018; Guyader et al. 2018). These local conflicts are generally settled among fishers, particularly in the case of private MFADs as these are often note adequately reported to the local authorities; such conflicts do not generally result in violence, but in some instances they can lead to theft or acts of vandalism on fishing gear or MFADs (Ramdine 2007). More instructive is perhaps that half the locations participating in the MFAD Survey reported that foreign fishers from nearby islands illegally set MFADs on their local waters or illegally fished on local MFADs, supporting that IUU fishing involving MFADs is widespread across the region (Appendix II).

2.12.4. MFAD monitoring

The baseline 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), which included 13 CARICOM countries, identified the generation and handling of fisheries statistics as an issue that needed much improvement across the Caribbean region. This study also recognized that the fishery statistical systems at that time differed markedly across the region in development and implementation and underscored the need for a regional database for the region (CRFM/JICA 2012).

Follow-up work recognized the need to (1) distinguish data from fishing trips to MFADs from other fishing activities during data collection, (2) to align minimum data requirements with those of ICATT's Recommendations on a Multi-annual Conservation and Management Program for Bigeye and Yellowfin tunas and in relation to ICCAT's Guidelines for Preparation of FAD management plans, and (3) to standardize data requirements and collection methods as much as possible across locations (Barnwell 2014; Mohammed and Masters 2014; Masters and Mohammed 2015; Mohammed 2015; Mohammed and Masters 2015). Such efforts culminated with the development of a MFAD logbook by the CRFM that is yet to be adopted by the different countries (CRFM 2015b). More recently, it has been recommended that such standardization across the region aligns as much as possible with the WECAFC Data Collection Reference Framework (WECAFC 2019a; WECAFC 2019b)

However, the MFAD Survey supports that considerable differences still exist among locations in the implementation of fishery statistical systems. For example, one quarter of the locations surveyed did not systematically collect fishery data. The rest of locations did have active fishery data collection systems involving the use of standardized data collection forms and nearly all these locations explicitly distinguished landings from MFAD fishing from non-MFAD fishing.

Table 8 summarizes the types of data currently collected across locations with systematic fishery data collection systems involving MFADs. More than ¾ of locations collect data on (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 8). In contrast, only half of these locations provided data on the number of fishing lines used, an important metric to refine fishing effort (Table 8). Even fewer locations recorded the location/identity of the MFAD used or fuel consumption expenses, which are necessary to understand potential variability in profits from MFAD use (Table 8). Because MFADs facilitate the exploitation of shared stocks across the region, more efforts are needed towards standardization of data requirements to facilitate regional data integration.

Table 8. Percentage of territories/countries (out of 15) that collect data on 12 variables from fishing trips to MFADs

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

2.12.5. MFAD co-management

It is now widely recognized that effective management of the MFAD fishery in most locations across the region will require more sharing of responsibilities between government and fishers (FAO 2002b). Although the actual nature of such arrangements remains to be resolved, to be truly effective it will likely have to go well beyond being simply instructing or consulting fishers, to actively include the fishers and other fishery stakeholders in the decision making (cooperative, advisory, informative models) (Sen and Raakjaer Nielsen 1996).

Defoe (2020) describes efforts in developing a co-management strategy for the MFAD fishery in Dominica. There, the rapid development of the MFAD fishery in the 1990's and early 2000's prompted a series of national consultations between the Fisheries Division and fishery stakeholders to improve management of the MFAD fishery. The formation of the National Association of Fisherfolk Cooperatives (NAFCOOP) in 2008, the umbrella association regrouping all registered fisher cooperatives in the island, provided an unprecedented opportunity to initiate a process of formal collaboration with MFAD fisher groups towards improved management. The proposed arrangement sought to hand over to NAFCOOP authority for the construction, deployment, maintenance, and fee collection of public MFADs. This arrangement was facilitated under The Fisheries Act no11 of 1987 (18), which makes provision for a fisher association to undertake functions aimed at managing local fisheries. The Fisheries Division and NAFCOOP also initiated a process of national consultations with stakeholders and legal experts to draft regulations for the MFAD fishery. In 2011 the draft MFAD fishery regulations were submitted for formal adoption into law, which is yet to be achieved. At that time, a MFAD fishery management initiative including deployment of public MFADs and advocated voluntary compliance of fishers with the draft regulations was initiated. Defoe (2020) states that this initiative, which relied on voluntary compliance, received little fisher support overall. Nonetheless, Defoe (2020) points out that such efforts did help tangibly reduce MFAD user conflicts.

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 covered 13 CARICOM countries and aimed to offer options for "*a comprehensive resource management approach in the Caribbean region that may include limited entry to coastal fisheries, diversification of the fisheries, and the promotion of the optimal* *use of fisheries resources with cooperation between government and communities*". This study led to the execution of a pilot project on the MFAD 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 MFADs and, (2) increasing the productivity of the MFAD fishery by developing skills and capacity to utilize pelagic resources. This pilot project focused primarily on technical aspects of MFAD design, construction, deployment, and maintenance as well as on a co-management approach to such fisheries in which fishers were expected to increase their participation in decision making but also share a greater responsibility in the provision of fisheries data.

Based on the experience of the MFAD 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 MFAD fisheries for each participating country. This project expanded to include five countries with MFAD 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 logbook system to be filled by fishers, as part of their responsibility to help monitor the MFAD fishery. At the time small groups of fishers in several beneficiary countries were participating voluntarily into data collection using these logbooks through the CARIFICO project.

In Dominica, with the Fisheries Division and NAFCOOP as partners, the CARIFICO project also aimed at helping transition the MFAD fishery from an open-access fishery to a restricted-access one governed by regulations and requiring the purchase of a license fee (Defoe 2020). This fee was also meant to provide the necessary funding to allow NAFCOOP to maintain and replace public MFADs, of which many were also deployed under the CARIFICO project with the collaboration of fishers. However, the licensing scheme continued to receive little voluntary support from fishers in spite of frequent consultations and public awareness campaigns, highlighting the difficulties of obtaining the buy-in from fishers in the absence of formal legislation (Defoe 2020). Thus, to a large degree, the lack of legal recognition of NAFCOOP as the national authority governing MFAD use has prevented it from securing adequate funding to strengthen institutionally and carry out its mandate in Dominica (Defoe 2020).

These recent experiences in co-management in the region have left a wealth of information and undoubtedly provided valuable lessons for future co-management efforts (CRFM/JICA 2011; CRFM 2012c; CRFM 2012b; CRFM 2012a; CRFM/JICA 2012; CRFM 2013e; CRFM 2013b; CRFM 2014b; Sidman et al. 2014; Sidman et al. 2015; CRFM 2017; Montes et al. 2017; Tamura et al. 2018; Montes et al. 2019; Defoe 2020). They have also likely contributed to guide the way forward. For example, in Greenville, Grenada, a local MFAD organization collects a levy per weight of fish landed to maintain a network of five MFADs and also enforces MFAD ownership via an internal licensing system and data collection; this provides a model of MFAD fishery co-management system based on community-owned rights (private collective MFADs) that could be refined locally (CRFM 2014b; Gentner et al. 2018) and perhaps exported elsewhere.

In the absence of effective dialogue between fishers and government authorities and in the presence of a system that remains open access in practice, the scenario that seems to emerge is that of a MFAD fishery based on the establishment of informal individual exclusive territorial-use rights around historical use of MFADs, as is the case of Guadeloupe (Guyader et al. 2018; Bugeja Said et al. 2021) (Fig 14) and the Dominican Republic (Gentner et al. 2018). Such scenario seems effective in limiting access to other fishers but raises serious issues about fairness and equity, leads to conflicts with those that challenge the informal system, and ultimately does not preclude the deployment of large numbers of MFADs in the race for fish (Gentner et al. 2018; Guyader et al. 2018; Bugeja Said et al. 2021).

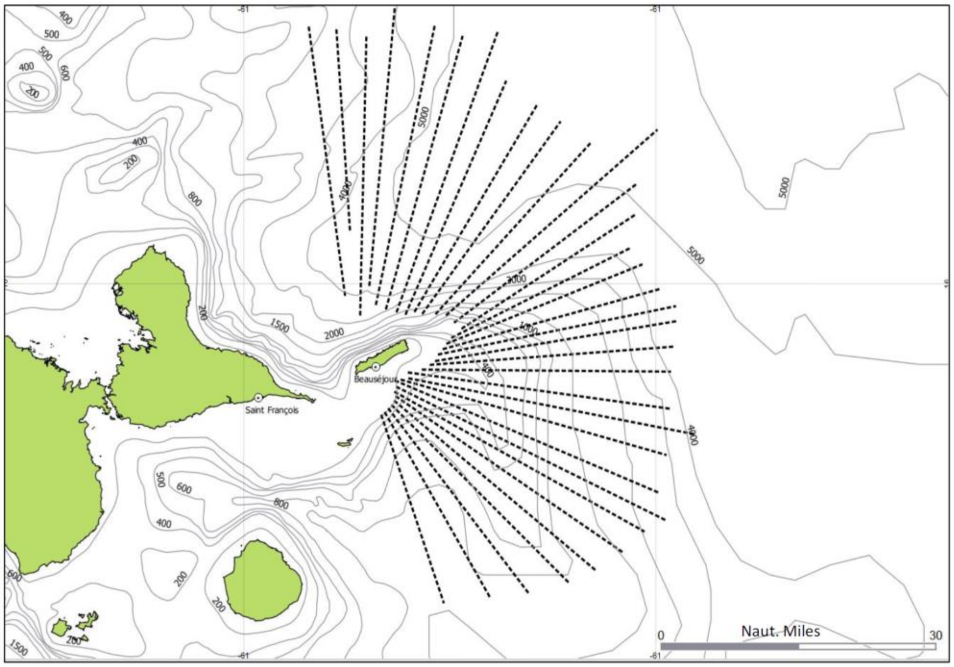

Figure 14. Informal territories of MFAD fishers in the Island of La Désirade (Guadeloupe) in 2014. Each line represents a fishing territory belonging to a MFAD fisher, with multiple MDAs deployed along the line.

3. Exploitation status of stocks

Arocha (2021) provides a summary of stock exploitation status and associated fisheries for large oceanic and coastal pelagic species typically caught on MFADs across the wider Caribbean region. A list of the species of interest and most recent stock assessments is given in Table 9. Following Arocha (2021), these species are divided into four groups, namely major tunas, small tunas, tuna-like species, and large pelagics. Additional information on stock exploitation status, management advice, biology, distribution and fisheries for these species based on Carpenter (2002) and Arocha (2021) is given in Appendix III.

Based on the most recent stock assessments for the four major tunas, namely yellowfin tuna, skipjack, bigeye tuna and albacore, only the stock assessment of bigeye tuna indicated that this stock was overfished but not undergoing overfishing (Table 9; Appendix III). The stock assessments for the other three species concluded that they were not overfished and not undergoing overfishing (Table 9; Appendix III).

It is worth pointing out that recommended management measures for bigeye tuna (and yellowfin) apply exclusively to semi-industrial and industrial fishing operations using large vessels (≥20 m long), which include purse-seine boats and bait-boats making use of drifting FADs (ICCAT 2020b). These measures do not directly apply to the small (<9 m long) vessels making use of MFADs in the Caribbean region. However, it is important that the region aligns, to the extent that it is practically possible, with ICCAT recommendations of improving the monitoring of catches on MFADs and developing and implementing MFAD fishery management plans (CRFM 2015a). Moreover, targeting juvenile tuna on MFADs for commercial purposes raises legitimate concerns about potential negative impacts on stocks; these same concerns are expressed in ICCAT 19-02 Recommendation. Further development of the fishery in the region should thus give this issue due consideration and, in addition to ensure adequate monitoring, it should seek to minimize such effects to the extent that it is possible under a precautionary approach.

In 2016, an Ecological Risk Assessment (ERA) was applied to a several small tunas from the north Atlantic by the SCRS-Small Tunas Group, which included blackfin tuna, little tunny, frigate tuna, bullet tuna, and Atlantic bonito. These species have historically been neglected in stock assessments, despite their importance for the small-scale fisheries of the region (Pons et al. 2019b). The ERA concluded that blackfin tuna had the highest risk of overfishing of the group (Table 9; Appendix III). However, qualitative evaluation of landing data from four Caribbean islands in 2012 by the CRFM's Working Group in Large Pelagics found no evidence of stock depletion or this species (Tietze and Singh-Renton 2012). The ERA also concluded that bullet tuna and Atlantic bonito had low risk of overfishing, whereas frigate tuna and little tunny had moderate risk of overfishing (Table 9; Appendix III). However, for little tunny, a more recent assessment in 2019 for the northwest Atlantic supported that the stock was not overfished (Pons et al. 2019b).

In relation to the tuna-like species, recent stock assessments warrant particular concern for three species: blue marlin, Atlantic white marlin, and wahoo. For blue marlin, the 2018 full stock assessment concluded that the Atlantic stock was overfished and undergoing overfishing, whereas for Atlantic white marlin, the 2019 full stock assessment concluded that the stock was overfished but not undergoing overfishing (Table 9; Appendix III). For wahoo, a 2019 stock assessment in the northwest Atlantic supported that the stock was overfished (Table 9; Appendix III).

In contrast, the 2017 stock assessment for swordfish in the North Atlantic supported that the stock was not overfished and was not undergoing overfishing (Table 9; Appendix III). For western Atlantic sailfish, the evidence available in 2016 also supported that the stock was unlikely to be overfished or undergoing overfishing, even though stock assessment models at the time could not conclude on stock status due to large uncertainty (Table 9; Appendix III)(Arocha 2021). For common dolphinfish, the most recent stock assessment was conducted in 2010 and found no evidence of stock declines at the time (Table 9; Appendix III). No assessments have been conducted for spearfishes as individual species (Table 9; Appendix III).

An Ecological Risk Analysis (ERA) for the species caught by longline and purse seine fisheries in the north Atlantic, which included king mackerel, Atlantic Spanish mackerel, serra Spanish mackerel and cero, was conducted in 2016 and showed marked differences among these *Scomberomorus* species. The assessment concluded that king mackerel and Atlantic Spanish mackerel exhibited high risk of being overfished, whereas cero and serra Spanish mackerel showed low and moderate risk of being overfished, respectively (Table 9; Appendix III). However, for the stock units of king mackerel and Atlantic Spanish mackerel that are managed by the US in the Gulf of Mexico and southeastern USA, the most recent assessments (2013 and 2014) indicated that these stocks were not overfished and not undergoing overfishing (see references in Arocha 2021).

Table 9. Most recent ICCAT (or ICCAT affiliated or CRFM) stock exploitation status assessments for major tunas, small tunas, tuna-like species, and large pelagics typically captured using MFADs. Adapted from Arocha (2021).

Common name	**Scientific name**	**Stock unit**	**ICCAT (or CRFM)**			
			Assessment Year	**Overfished**	**Overfishing**	**Ref.**
Major tunas						
Yellowfin tuna	*Thunnus albacares*	Atlantic	2019	NO	NO	ICCAT (2020c)
Skipjack tuna	*Katsuwonus pelamis*	West Atlantic	2014	NO	NO	ICCAT (2015)
Albacore	*Thunnus alalunga*	North Atlantic	2020	NO	NO	ICCAT (2021a)
Bigeye tuna	*Thunnus obesus*	Atlantic	2021	YES	NO	ICCAT (2021b)
Small tunas						
Blackfin tuna	*Thunnus atlanticus*	North Atlantic	2016	-	Vulnerability : High	ICCAT (2017b)
Little tunny	*Euthynnus alletteratus*	NW Atlantic	2016/2019	NO	Vulnerability : Moderate	ICCAT (2017b) Pons et al. (2019b)
Frigate tuna	*Auxis thazard*	NW Atlantic	2016	-	Vulnerability : Moderate	ICCAT (2017b)
Bullet tuna	*Auxis rochei*	NW Atlantic	2016	-	Vulnerability : Low	ICCAT (2017b)
Atlantic bonito	*Sarda sarda*	NW Atlantic	2016	-	Vulnerability : Low	ICCAT (2017b)
Tuna-like species						
Swordfish	*Xiphias gladius*	North Atlantic	2017	NO	NO	ICCAT (2020c)
Atlantic sailfish	*Istiophorus albicans*	West Atlantic	2016	Not likely	Not likely	ICCAT (2017a)
Blue Marlin	*Makaira nigricans*	Atlantic	2018	YES	YES	ICCAT (2019)
Atlantic white marlin	*Tetrapturus albidus*	Atlantic	2019	YES	NO	ICCAT (2019)
Longbill spearfish	*Tetrapturus pfluegeri*	West Atlantic	Not assessed	-	-	-
Roundscale spearfish	*Tetrapturus georgii*	Not defined	Not assessed	-	-	-
Common dolphinfish	*Coryphaena hippurus*	NW Atlantic	2010	No evidence to suggest stock is declining		CRFM (2010)
Wahoo	*Acanthocybium solandri*	NW Atlantic	2019	YES	-	Pons et al. (2019a) Pons et al. (2019b)
Large pelagics						
King mackerel	*Scomberomorus cavalla*	North Atlantic	2016	-	Vulnerability: High	ICCAT (2017b)
Atlantic Spanish mackerel	*Scomberomorus maculatus*	North Atlantic	2016	-	Vulnerability: High	ICCAT (2017b)
Serra Spanish mackerel	*Scomberomorus brasiliensis*	North Atlantic	2016	-	Vulnerability: Moderate	ICCAT (2017b)
Cero	*Scomberomorus regalis*	North Atlantic	2016	-	Vulnerability: Low	ICCAT (2017b)

4. Challenges of the MFAD fishery

The challenges to the MFAD fishery identified by the CRFM (2015a) plan remain highly relevant for the Wider Caribbean region and are therefore revisited and described in Table 10. Moreover, during the MFAD Survey, key informants were asked to score these challenges based on their severity and the urgency with which they felt they needed to be addressed in their respective locations using a scale of 1 (very low priority) to 4 (high priority) (Tables 11 to 14). Issues with high scores are here interpreted as those that are largely shared across many locations in the region, whereas issues with low scores will be those that are particularly important in some locations, but not so much in others. As in the CRFM (2015a) subregional plan, these challenges are allocated into four broad categories, namely governance, socio-economic, biological, and ecosystem (Table 10).

Table 10 – List of challenges of the MFAD fishery in the WECAFC region

Area	Challenge	Description	Consequences
Governance	Inexistent/inadequate local capacity to enforce regulations	Even when regulations exist, they tend to be rarely enforced by the relevant authorities due to limited human resources and low prioritization of MFAD-related issues (see Section 2.12.2)	Lack of penalties for those who breach regulations discourages compliance by the rest of stakeholders
	Weak organization of MFAD fisher groups	Limited organization of fishers in groups, cooperatives, or associations. When such groups exist, they might not be cohesive enough nor sufficiently well trained nor funded to be capable of effectively representing their collective interests. Whatever fisher organizational structure is best suited for the local context, it will still require strong leadership and substantial investment in capacity building in local governance to effectively defend fishers' collective interests.	Any attempt to successfully co-manage the MFAD fishery, including setting regulations and ensuring compliance, will require active participation of MFAD fishers in the process. Weak organization of fishers in groups will preclude an effective integration and participation of fishers and other stakeholders in decision making, which is critical for the development of local management plans and any other co-management arrangement.
	Inexistent or poor data collection systems	Several countries do not have data collection systems in place to monitor fishing trips on MFADs. Of the countries that do have data collection systems in place: • Few capture data on all relevant aspects of economic performance of MFADs (e.g. fuel costs) (See Section 2.12.4); • Few capture refined data on fishing effort (e.g. number of fishing lines) (See Section 2.12.4) and in some cases landing data might not be disaggregated by species (Barnwell 2014; Mohammed 2015; Arocha 2019); • Few locations engage in systematic collection of biological data of target species (individual fish length and weight frequencies, maturity stage, gonad weight) (Barnwell 2014; Mohammed 2015; Arocha 2019).	Socio-economic consequences: MFAD fishing can result in quite variable fishing yields, high fuel costs, and dilution of fishing yields due to multiple fishers using the same MFADs (See Socio-Economic aspects of MFADs section). Lack of economic data on MFAD fishing trips precludes assessing whether MFAD programs will be profitable enough to tangibly benefit fishers while ensuring maintenance, repairs and replacement of MFADs in the long-term. Biological consequences: Lack of accurate catch and effort and biological data precludes adequately assessing the impact of the MFAD fishery on stocks, which threatens the sustainability of the fishery.

	Inexistent/inadequate local MFAD management plans	Very few locations have local management plans for the MFAD fishery (see Section 2.12.2). These plans are necessary to establish rules and/or codes of conduct agreed upon by the key stakeholders as well as to clarify the rights and responsibilities of each stakeholder group within the fishery. Moreover, it is important that, to the extent that it is possible, local management plans are harmonized across the region and aligned with ICCAT recommendations for the management and conservation of tuna and tuna-like species	A lack of local management plans will likely lead to excessive deployment of MFAD numbers, dilution of fishing yields, increases in marine litter due to MFAD losses, increases in user conflicts, lack of control, surveillance and monitoring, and increases in biologically unsustainable fishing practices.
	Inexistent/inadequate local MFAD regulation	Lack of comprehensive regulation for MFAD use; where pieces of regulation exist, they do not consider the biological (e.g. minimum size for target species) or ecosystem (e.g. use of biodegradable materials) dimension of the fishery (See Section 2.12.2) (FAO 2016a). Also, there is a general lack of provisions for area-based user rights approaches such as Territorial User Rights for Fishing (TURFs), which are particularly amenable to MFAD fishing (FAO 2016a; FAO 2016b; Sadusky et al. 2018). Moreover, there is great need to implement systems for MFAD marking that allow identifying the owners when these gest lost; to the extent that it is possible, these systems be should harmonized across the region and align with the Voluntary Guidelines on the Marking of Fishing Gear (FAO 2019).	A legal framework to support development and implementation of local MFAD management plans under an ecosystem-based approach to fisheries is necessary to increase acceptance and compliance of stakeholders. A lack of such framework undermines the legitimacy of any measure.
	Inexistent/inadequate representation in ICCAT	A considerable number of WECAFC countries/territories with significant MFAD fisheries are not contracting parties to ICCAT, including Antigua and Barbuda, Dominica, the Dominican Republic, Haiti, St Kitt and Nevis, St Lucia, and the islands of the Dutch Caribbean (except Curacao).	As stated in CRFM (2011), "… *A main problem is that many countries of the Caribbean, often SIDS, presently take only a small proportion of the catch of species managed by ICCAT. These countries may, by virtue of the size and productivity of their EEZs, be entitled to a larger share, but lack the technical capacity or the financial resources to participate in ICCAT where their case would be made*". This also results in a reduced ability to defend collective interests regarding the exploitation of tuna and tuna-like species in the region.
	Weak governance structure across stakeholder groups	Organizational structures that integrate diverse stakeholder groups from various sectors such Fishery Advisory Councils could facilitate dialogue among stakeholders and oversee the implementation of local management plans (Compton et al. 2017). However, such structures need to be first adequately strengthened and funded and given clear mandates (CRFM 2015a).	The degree of trust and cooperation between government agencies (Fishery Authorities) and fishers is likely to vary across the region. Moreover, the ecosystem-based approach to fisheries requires the participation of a wide range of stakeholders into decision-making. Establishing multi-stakeholder multi-sectoral organizations might be critical to facilitate national dialogue and rebuilding of trust among key stakeholder groups.
	Illegal, Unreported, Unregulated (IUU) fishing	IUU fishing might currently take place across most locations in the region at various levels: • First, several locations do not have fishery data collection systems in place to monitor MFAD landings (Section 2.12.4), so their catches go largely unreported;	IUU fishing precludes adequately assessing the impact of the MFAD fishery on stocks and might lead to quota overruns .

		• Second, even in locations where data are routinely collected, there still might be issues precluding an effective disaggregation of data by species (inadequate data collection forms; problems identifying species) (Arocha 2019); • Third, in many locations the fishery remains open access in practice with little enforcement of existing regulations; • Fourth, the wide use of drifting drop lines with live bait implies that baitfish are commonly captured around MFADs. These captures, which often include small pelagic fishes but also small-bodied or juvenile tuna (Section 2.9), are rarely reported as part of the catch; • Fifth, the MFAD Survey indicated that in half the locations, foreign fishers illegally came to local waters to fish MFADs, supporting that illegal transboundary fishing is widespread (Appendix II). On the other hand, by-catch discards are rare in MFAD fishery across the region.	
	Inexistent/inadequate sharing of info/data on MFADs across region	The lack of harmonization and standardization of data collection systems across locations hinders the ability to share data across the region and thus the ability to meaningfully inform management decisions at the regional scale. In the insular Caribbean, CRFM, IFREMER, JICA and WECAFC have played a particularly important role in facilitating data sharing across member states over the last two decades through various projects, open libraries, ad hoc workshops, and via the WECAFC Working Group of sustainable use of MFADs in the Lesser Antilles (FAO 2002a; FAO 2002b; FAO 2007; CRFM/JICA 2012; CRFM 2013e; CRFM 2013b; CRFM 2013c; CRFM 2013d; CRFM 2014a; CRFM 2014b; CRFM 2015c; CRFM 2017). However, it is widely recognized that there is need for greater integration of data across the region, including the development of a common regional database for CRFM, OSPESCA and WECFAC members. The Caribbean Anchored Fish Aggregating Devices website (CARAFAD)[1] hosted by IFREMER has attempted to fill some of this gap. It hosts the reported position of some MFADs across the region and provides access to a valuable collection of research papers on MFADs. However, it is still are the early stages of development and the MFAD Survey indicated that very few of the key informants surveyed knew of its existence (Appendix II).	Lack of integration and standardization across the region in data collection systems leads to the need for additional resources and processing steps for data integration. Combining datasets obtained using different methodologies, data requirements, and protocols raises uncertainty in regional stock assessments.

[1]https://wwz.ifremer.fr/carafad/FAD-location

	Inexistent/insufficient MFAD fisher participation in decision making	The integration of MFAD fishers into the decision-making process remains a challenge in many locations.	Co-management arrangements are not possible without sufficient fisher participation.
	Transboundary fishing	The MFAD Survey indicated that in half the locations, foreign fishers illegally came to local waters to fish MFADs suggesting that illegal transboundary fishing is widespread (Appendix II).	See IUU fishing
	Uncontrolled/excessive proliferation of MFADs	A lack of policy/regulation setting limits to total MFAD numbers in national waters or setting private MFAD quotas for individual fishers can lead to high densities of private MFADs in the race for fish.	Beyond the legitimate concerns about the impact on fish stocks that increases on MFAD numbers and fishing effort would raise, such increases would also likely lead to the dilution fishing yields, higher fuel consumption when visiting multiple MFADs, higher levels of marine littering as MFADs are increasingly lost and replaced, and escalation of conflicts among fishers due to the diminishing available fishing space.
Socio-economic	High fuel consumption and costs	Visits to multiple MFADs during the same trip and deployment of private MFADs increasingly away from coast to minimize interference with other MFADs or competition with other fishers will increase fuel costs (Guyader et al. 2018). Fuel costs represent the single largest expense during a fishing trip (Doray et al. 2002)	MFAD fishing might not always yield sufficient catches to offset increases in fuel costs, which is generally the biggest trip expense. For example, in southeast Haiti, Vallès (2018) found that economic returns of MFAD fishing at twelve landing sites tended to be higher overall than those of coastal fishing. However, he also found that this effect was largely driven by data from the sites that were closest to the MFADs partly because of lower fuel consumption. Data from the sites that were further away from MFADs did not show any improvement in economic returns when fishing on MFADs and at one of such sites, MFAD fishing resulted in net economic losses (Vallès 2018).
	Inexistent/inadequate fisher training in business management	Higher inherent variability of catches on MFADs and possibly greater capital investment in MFAD fishing (bigger vessels, MFAD materials) and fuel consumption as more MFADs are deployed require careful accounting and analyses of revenue and expenses (e.g. Guyader et al. 2013). Yet, many private MFAD fishers are not adequately trained to conduct such financial tasks (see Section 2.11)	MFAD fishing might be practiced and even promoted in local contexts where it is not cost-beneficial for fishers in the long-term or does not lead to the desired policy outcomes.
	Inexistent/inadequate systems for repair and maintenance of deployed MFADs	Public MFADs are often deployed on an ad hoc basis as funds become available (e.g.. via short-term projects or donations); such funding is rarely integrated into part of the country's national budget expenditure.	This precludes an appropriate development of the MFAD fishery using public MFADs (as it often takes too long to replace them when they get lost) and encourages the multiplication of private MFADs.
	Inadequate commercialization circuits for target species	In most locations, catches from MFADs are destined to domestic short-chain fish markets where large pelagic fish might have lower market value than more traditional coastal or reef species (e.g. Doray and Reynal 2002; Gentner et al. 2018; Vallès 2018) and with limited value addition opportunities and product differentiation.	Low economic returns per unit weight for MFAD fishers compared to other types of fishing.

	Low capacity to replace lost MFADs	Public MFAD funding has historically relied on short-lived projects for initial construction and deployment and on the collection of user fees for their subsequent MFAD maintenance and replacement. MFAD funding is rarely integrated into part of the country's national budget expenditure. Generating sufficient funds from user fees to maintain MFAD programs has been difficult to achieve in practice, in some instances because these depended on fishers' voluntary contributions in the absence of formal regulations (e.g. Defoe 2020).	This precludes an appropriate development of the MFAD fishery using public MFADs (as it often takes too long to replace them when they get lost) and encourages the multiplication of private MFADs.
	Impact of Sargassum on fish abundance around MFADs	The abundance of Sargassum rafts seasonally moving through the Caribbean has dramatically increased since 2011. Sargassum rafts act as natural fish aggregating objects.	High abundance of Sargassum rafts might reduce the abundance of fish aggregating around MFADs, ultimately reducing fishing yields (Monnereau and Oxenford 2017).
	Lack of adequate facilities/infrastructure to handle large pelagics	Large pelagic fish require additional conservation space and special pieces of equipment to be handled (e.g. scales; trollies) in a way that maximizes product quality. Such facilities are lacking in many landing sites across the region (Section 2.7)	This sets a limit to the quality of the landed product, which might be acceptable for local markets. However, this lack of infrastructure needs addressing if the fishery seeks to generate greater revenue by targeting exports or by post-harvest processing to add value and create product differentiation.
	Inadequate MFAD designs for local context	A MFAD design represents a marriage between unit cost and lifespan, whereby bigger costs tend to lead to longer lifespans. Private MFAD fishers, who generally have limited buying power, will prioritize a strategy of minimizing costs, even if this means shorter lifespans (see Section 2.8). There is thus great need to improve MFAD designs to minimize losses while at the same time minimizing costs, which is challenging. The use of sub-surface MFADs is being explored in the region (e.g. St Lucia) as a means of reducing losses. On the other hand, the use of biodegradable MFADs remains largely unexplored.	A strategy of minimizing costs at the expense of lifespan leads to high levels of MFAD losses and replacement thus to high levels of marine littering if the MFAD units are not made of biodegradable materials, which is generally the case in the region. It will also contribute to promote having multiple MFADs deployed at any given time to ensure that at least some are available.
	Lack of safety at sea (MFAD deploying and fishing)	Fishers use small vessels to deploy MFADs and to fish around them. The risk of vessel capsizing increases when the anchoring components are transported and launched using such small vessels. During fishing, limited space on the vessel increases the chances of the fisher getting entangled on an active fishing line. Moreover, bringing large fish into the boat by hand also poses a risk of injury during lifting and handling of the catch. Finally, fishers might deploy MFADs at increasingly greater distances from shore to avoid competition with other fishers, potentially exceeding the statutory operating limits for small vessels.	Death and/or serious injury can occur; loss at sea

	Lack of access of MFAD fishers to training	Widespread lack of training of MFAD fishers on a number of areas relevant to navigation and fishing (Section 2.11).	Reduced safety at sea, suboptimal working conditions, and lower diversity and quality of landed products
	Poorly equipped boats for MFAD fishing	Boats in many locations are equipped with iceboxes, but few are equipped with winches facilitating bringing large fish on board (Section 2.6). In some locations, boats might not be equipped with bait tanks to keep bait alive.	Lack of winches might pose an injury risk while bring large fish on board; lack of iceboxes will the quality of landed products; lack of bait tanks might limit the diversity of target fish and/or increase the time spent fishing for bait on the MFAD.
	Competition with fish imports	Fish imports can lead to a reduction of sale price of fish if the supply exceeds demand (e.g. Mathieu et al. 2014).	Reduction of economic returns per unit weight of fish; difficulty in selling the catch.
	Fluctuating or low prices for target species	Market gluts associated with seasonality of MFAD fishing and markets destined primarily for local consumption.	If large pelagics are destined for the local market, seasonal increases in abundance of fish might lower the value of the catch or preclude its sale (e.g. Diaz et al. 2002).
	Low or highly variable catches on MFADs	Higher inherent variability of catches on MFADs (compared to other types of fishing) due to fish aggregation dynamics on MFADs. For example, Vallès (2016) monitored MFAD landings in south Haiti and found that about ¼ of fishing trips returned to the port with no catch. Although it is important to highlight that such study was carried out during the low MFAD season, it still highlights the economically risky nature of MFAD fishing.	Fishing trips to MFADs might not yield enough catches to offset expenses. This might also promote fishing for juvenile tunas and other non-target baitfish to help offset costs.
	Conflicts with other sea users (e.g. shipping)	Lack of regulation might lead to the deployment of MFADs in areas of heavy boat traffic or in areas that are amenable to other uses of the sea (e.g. whale watching)	Collision of boats with MFADs, leading to damage and MFAD losses, and elevation of conflicts among stakeholders.
	Conflicts between local and foreign MFAD fishers	Foreign fishers illegally fishing MFADs on local waters or local fishers fishing MFADs that foreign fishers set on local waters (Section 2.12.3)	Escalation in conflicts potentially leading to acts of vandalism and even violence. Resolving such issues will require cooperation between concerned countries/territories.
	Conflicts between local commercial MFAD fishers	Fishers fishing on MFADs from other fishers or interfering with each other while fishing the same MFAD (Angelelli and Reynal 2007; Ramdine 2007) (Section 2.12.3).	These conflicts are generally settled among fishers, but if left unresolved they could lead to acts of vandalism and even violence.
	Conflicts between local commercial vs recreational MFAD fishers	Recreational fishers fishing MFADs from commercial fishers (Angelelli and Reynal 2007; Ramdine 2007; Gentner et al. 2018) (Section 2.12.3)	These conflicts are generally settled among fishers, but if left unresolved they could lead to acts of vandalism and even violence.

Biological	Fishing of juvenile fish (e.g. yellowfins) for commercial purposes	Juvenile tuna of several large tuna species (yellowfin, bigeye) and juveniles of tuna-associated species such as dolphinfish tend to aggregate around MFADs, which facilitates their capture. Fishers across the region use small-bodied tunas (bonitos) and juvenile of large-bodied tunas (e.g.yellowfin) as live bait in drop lines targeting large tuna and billfishes (Section 2.9). However, fishers might also specifically target juvenile tuna and dolphinfish around MFADs for commercial purposes. Even though fishing techniques currently used on MFADs are highly selective, there is great need to refine those techniques so that catches of the most vulnerable species/groups are minimized and those of least concern are maximized, while still providing good economic returns to fishers. This purpose has received some attention in the region (Diaz and Gervain 2007; Dromer et al. 2015; Sidman et al. 2015), but more work is needed.	The use of juvenile tuna as live bait is contentious given that relatively small numbers are used on a fishing trip and juveniles might experience high natural mortality rates at that size anyway (e.g. Hampton and Fournier 1999). On the other hand, specifically targeting immature fish (tuna, dolphinfish) for commercial purposes should be carefully monitored as this is more likely to lead to growth overfishing (and potentially recruitment overfishing) (Fonteneau et al. 2000). Because data on natural mortality rates of juvenile tuna are lacking (Fonteneau et al. 2000), the use of juvenile tuna for commercial purposes should be minimized to the extent that it is possible under the precautionary approach.
	Intense targeting of regionally overexploited species (e.g. blue marlin)	Catches on MFADs typically include multiple species (See 2.9). Some of these species currently are considered overexploited or might be in the process of stock recovery. There is great concern that the MFAD fishery might further negatively impact some of these stocks. In particular, the regional stock of blue marlin is currently considered overfished and undergoing overfishing (See Section 3). This species is particularly amenable to be caught near MFADs and it is currently being (and has historically been) targeted by MFAD fishers across the region (Bealey et al. 2019). Even though fishing techniques currently used on MFADs are highly selective, there is great need to refine those techniques so that catches of the most vulnerable species/groups are minimized and those of least concern are maximized, while still providing good economic returns to fishers. This purpose has received some attention in the region (Diaz and Gervain 2007; Dromer et al. 2015; Sidman et al. 2015), but more work is needed.	Continued high levels of fishing of blue marlin, whether as target species or by-catch, and underreporting of catches across the region undermines the potential for the stock to recover. There is urgent need to better understand spatiotemporal variability in species composition on MFADs - which will depend on location - to minimize impacts of MFAD fishing on vulnerable species (Reynal et al. 2002).
	Disruption of fish migrations	It has been proposed that MFADs might act as ecological traps and interfere with the habitat selection instincts of migratory fish by attracting them and retaining them into poor quality habitat. However, this phenomenon is very difficult to test and the various studies that have attempted to do so have found conflicting results (Dagorn et al. 2013).	Diverting and retaining large oceanic fish into poor quality habitat (e.g. with fewer feeding opportunities; Hallier and Gaertner 2008)) should ultimately reduce their growth, condition, fecundity and/or survivorship.

	Hyperstability in catch and effort estimates*	Estimates of catch per unit effort on MFADs are not reliable indices of population abundance because MFADs are likely to continue to aggregate fish (and thus yield stable catches) even when total fish abundance might be rapidly declining (Ehrhardt et al. 2017a)	Since catch per unit effort on MFADs cannot be reliably and solely used as index of population abundance, it is critical to develop fishery-independent abundance estimates to complement fishery-dependent ones (Moreno et al. 2016a).
Ecosystem	Insufficient reduction of fishing pressure on coastal/reef resources	MFADs have been historically promoted in the region as a means of reducing fishing pressure on coastal/reef resources. However, the few studies in the region that have examined this proposition have not found support for it (Mathieu et al. 2014; Defoe 2020). This aligns with the finding that across most locations, most MFAD fishers continue to practice other types of fishing (Section 2.11).	High levels of fishing pressure on coastal/reef resources might be maintained by multipurpose fishers who can switch between MFAD fishing and coastal fishing, with coastal fishing generally providing lower, but more stable, yields. Thus, if the goal is to reduce coastal fishing pressure, MFAD programs need to be accompanied of effective regulation limiting fishing effort on coastal/reef resources by MFAD fishers.
	High levels of marine littering via MFAD losses	MFAD designs in the region mainly incorporate a diversity of non-biodegradable synthetic materials. Moreover, each MFAD requires that an anchoring component is deployed on the sea floor. Finally, most private MFADs, which account for the vast majority of MFADs in the region, get lost within a year of deployment and are quickly replaced, but very few of the lost ones are ever recovered (Section 2.8). On the other hand, efforts are currently being undertaken in the drifting FAD fishery for tuna to integrate biodegradable materials into FAD construction in terms of research (Moreno et al. 2016b; Lopez et al. 2019) and legislation (ICCAT 2020a). However, similar efforts are yet to be undertaken for the small-scale MFAD fisheries of the WECAFC region.	Most MFAD materials ultimately enter the ocean as marine litter. If these materials include entangling components such as old nets, lost MFADs could engage in *ghost fishing* and/or damage reef and nearshore habitats (Balderson and Martin 2015). The impact of the anchoring component on the sea bottom will depend on the type of surrounding substrate and on whether the mooring line attached to the anchoring component sinks or floats; this is an area of MFAD use that has received little attention (Sinopoli et al. 2020).
	High catches of non-target species (e.g. sea turtles)	Many non-target species might be occasionally captured on MFADs. If MFADs have entangling materials, marine mammals, sea birds and sea turtles might get entangled and drown. The MFAD Survey suggested that catches of marine mammals, sea birds and sea turtles occurred rarely (Section 2.9), but this remains largely undocumented in a rigorous manner.	If substantial incidental by-catch takes place on MFADs, this could threaten the recovery of species that are currently considered threatened or endangered such as sea turtles.

4.1. Governance challenges

During the MFAD Survey, challenges associated with the systems of governance of MFADs in Table 10 scored the highest across the region in terms of urgency of addressing, with an overall mean score per challenge of 2.6 on average per challenge. Table 11 ranks the individual challenges based on their perceived priority.

High ranking challenges (≥59% of respondents scored medium to high priority) were those pertaining to the inadequate or inexistent regulatory backdrop within which the MFAD fishery currently operates across most locations in the region, including **inadequate or inexistent regulations and management plans** as well as **inadequate or inexistent capacity to enforce regulations** when the latter exist (Table 11). This is consistent with the lack of a comprehensive and harmonized regulation framework (Section 2.12.2) and the lack of local management plans across locations previously reported. Moreover, **weak organizational structure of MFAD fishers** also ranked high across the region (Table 11).

With lower but still relatively high ranks came a second group of challenges (45-55% of respondents scored medium to high priority) that included the **lack of representation in ICCAT**, **weakness in inter-sectoral organizational structures** integrating a broad range of local stakeholder groups to facilitate dialogue and transparent decision-making such as Fishery Advisory Committees, **inexistent or poor data collection systems** (biological, economical), **illegal, unreported and unregulated (IUU)** fishing, **inexistent/inadequate sharing of info/data on MFADs across region,** and **inexistent or insufficient participation of MFAD fishers** in the decision-making process (Table 11).

The lower rank challenges (<30% of respondents scored medium to high priority) were **transboundary fishing** and **uncontrolled and excessive proliferation of private MFADs**, likely because these issues are likely to be more location-specific (Table 11).

Table 11. Governance challenges of the MFAD fishery and associated priority score breakdown

Governance challenge	Mean score (1 to 4)	Percentage of respondents				
		High priority	Medium priority	Low priority	Very low priority	Not known
Inexistent/inadequate local capacity to enforce regulations	3.1	55%	23%	5%	18%	0%
Weak organization of MFAD fisher groups	3.1	50%	14%	23%	9%	5%
Inexistent/inadequate local MFAD management plans	2.9	41%	18%	18%	18%	5%
Inexistent/inadequate local MFAD regulation	2.8	50%	9%	5%	32%	5%
Inexistent/inadequate representation in ICCAT	2.7	27%	27%	9%	23%	14%
Weak governance structure across stakeholder groups	2.7	32%	23%	27%	18%	0%
Inexistent or poor data collection systems (biological, economical)	2.6	32%	23%	14%	27%	5%
IUU fishing	2.6	23%	27%	5%	27%	18%
Inexistent/inadequate sharing of info/data on MFADs across region	2.4	18%	27%	23%	27%	0%
Inexistent / insufficient MFAD fisher participation in decision-making	2.3	14%	36%	18%	32%	0%
Transboundary fishing	1.9	14%	14%	14%	45%	14%
Uncontrolled/excessive proliferation of MFADs	1.9	14%	9%	27%	45%	5%

4.2. Socio-economic challenges

The socio-economic challenges in Table 10 came second overall in terms of perceived urgency in addressing, with an overall mean score per challenge of 2.3 on average per challenge. However, this component exhibited considerable heterogeneity in scores across the region, which is expected given that the socio-economic and ecological context in which the MFAD fishery operates also differs markedly across the region (Section 2.11). Table 12 ranks the challenges based on their perceived priority.

The highest-ranking challenges (≥64% of respondents scored medium to high priority) were those pertaining to **high levels of fuel consumption** and the **lack of training of fishers in business management**, followed by the **inadequate commercialization circuits for target species** (59% of respondents scored medium to high priority) (Table 12).

With lower ranks came a second group of challenges (45-55% of respondents scored medium to high priority), which included **inexistent/inadequate systems for repair and maintenance of deployed MFADs** and **low capacity to replace lost MFADs**, along with **lack of adequate facilities/infrastructure to handle large pelagics**, **lack of access of MAD fishers to training**, **competition with fish imports**, and **poorly equipped boats for MFAD fishing** (Table 12).

With even lower ranks (35-45% of respondents scored medium to high priority) came a group of challenges that included **inadequate MFAD designs for local context**, **lack of safety at sea**, **low or highly variable catches on MFADs**, and **fluctuating or low prices for target species** (Table 12).

The lowest ranking group (<35% of respondents scored medium to high priority) included challenges associated with conflicts among users, including **conflicts between local and foreign MFAD fishers**, **conflicts between local commercial MFAD fishers**, **conflicts between local commercial vs recreational MFAD fishers**, and **conflicts between MFAD fisher and other sea users** (Table 12).

Finally, one potential challenge, the **impact of Sargassum on fish abundance on MFADs** stood out because of the lack of clear prioritization score, precluding any straightforward allocation to any of the aforementioned groups (Table 12).

Table 12. Socio-economic challenges of the MFAD fishery and associated priority score breakdown

Socio-economic challenge	Mean score (1 to 4)	Percentage of respondents				
		High priority	Medium priority	Low priority	Very low priority	Not known
High fuel consumption and costs	3.0	45%	18%	18%	14%	5%
Inexistent/inadequate fisher training in business management	3.0	41%	27%	5%	18%	9%
Inexistent/inadequate systems for repair and maintenance of deployed MFADs	2.7	36%	14%	18%	23%	9%
Low capacity to replace lost MFADs	2.6	36%	9%	14%	32%	9%
Inadequate commercialization circuits for target species	2.5	18%	41%	0%	32%	9%
Impact of Sargassum on fish abundance around MFADs	2.4	18%	18%	14%	23%	18%
Lack of adequate facilities/infrastructure to handle large pelagics	2.4	32%	14%	14%	36%	5%
Lack of access of MFAD fishers to training	2.3	18%	36%	0%	41%	5%
Inadequate MFAD designs for local context	2.3	27%	14%	23%	36%	0%
Competition with fish imports	2.3	27%	23%	0%	50%	0%
Poorly equipped boats for MFAD fishing	2.2	18%	32%	5%	45%	0%
Lack of safety at sea (MFAD deploying and fishing)	2.2	18%	27%	14%	41%	0%
Low or highly variable catches on MFADs	2.1	14%	18%	18%	36%	14%
Fluctuating or low prices for target species	2.1	18%	18%	9%	45%	9%

Conflicts between local and foreign MFAD fishers	2.0	23%	5%	23%	45%	5%
Conflicts between local commercial MFAD fishers	1.9	23%	5%	9%	59%	5%
Conflicts between local commercial vs recreational MFAD fishers	1.9	5%	23%	18%	45%	9%
Conflicts with other sea users (e.g. shipping)	1.5	5%	9%	14%	64%	9%

4.3. Biological challenges

The biological challenges in Table 10 came third overall in terms of perceived urgency in addressing, with an overall mean score per challenge of 2.0 on average per challenge. Table 13 ranks the challenges based on their perceived priority.

With only three challenges identified, **fishing of juvenile fish for commercial purposes** ranked highest but with only a moderate score (45% of respondents scoring medium to high priority), followed by **intense targeting of regionally-overexploited species** with a relatively low score (32% of respondents scoring medium to high priority) and **disruption of fish migrations** with an even lower score (18% of respondents scoring medium to high priority), although the latter had particularly high levels of unknown (36% of respondents) (Table 13).

Table 13. Biological challenges of the MFAD fishery and associated priority score breakdown

Biological challenge	Mean score (1 to 4)	Percentage of respondents				
		High priority	Medium priority	Low priority	Very low priority	Not known
Fishing of juvenile fish (e.g. yellowfins) for commercial purposes	2.3	14%	32%	5%	36%	14%
Intense targeting of regionally-overexploited species (e.g. blue marlin)	2.1	14%	18%	23%	36%	9%
Disruption of fish migrations	1.7	0%	18%	9%	36%	36%

4.4. Ecosystem challenges

Overall, ecosystem challenges in Table 10 came also third overall in terms of perceived urgency in addressing, tying with the biological challenges with an overall mean score per challenge of 2.0 on average per challenge. Table 14 ranks the challenges based on their perceived priority.

With only three challenges identified, **insufficient reduction of fishing pressure on coastal/reef resources** ranked highest with relatively high score (50% of respondents scoring medium to high priority), followed by **high levels of marine littering via MFAD losses** with a relatively low score (23% of respondents scored medium to high priority) and **high catches of non-target species** with an even lower score (only 5% of respondents scored medium to high priority) (Table 14).

Table 14. Ecosystem challenges of the MFAD fishery and associated priority score breakdown

Ecosystem challenge	Mean score (1 to 4)	Percentage of respondents				
		High priority	Medium priority	Low priority	Very low priority	Not known
Insufficient reduction of fishing pressure on coastal/reef resources	2.6	27%	23%	14%	23%	14%
High levels of marine littering via MFAD losses	2.1	18%	5%	32%	32%	14%
High catches of non-target species (e.g. sea turtles)	1.3	5%	0%	9%	77%	9%

4.5. Summary

Overall, the governance challenges scored highest in terms of perceived priority, underscoring a regionwide consensus on the urgent need to strengthen governance and regulation frameworks and the organizational capacity of stakeholders. This certainly reflects that effectively addressing these challenges is required in order to help resolve many of those operating in the socio-economic, biological and ecosystem dimensions. The fact that there was also considerable regionwide agreement on the importance of addressing high fuel consumption and lack of training of fishers in business management suggests that MFADs might not always yield the expected economic benefits. There is therefore a need for better assessment of the economic performance of MFADs and its drivers and this should be accompanied with building the necessary capacity in fishers to make decisions that will ensure sustained profits. Finally, biological and ecosystem challenges came last, suggesting a greater diversity in the perceived importance of these challenges across the region. The exception was the recognition that MFAD fishing might not necessarily lead to a reduction in coastal fishing pressure. Overall, the lower ranking of biological and ecosystem challenges might reflect differences in ecological context and in the relative importance of MFAD fishing at the local scale. However, it might also reflect a pervasive lack of data across the region to adequately inform these issues, which can only be adequately addressed via improved monitoring of the MFAD fishery.

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